Ex-Post Analysis of the Innovation Diffusion Process of the “System of Rice Intensification”: Case Study the Volta Region of Ghana

By: Ariel Mark
Student of Global Change Management (M.Sc.)
Matriculation Number: 14209342
University of Applied Sciences, University for Sustainable Development Eberswalde (HNEE)
Faculty of Forest and Environment

<u>Evaluators:</u>
Prof. Dr. Martin Welp
(Chair of Socioeconomics and Communication, Faculty of Forest and Environment, Eberswalde University for Sustainable Development), first evaluator
Mike Bartels
(Project Leader, Agriculture Project, Deutsche Gesellschaft für Internationale Zusammenarbeit)

HNE Eberswalde
Hochschule für nachhaltige Entwicklung

Candidate:	Ariel Mark Student of Global Change Management (M.Sc.) Eberswalde University for Sustainable Development – University of Applied Sciences Faculty of Forest and Environment Ariel.Mark@hnee.de Matriculation Number: 14209342

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Ariel Mark
Berlin
21 September 2016

Summary

The motto 'more crop per drop' is synonymous with the climate-smart, agroecological rice cultivation method called "*System of Rice Intensification"* (SRI). SRI is renowned for increasing rice yields while conserving or even reducing the required amount of external inputs like fertilizer, water and seeds. Rice plays a large role in the Ghanaian agriculture sector as a major household and cash crop. Yet, rice production in Ghana falls well below climatic yield potential and fails to satisfy national demand. SRI was first introduced to Ghana in the early 2000s and since then trainings, demonstration fields and nation-wide "upscaling" projects have spread throughout the country to improve the rice sector. This paper is an ex-post analysis of the introduction of SRI to Ghana and focuses on the case study of rice farming communities in the Volta Region. The SRI dissemination process was examined through the perspective of Rogers (2003) *Diffusion of Innovations* theory. Based on these findings, recommendations for the dissemination process were made to aide change agents and policy makers.

Results showed farmers have a positive perception of SRI. Their motivation to continue practicing SRI methods was influenced by higher crop yields. Results also revealed challenges and constraints the farmers faced with SRI implementation such as lack of capital, tool accessibility and labor. Additionally, challenges were rooted in the complexity of SRI management practices such as SRI transplanting propagation techniques. SRI is a knowledge-intensive innovation that requires an extensive amount of support for practitioners.

Recommendations for the SRI diffusion process are characterized by the following themes: *global phenomenon, localized solutions* (knowledge exchange), *WAY – women, age, youth* (target group) and *inclusion of a value chain perspective*. SRI is a *global phenomenon* that requires *localized solutions* in the form of adaptations to local conditions. This research recommends change agents to further encourage localized modifications such as local alternative sources for organic fertilizer (rice bio-waste, home-produced compost etc.). Secondly, it was recognized that a special emphasis should be placed on the social groups *WAY – women, youth and elderly*. Though women are main producing stakeholders in agriculture, they are often marginalized and tend to be the last to access innovations. The diffusion process would benefit to expand opportunities for women farmers and examine the health and gender impacts of SRI dissemination. Furthermore, an aging farmer population and youth migration to urban areas harrow the rice sector. Strategies for improving the rice sector would benefit from recognizing these shifts in farmer demographics and structural changes in the agriculture system to attract new farmers. Lastly, SRI diffusion strategies could benefit from including a *rice value chain perspective*. SRI focuses on production, but does not address other issues within the Ghanaian rice sector such as post-harvest activities like processing and storage, quality control and marketing. In conclusion, SRI has potential to boost the Ghanaian rice sector and improve famer livelihoods.

Zusammenfassung:

Das Motto 'more crop per drop' ist mit dem Klima-smarten, agrarökologischen Reisanbauverfahren *System of Rice Intensification* (SRI) gleichbedeutend. SRI ist bekannt für eine Wirkung, die zu einer Vermehrung der Ernte und gleichzeitigen Aufrechterhaltung oder sogar Reduzierung des Verbrauchs der externen Inputs wie z. B. der Dünger, des Wassers und des Saatguts, führt. SRI ist in den frühen 1980er Jahren in Madagaskar entwickelt worden und wurde erst in den frühen 2000er Jahren in Ghana eingesetzt. Seitdem gab es Trainings, Anschauungsfelder und landesweite Projekte für die Ausbreitung der Methode. Reis spielt eine große Rolle in dem ghanaischen Agrarsektor als eine wichtige Haushaltspflanze und „Cash Crop", aber bisher hat die Reisproduktion den Ernteertrag, den das Klima potenziell ermöglichen könnte, noch nicht erreicht. Diese Forschung ist eine Ex-post-Analyse der Einführung von SRI Ghana und konzentriert sich auf die Fallstudie von reisanbauenden Kleinbauern in der Volta Region. Der SRI-Verbreitungsprozess wurde durch die Perspektive von Rogers Theorie der *Diffusion von Innovationen* aus dem Jahre 2003 untersucht. Auf der Grundlage dieser Ergebnisse werden Empfehlungen für den Verbreitungsprozess zur Unterstützung der Change Agents und politischen Entscheidungsträger ausgesprochen.

Die Ergebnisse zeigten, dass die Landwirte eine positive Wahrnehmung von SRI haben. Ihre Motivation, SRI Methoden weiterhin zu praktizieren geht hauptsächlich auf höhere Ernteerträge zurück. Die Ergebnisse zeigten auch Herausforderungen und Einschränkungen mit denen Bauern, die SRI umsetzen, konfrontiert sind, wie der Mangel an Kapital, Werkzeug, Zugänglichkeit und Arbeitskraft. Zusätzliche Herausforderungen haben ihre Ursache in der Komplexität der SRI-Management-Praktiken, wie SRI Verpflanzung Vermehrungstechniken. SRI ist ein Wissen voraussetzende Innovation, die eine umfangreiche Menge an Unterstützung in der Praxis erfordert.

Empfehlungen für die SRI-Diffusionsprozess werden durch die folgenden Themen charakterisiert: globales Phänomen, lokalisierte Lösungen (Wissensaustausch), WAY – women, age, youth (Frauen, Alter, Jugend Zielgruppen) und die Einbeziehung einer Wertschöpfungskette-Perspektive. SRI ist ein globales Phänomen, das in Form von Anpassungen an die lokalen Gegebenheiten lokalisierte Lösungen erfordert. Diese Forschung empfiehlt Change Agents, weitere lokalisierte Änderungen zu fördern wie lokale alternative Quellen für Bio-Dünger (z.B. Reis Bioabfall, selbst produzierten Kompost usw.). Zweitens wurde erkannt, dass ein besonderes Augenmerk auf die sozialen Gruppen Weg gelegt werden sollten - Frauen, Jugendliche und ältere Menschen. Obwohl Frauen wichtig produzierenden Akteure in der Landwirtschaft sind, werden sie oft ausgegrenzt und stehen in der Regel an der letzten Stelle, was den Zugriff auf Innovationen betrifft. Der Diffusionsprozess würde von einer Erweiterung der Chancen für Frauen in der Landwirtschaft profitieren, sowie die Gesundheits- und Gender-Auswirkungen von SRI Verbreitung untersuchen. Außerdem sind eine Alterung in der landwirtschaftlichen Bevölkerung und Jugendmigration Kernfragen des Reissektors. Change Agents und Entscheidungsträger würden von der Anerkennung dieser Wandlung der Demografie Chancen sehen. Zudem könnten SRI Diffusionsstrategien von einer Einbeziehung einer Reiswertschöpfungsketten-Perspektive Nutzen ziehen. SRI konzentriert sich auf die Produktion, aber befasst sich nicht mit den anderen Problemen innerhalb des ghanaischen Reissektors, wie Tätigkeiten, die nach der Ernte anfallen, z.B. Verarbeitung und Lagerung, Qualitätskontrolle und Marketing. Schließlich hat SRI Potenzial um den ghanaischen Reissektor und den Lebensunterhalt der Bauern zu verbessern.

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List of Abbreviations

CSIR	Crop Research Institute
CIIFAD	Cornell University Food, Agriculture and Development
FAO	Food and Agriculture Organization of the United Nations
FBO	Farmer Based Organization
GHG	Greenhouse Gas
GRIB	Ghana Rice Inter-Professional body
JICA	Japan International Cooperation Agency
MDG(s)	Millennium Development Goals
MoFA	Ministry of Food and Agriculture
NRDS	National Rice Development Strategy
rspd.	Respondent
SARI	Savannah Agricultural Research Institute
SDG(s)	Sustainable Development Goals
SRI	System of Rice Intensification
SRI-RICE	SRI International Network and Resources Center
SRI-WAAPP	SRI West African Agricultural Productivity Program
ToTs	Training of Trainers

WFS	World Food Summit
UN	United Nations

1 Introduction

1.1 Importance of Rice

The motto 'more crop per drop' is synonymous with the climate-smart rice cultivation method the *"System of Rice Intensification"* (SRI) that has propelled sustainable increases of rice production around the world (SRI-Rice 2016). Rice is one of the world's most important grains, feeding half of the global population and employing over one billion people on an estimated 250 million small family farms (Vent et al 2015). However, rice sectors in many countries are currently experiencing declines in productivity largely due to diminishing returns with the use of chemical inputs, limited natural resources, environmental factors and reduction in agricultural research investments (Rosegrant et al 2003). Moreover, hunger and poverty continue to plague societies around the world and climate change presents added challenges for agriculture systems to ensure food security. Agroecological approaches that focus on dual land management for agriculture and ecosystem services offer a potential solution to improving agricultural productivity with added ecological benefits (i.e. reduced pollution, biodiversity reserves, natural resource conservation). In this light, the SRI, provides agroecological management alternatives to sustainably improve crop production (SRI-Rice 2016). Around the world, farmers practicing SRI management techniques have seen an increase of crop yields of up to 20 - 100 percent. SRI practitioners have also experienced reductions in the required amounts of external inputs such as a 30 - 50 percent decrease in water use for irrigated systems and up to 90 percent reduction in required seed. Additionally, research has shown SRI management practices to increase soil organic matter in rice fields and reduce greenhouse gas emissions.

SRI was initially established in Madagascar in the early 1980s with the objective to improve the productivity and livelihoods of Malagasy smallholder farmers (Styger et al 2014). Following its inception, SRI spread to rice communities throughout the world. SRI is a set of recommended management practices of the rice plant, water, fertilizer (source and application) and soil (inter-cultivation and nutrients). Within the context of food security and agricultural development, this study analyzes the introduction and dissemination of SRI to the rice sector in the West African country of Ghana. SRI was first introduced to Ghana in 2001 and since then, SRI practices and programs are being up-scaled and disseminated to smallholder rice farmers throughout the country (SRI-Rice 2016).

Rice is one of the most important household and commercial crops in Ghana (Boansi 2013). Yet, despite a large number of people involved in rice production and ample natural resources, the country depends on immense quantities of rice imports to satisfy national consumption demands (Boansi 2013; Kranjac-Berisavljevic et al 2003). Similar to other West African countries, Ghana's agriculture sector is marked by low productivity at the farmer field level (Boansi 2013). Moreover, past increases in crop production in Ghana were attributed to expansion of agricultural land and harvested area. However, rapid population growth and urban expansion are putting pressure on available land for agriculture (Boansi 2013). Thus, increasing farm productivity on current agricultural land is extremely vital to mitigating potential land use conflicts between urbanization and social welfare issues such as food security and poverty reduction. A World Food Program (WFP) Comprehensive Food Security and Vulnerability Analysis of Ghana in 2012 revealed poverty to be the root cause of food insecurity in the country. Under this context, the System of Rice Intensification could be a potential solution to increasing crop productivity in current Ghanaian agriculture systems (Boansi 2013).

This research provides an ex-post analysis of the dissemination process of SRI in the case study area of the Volta Region in Ghana. Individual questionnaires were administered to rice farmers in the Nsuta, Kasec and Akpafu Mempeosem communities. The objective of the farmer interviews was to gain an understanding of the farmers' perception of SRI in order to provide recommendations for policy makers and SRI change agents.

1.2 Research Questions and Objectives

This study focuses on three research questions that perceive the System of Rice Intensification (SRI) management practices as an agricultural innovation in the Ghanaian rice sector, see Table 1. And as such, the SRI innovation dissemination process is examined through the lens of Rogers (2003) *Diffusion of Innovations* theory and set against the backdrop of food security and agricultural development. Analysis of innovation diffusion is a topic of increasing interest among researchers and practitioners (Rogers 1983). The adoption of a new idea, innovation or technology is a difficult and often lengthy process that requires an astute examination of the innovation characteristics as well as acute understanding and awareness of the nuances in the innovation-receiving social system.

Table 1. Shows the three research questions and objectives.

Research Question	Objective
1. Ex-post analysis, how was the *System of Rice Intensification* introduced to Ghana?	An ex-post analysis of the innovation SRI diffusion process at a national level. To examine how SRI as an agricultural innovation has permeated throughout different scales and scopes of the Ghanaian rice sector.
2. How does Rogers (2003) *Diffusion of Innovations* theory explain smallholder rice farmers' perception of the agricultural innovation the *System of Rice Intensification*?	An ex-post analysis of the innovation SRI diffusion process at a local level in the case study area of the Volta region. To determine the feasibility of SRI adoption under local socio-economic and ecological conditions.
3. What are recommendations for the diffusion process of the *System of Rice Intensification* in Ghana?	To provide disseminators with recommendations for how to improve the adoption rate of SRI or other agricultural innovations. Use the case study example of SRI farming communities in the Volta region as a proxy for general diffusion of innovations in the agriculture sector of Ghana.

The research objective is to examine the dissemination process of SRI at the national and local level and use the case study of SRI practicing communities in the Volta Region to provide recommendations for the innovation diffusion process. The objective of research question 1 "Ex-post analysis, how was the *System of Rice Intensification* introduced to Ghana?" is to analyze the innovation diffusion process at the national level and observe how it has permeated throughout the Ghanaian rice sector. The objective of research question 2 "How does Rogers (2003) *Diffusion of Innovations* theory explain smallholder rice farmers' perception of the *System of Rice Intensification*?" is to analyze the innovation diffusion process at a local level in rice farming communities of the case study area in the Volta Region. Furthermore, the Diffusion of Innovations theory is used as a tool to observe farmer activity and opinions of SRI to determine the feasibility of the innovation adoption. The objective of research question 3 "What are recommendations for the diffusion process of the *System of Rice Intensification* in Ghana?" is to provide policy makers and change agents with insight of SRI implementation at the farmer level to aid the dissemination process.

2 System of Rice Intensification Management Practices

The System of Rice Intensification (SRI) is an agro-ecological method for rice production that has shown to produce higher crop yields with less required external inputs than traditional or conventional methods (Styger et al 2014). More specifically, SRI is a knowledge-based approach of plant, soil, water and nutrient management that promotes plant productivity through maximizing resource efficiency. Rather than relying on new seed varieties or chemical inputs like fertilizers, herbicides or pesticides, SRI achieves higher yields by enabling "the rice plants' genetic potential for increased productivity" (Styger et al 2014).

2.1 Origin of the System of Rice Intensification

The *System of Rice Intensification* (SRI) is a method of rice cultivation that was developed in the 1980s by the French Jesuit priest and agronomist Fr. Henri de Laulanié (Thakur 2015; SRI-Rice 2016). Laulanié spent 34 years working with Malagasy smallholder farmers to help improve their agricultural productivity. Laulanié's work focused specifically on rice which is the country's staple crop (Styger et al 2014). He experimented on changing variations in rice cultivation including some practices such as reduction in water use and promotion of organic fertilizers as well as transplanting seedlings at a young age and with wide spacing. Laulanié strived to find agricultural methods that were relatively independent of external inputs, which tend to be difficult and expensive for resource-poor farmers to access. And thus, the foundation principles of SRI were discovered.

Laulainé established Tefy Saina, a local non-profit organization, to aid rural Malagasy communities in the early 1990s (Styger et al 2014). In the mid 1990s, the Cornell University International Institute for Food, Agriculture and Development (CIIFAD) project learned about SRI through Tefy Saina and conducted three years of trials to test the method performance. CIIFAD was convinced of the success of SRI practices and since 1997, has been sharing farmer-based experiences with the international community. Since its first inception in Madagascar, SRI has spread throughout the rest of the world and includes a large international network of researchers and SRI practitioners who have adapted or modified SRI practices to various rice systems. In 2010, in response to this international phenomenon, the SRI International Network and Resources Center (SRI-Rice) was established at the Cornell University with the objective to support the global SRI community. SRI-Rice provides a platform for sharing SRI experiences with the aim to continually improve SRI knowledge and practices. Since 2014, between 8 and 10 million farmers worldwide have been estimated to be practicing SRI methodology. Furthermore, SRI is recognized at the national level and has received national policy support in over 50 countries throughout Africa, Asia, the Middle East, Central and South America and the Caribbean, see Figure 1.

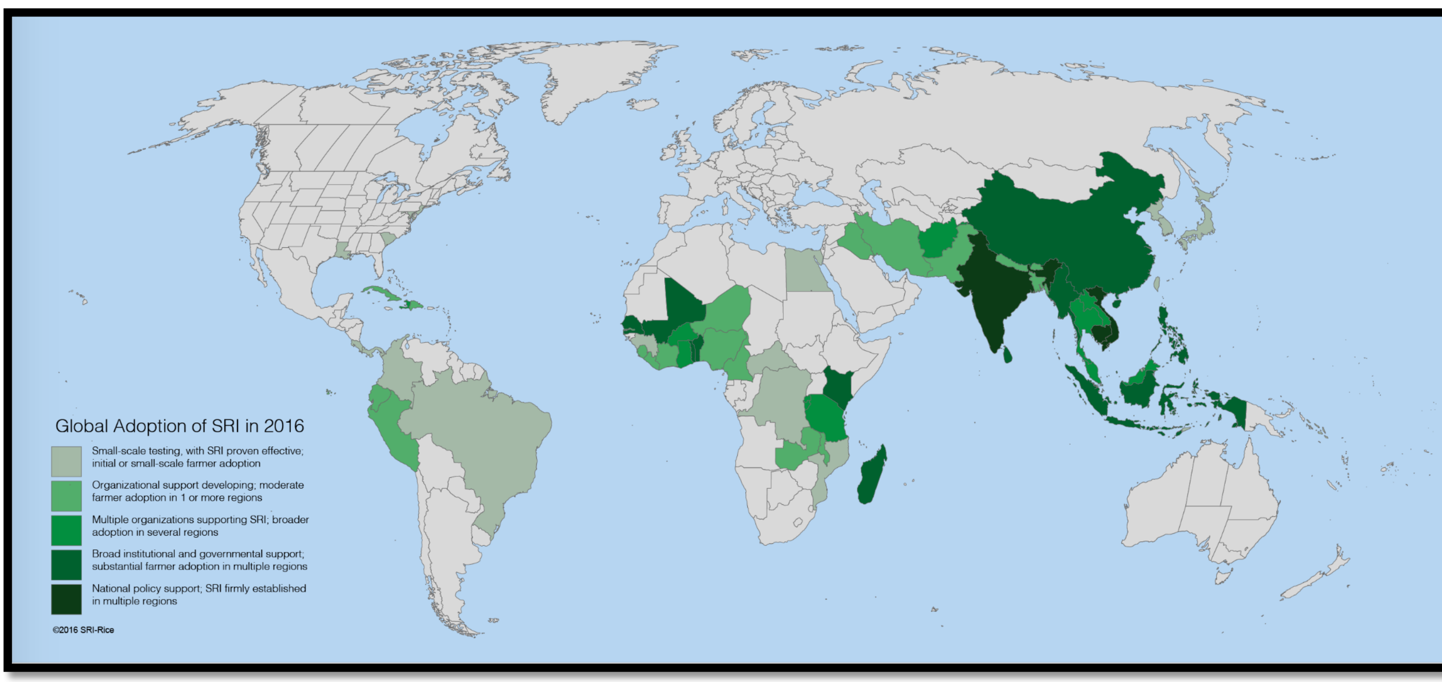

Figure 1. Global distribution of SRI practitioners. The light green areas represent small-scale SRI testing and beginning farmer adoption. The darkest green areas show where SRI is firmly established and has gained national policy support (SRI-Rice 2015).

2.2 System of Rice Intensification Management Principles

Friar Laulanié first created SRI as a set of principles for optimizing rice production with less required external inputs (Uphoff 2007). That basis in itself has made skeptics within the research and scientific community. SRI is based on observations and experiments rather than a concrete scientific theory and therefore is often criticized by more mainstream agriculture institutes as having no scientific backing. As Uphoff (2007) notes "*The SRI methods produce more output with less input makes it suspect in a world where we are told that there is 'no free lunch,' and where financial interests reinforce a preoccupation with input-centered innovation*." An increase in production with less required external inputs is achievable through the SRI principles by utilization and enhancement of "existing genetic potentials" of the rice genome, which are often inhibited by many cultivation practices. Almost all of the genotypes of rice, *Oryza sativa*, respond positively to SRI practices in large part due to the improvement of soil ecology associated with the method (Uphoff 2007). SRI principles enhance soil structure; organic matter, temperature, oxygen and moisture that benefit and induce soil biota growth. The foundation of healthy, fertile soil creates an optimal growing environment that enables higher productivity of the rice plant with more efficient use of land, labor, inputs and water.

The foundation of SRI is based on four main interrelated principles: 1) *"early, quick and healthy plant establishment"* 2) *"reduced plant density"* 3) *"improved soil conditions through enrichment with organic matter"* and 4) *"reduced and controlled water application"* (SRI-Rice 2016). SRI is a set of principles and recommended practices as opposed to a rigid technology of prescribed rules. The notion behind SRI is that practitioners are able to adapt, modify or reinvent the SRI principles according to their own socio, economic and ecological conditions (SRI-Rice 2016). Most often the majority of adaptations to SRI practices are made to accommodate differences in soil fertility, weather patterns, labor availability, water accessibility and access to organic inputs. SRI is commonly practiced in irrigated systems, although it is also adaptable to rainfed systems. SRI principles promote organic agriculture, but the use of chemical inputs is accepted depending on farmer resources, capabilities and ecological capacities. The major SRI recommended practices can be broken down into plant management, soil management, water management, nutrient/fertilizer management and weeding management, see **Table 2.** (SRI-Rice 2016).

Photo 1. The plant on the right was grown using traditional methods and the plant on the left was grown with SRI methods. The SRI plant exhibits more tillers and a larger root complex (Singh 2012).

SRI practices advocate the crop propagation method of transplanting, which involves planting the seeds in a nursery before transplanting the seedlings onto the rice field (SRI-Rice 2016). SRI practices encourage transplanting seedlings at a younger age than traditional transplanting methods, 8 – 10 days old versus 30 days or older. The younger seedling age reduces transplanting shock, increases the time allowed for root growth, promotes earlier tillering, increases tiller growth and more tillers. Additionally, SRI methods involve planting one seedling per hill, at a shallow depth and wide in-row spacing. Low density planting reduces competition for nutrients, water, sunlight and space. It also encourages robust root growth and promotes more photosynthate to the roots. The SRI water management regime of non-flooded or alternation between flooded and dry periods promotes aerobic soil conditions that encourage robust root growth and soil biota. Moreover, it releases water stress on the plant and does not cause degeneration of the roots during the flowering phase. SRI water management can reduce water use by up to 40 – 50 percent and decrease greenhouse gas emissions of rice fields. The practice of inter-cultivation with mechanical weeders promotes soil aeration in addition incorporating the weed biomass as green manure and activating soil microbiota. SRI principles strongly recommend the use of organic fertilizer sources, most commonly in the form of manure.

Organic fertilizer improves soil structure and nutrients while promoting soil organism activity and plant root growth.

Table 2. Shows six prominent principles of SRI management practices and associated benefits based on global research and observed trials. These principles promote root and tiller growth, reduce resource competition, reduce requirement for water and seeding material and improve soil fertility (Thakur 2015; Styger et al 2014; SRI-Rice 2016).

SRI Management Principles & Effects	
Principle	**Effect**
Transplanting young seedlings	Reduced transplanting shock; increased root growth; earlier tillering, increased tiller growth and increased tillers
Crop propagation of transplanting; Single seedling planted per hill at shallow depth	Transplanting and use of fewer seedlings reduces seeding material requirement; reduced resource competition for seedlings for nutrients, water, sunlight, space; lower plant density increases light and photosynthate to the roots
Wider spacing	More space for root growth and less competition for resources; promotes robust root and tiller growth
Non-flooded water management regime	Aerobic soil conditions enable robust root growth and support aerobic soil organisms; no degeneration of roots, which occurs under flooded conditions during the flowering phase; reduced water use, by up to 40-50 percent; reduced greenhouse gas emissions
Inter-cultivation with mechanical weeders	Aerates surface soil; incorporates weed biomass into the soil as green manure; activates and generates beneficial microbial, physical and chemical soil dynamics
Promotion of organic manure application	Improved soil structure and nutrients; promotes growth and activity of soil organisms; improves root growth and activity

3 Situational Analysis

The analysis of the SRI diffusion process in Ghana is situated within the context of two doctrines: food security and agricultural development. The transformation of the concept food security and the transformation of agricultural development are described in this chapter to set the backdrop for the significance of SRI under constraints of natural resource management and climate change.

3.1 Global Stage for Addressing Food Security

Global discourse on eradicating hunger and malnutrition first gained widespread recognition at the 1974 World Food Conference in Rome (FAO n.d). As a result of the conference, attending governments agreed *"every man, woman and child has the inalienable right to be free from hunger and malnutrition in order to develop their physical and mental faculties."* Twenty years later, the 1996 World Food Summit (WFS) at the Food and Agriculture Organization of the United Nations (FAO) headquarters in Rome provided a platform for world leaders to discuss prominent concerns for the new millennium, namely hunger and poverty. At the summit, all representatives from 182 governments pledged "…*to eradicate hunger in all countries, with an immediate view to reducing the number of undernourished people to half their present level no later than 2015*" (FAO 2015).

Shortly thereafter in 2002, the United Nations (UN) launched a UN Millennium Project calling on the global stage to take action in achieving eight Millennium Development Goals (MDGs) addressing poverty, education, women's empowerment, maternal health and the environment (UN n.d.). The main objective of the MDGs was to eradicate the diverse dimensions and causes of poverty around the world and over a 15-year time period. At the forefront of the MDGs was Goal 1 with the specific focus on poverty and hunger (UN n.d.). The year 2015 marked the end of the 15-year MDG timeframe with results showing huge strides towards achieving the goals in fighting multiple dimensions of poverty (Un.org 2015). Since then, extreme poverty and hunger in developing countries has drastically declined, with the proportion of the population living on less than $1.25 a day dropping from over 50 percent in 1990 to 14 percent in 2015. Furthermore, the proportion of undernourished people fell by nearly half, from 23.3 percent in 1990 to 12.9 percent in 2014.

Yet, despite this extraordinary progress, inequalities continue to persist (Un.org 2015). An estimated 800 million people still live in extreme poverty and are food insecure. Thus, the

MDGs transformed into a set of 17 Sustainable Development Goals (SDGs) (UNDP 2016). The *2030 Agenda for Sustainable Development* is a continuation of the MDGs with the aim to end poverty, stop inequality and injustice and address climate change within the next 15 years. Similar to the MDGs, fighting poverty and global hunger still remain the first two priorities of the SDGs: *SDG 1 No Poverty* and *SDG 2 Zero Hunger* (UNDP 2016). SDG 2 Zero Hunger aims to *"end hunger, achieve food security and improved nutrition and promote sustainable agriculture"* (UN 2016).

The concept food security has evolved over the past decades in parallel with development in agriculture as a reflection and result of policy transformations. Ensuring adequate food supplies will remain a prominent global issue over the next 50 years. At the same time, increasing agricultural production will become ever more challenging in the face of climate change and natural resource depletion (Rosegrant et al 2004).

3.2 Transformation of the concept Food Security

The term *food security* originated at the 1974 World Food Conference with the objective to ensure adequate food supply and quantity at all international and national levels (FAO 2006). Early definitions and concepts of food security focused on ensuring global availability and price stability of basic food supplies. This concept gradually transformed into inclusion of food accessibility, specifically a balance between supply and demand at the international and national level as defined by FAO 1983, *"Ensuring that all people at all times have both physical and economic access to the basic food that they need."*

The 1996 World Food Summit defined food security as *"exist[ing] when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life."* The 1996 WFS definition of food security vastly expanded upon the original term to include multiple dimensions such as food access, availability, use and stability (FAO 2006). In addition, the definition included a temporal dimension involving chronic and transitory food insecurity. All dimensions and temporal components of food security are vital for addressing global issues of hunger and poverty. The shift to a more holistic view of food security procured a political response in promoting livelihood options and livelihood approaches, which has set the foundation for frameworks of many international development programs.

3.3 Transformation of Agricultural Development

One of the most profound transformations in agriculture history is the "Green Revolution" of the 1960s and 1970s, which dramatically altered the practices of agriculture production as a response to global food shortages (Wallace n.d.). The Green Revolution introduced innovations such as high yielding crop varieties or so called "miracle crops," inorganic fertilizers, irrigation and pesticides. These innovations increased productivity to levels that had never before been attained in agricultural history (Jain 2010). The technology of the Green Revolution was based largely on scientific discoveries during the early 20th century that changed the face of modern agriculture. Mendel's Laws of genetic inheritance provided scientific foundation for selective plant breeding and the creation of miracle crops. Exorbitant use of inorganic fertilizer was spurred by Liebig's theory that soil fertility could be restocked through application of inorganic fertilizers, thus replenishing soil nutrients removed by crops. Paul Muller's discovery of the chemical DDT paved the way for experimentation and use of pesticides in crop protection practices. Moreover, the invention of tractors and introduction of machinery to modern farming greatly increased farmers' efficiency and productivity.

The two International Agricultural Research Centers - CIMMYT in Mexico and IRRI in the Philippines - became world leaders for maize, wheat, and rice breeding programs designed to produce fertilizer responsive, high yielding crop varieties (Jain 2010). A few years after the first introduction of the new miracle crops, many countries experienced successful increases in agricultural productivity (Wallace n.d.). Yet, success of the Green Revolution was not experienced equally throughout the globe (Halberg 2009). While Asia and Latin America observed acceleration in agricultural productivity, Green Revolution technology did not have the same successful results on the African continent. Furthermore, technologies of the Green Revolution often created farmer dependency on commercial seeding material, chemical inputs, depleted soil nutrients and polluted water sources (Wallace n.d.). Moreover, many agriculture systems are currently experiencing a deceleration in agricultural productivity (Thakur et al 2015). For instance, the International Rice Research Institute (IRRI) has not observed a significant increase in rice breeding trails in the past 30 years.

Countries are now more than ever confronted with the challenge to alter agriculture systems that are highly productive, but do not further degrade natural resources (De Schutter et al 2011). International institutions are recognizing the need for a new green revolution that combines *"modern technology, traditional knowledge and an emphasis on farming, social and agro-ecological systems as well as yields"* (FAO 2016). The objective of the new green revolution is to find alternative approaches for improving agricultural systems that minimize environmental impact and benefit poor farmers on marginalized land. Agriculture is extremely dependent on climate conditions (Scialabba et al 2010). Changes in rainfall patterns, rising temperatures and extreme weather events adversely impact agricultural productivity and increase farmer vulnerability, especially in regions where livelihoods depend solely on agriculture. As a temperature increase of 2˚C and related climate change impacts are inevitable, agro-ecosystems are essential to ensuring food security and improving rural livelihoods in vulnerable regions (Scialabba et al 2010; Gliesmann n.d.).

3.4 Emerging Agriculture Methods

Global actors are increasingly acknowledging shortcomings of conventional agriculture practices of the 1960s Green Revolution and finding potential in other agriculture methods for ensuring food security that have less impact on the environment (Halberg et al 2015). FAO states "*ecosystem services sustain agricultural productivity and resilience*" (FAO 2013). FAO promotes the use of ecosystem-based approaches as the method for addressing food insecurity and the future of food production. The method of *agricultural intensification* is an agricultural method that is increasingly more prevalent in modern day discourse.

The intensification agriculture approach is based on efficient use of ecological functions and existing natural resources to minimize negative impacts of agriculture activities (FAO 2013). Ecological intensification is defined as a "*knowledge-intensive process that requires optimal management of nature's ecological functions and biodiversity to improve agricultural system performance, efficiency and farmers' livelihoods.*" Ecological intensification includes two similar approaches "*eco-functional intensification*" and "*sustainable intensification*" (FAO 2013). All three intensification approaches focus on "*increasing/maximizing productivity while reducing/minimizing negative impacts of the environment and ecosystem services in order to meet the anticipated increase of food demand*" (FAO 2013).

The System of Rice Intensification (SRI) falls under the category of sustainable intensification agriculture (Pretty et al 2011). Sustainable intensification focuses on increasing natural resource efficiency to improve crop productivity, crop quality and enhancement of ecosystem services (FAO 2013). According to Petty et al (2011), "*sustainable agricultural* *intensification is defined as producing more output from the same area of land while reducing the negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services*."

Sustainable intensification promotes land sparring and limited use or exclusion of external agricultural inputs (Pretty et al 2011). Sustainable intensification is a very knowledge intensive approach and process of social learning that requires extensive training, extension services and active participation. The actual "intensification" of the agriculture system can occur within the ecologic, genetic or socio-economic spheres. Sustainable production systems utilize high yielding crop varieties, avoid unnecessary use of chemical fertilizers and pesticides, promote ecological processes like nutrient cycling and natural nitrogen fixation, minimize use of environmentally harmful technologies, utilize human knowledge and learning capacities, and adapt system management to minimize negative externalities such as GHG emissions and water pollution (Pretty et al 2011). Many authors note that because the sustainable intensification approach has an ecosystem-based foundation with a "production" focus, it falls in between the ecological concepts of agroecology and high input intensive Green Revolution methodologies (FAO 2013).

3.5 Agriculture in sub-Saharan Africa

Climate change is a prominent driver of food insecurity around the world (Connolly-Boutin et al 2015). Already, climate change induced extreme weather events like severe droughts have threatened rural livelihoods. Impacts of climate change can be observed around the globe, yet sub-Saharan Africa is one of the most vulnerable regions to its adverse effects. Sub-Saharan Africa has a lower adaptive capacity than other regions due to biophysical, political and socioeconomic stresses. The main climatic changes that afflict the region are temperature rise, changes in rainfall pattern, intensity and increases in extreme weather events, increases in desertification and alterations in disease vectors and transmissions of diseases. These predicted environmental changes are projected to greatly disrupt the agriculture sector through reduction in the amount of land appropriate for agriculture and a decline in crop yields. Smallholder agriculture and family farming are essential cornerstones for providing food security and nutrition, with over 80 percent of the population being smallholder farmers (FAO 2015). Roughly 84 percent of these smallholder farms are operating on less than two hectares of land, typically of marginal quality and with limited access to resources. These farmers are particularly vulnerable to climate change impacts as their livelihoods are dependent on agriculture (AGRA 2014).

While many Asian and Latin American countries experienced high yields and accelerated agricultural growth with the Green Revolution technologies, smallholder farmers on the African continent did not observe similar success (Halberg et al 2009). After the independence wave in the late 1960s and 1970s, many African governments and aid donors attempted to promote an Asian-inspired Green Revolution to boost economies and improve livelihoods (Nin-Pratt et al 2014). As a result, the influx of policies and programs promoting Green Revolution innovations created a large reliance on subsidies for inputs and government services i.e. marketing, infrastructure, extension, research, and parastatals. Yet in the end, the policies had a limited effect on adoption of chemical fertilizers or high yielding varieties by African farmers.

Halberg et al (2009) argue that many reasons for the lack of Green Revolution success in Africa resides in the continent's weaker infrastructure and marketing systems, lower population density, poor extension services, low investment in agricultural development and higher variations in agro-ecological conditions. Nin-Pratt et al (2014) attribute the Green Revolution failure in Africa to the existence of different structural and ecological conditions. At the time of the Green Revolution, demand for chemical fertilizers in Africa was quite low. Land was relatively abundant, so farmers had little motivation to increase cultivation intensity on existing agricultural land. Additionally, in contrast to Asia, African agriculture lands were cultivated by hoes with limited animal or mechanical ploughing and were mostly unfertilized. African farmers traditionally practice intercropping with long intervals of fallow as a main strategy for reducing weeds and pest control. On the other hand, Asian agricultural practices employ wide use of hand-weeding, manual pest control and agrochemicals. Increases in agricultural output in Africa between 1960 and 2000 are largely attributed to expansion of cultivated land area or decreased fallow periods rather than increased crop production intensity.

Other reasons for the lack of Green Revolution success in Africa lie in labor availability and the diverse crop varieties available in sub-Saharan Africa (Nin-Pratt et al 2014). Many African nations tend to be rich in natural resources, have low population density in rural areas (despite continental rapid population growth) and high labor costs or low labor availability. Further, most African smallholders produce primarily non-cereal staples like cassava, yam and plantain as well as other food crops for household consumption or sale at local markets. So, the high yield increases of cereal crops like wheat, maize and rice that improved food security in Asia during the Green Revolution were not befitting to African regions where food security in some places relied on non-cereal crops. In African regions where cereal crops are abundantly cultivated, high yielding varieties for those agroecologies only became available during the 1980s through specialized research. Finally, African policies based on the Asian Green Revolution were financially unsustainable and foundered in sequence with economic crises in many African nations. After economic downturns, many African governments' focus on agricultural development began to wane. Yet recently state-led support for technical innovation in the African agriculture sector is once again becoming a priority on political agendas.

4 Theoretical Framework: Diffusion of Innovations

The agricultural innovation SRI is being widely practiced and up-scaled throughout the African continent in over 13 nations including Benin, Burkina Faso, Cote d'Ivoire, The Gambia, Ghana, Guinea, Liberia, Mali, Nigeria, Senegal, Sierra Leone and Togo (SRI-Rice 2016). As a knowledge-based method, SRI requires extensive training, information transfer and social structure transformations for its adoption and practitioners to observe its full benefits (Styger et al 2014). The adoption of any innovation or new idea, system or practice is a social process as much as a technical process, which involves dissemination through both social and technical channels and decision making processes (Rogers 2002). Chapter 4 describes the process of innovation adoption as expressed in Rogers (2003) *Diffusion of Innovations* theory.

4.1 Introduction to Diffusion of Innovations

E.M. Rogers *Diffusions of Innovations* (2003) theory is one of the most prominent theories for studying the enabling environment and influencing factors behind the adoption of innovations (Sahin 2006). The introduction of new innovations is a difficult and often lengthy process, even if the advantages of the innovations are obvious (Rogers 1983). According to Rogers (1983), *"An innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption"* (p. 11). Diffusion is described as *"the process through which an innovation is communicated through certain channels over time among the members of a social system"* (Rogers 1983 p. 5). In alignment with Rogers (1983) definitions, diffusion of innovations is composed of four key elements: *innovation*, *communication channels*, *time* and *social system* (Sahin 2006). Each element is further characterized by attributes as depicted in Table 3.

The element *innovation* includes the attributes *software information vs. hardware information* and *attributes of innovations*. Attributes of innovations are categorized further by *relative advantage, compatibility, complexity, trialability* and *observability*. The element *communication channel* is composed of *heterophily & homophily characteristics* and *mass media vs. interpersonal communication*. The element *time* involves the *innovation-decision process, adopter categories,* and *rate of adoption.* The element *social system* includes *social norms* and *change agents & opinion leaders*.

Table 3. Shows a chart of the four elements of the *Diffusion of Innovations Theory* as described by Rogers (2003) (own table).

Four Elements of Diffusion of Innovations Theory (Rogers 2003)			
Element	**Attribute**	**Attribute**	**Attribute**
Innovation	Software Information vs. Hardware Information	Attributes of Innovations (Relative Advantage, Compatibility, Complexity, Trialability, Observability)	—
Communication Channels	Heterophily & Homophily Characteristics	Mass Media vs. Interpersonal Communication	—
Time	Innovation-Decision Process (Knowledge, Persuasion, Decision, Implementation, Confirmation, Reinvention)	Adopter Categories (Innovators, Early Adopters, Early Majority, Late Majority, Laggards)	Rate of Adoption (Adoption, Rejection, Discontinuation)
Social System	Social Structure (Social Norms)	Change Agents & Opinion Leaders	—

4.2 Innovation

Innovations: Innovations come in the form of new ideas, concepts or technologies (Sahin 2006). The newness factor of an innovation depends on how an individual perceives the innovation. Innovations could be entirely new or have been invented a long time ago, but seen as new by an individual. Innovation introduction comes with a level of uncertainty about the functioning and consequences of the innovation (Rogers 2003). Thus, information is a key component to an individual presented with an innovation and the decision to use, adopt or reject the new idea or technology. Innovations are often associated with new forms of technology and Rogers (2003) often refers to “innovation” and “technology” as synonyms. Innovations whether they be in the form of a concept or technology have two components, one being *hardware* *information* and the other *software information*. Hardware information is the physical tool or innovation object whereas software information is the knowledge base for the innovation tool. Innovations that are software-heavy and knowledge-intensive are less observable than hardware-focused innovations and often more challenging to disseminate.

Attributes of Innovations: Rogers (2003) proposes five *attributes of innovations* that influence how an individual perceives an innovation and affect his or her rate of adoption or innovation-decision process. The five attributes are *relative advantage*, *compatibility*, *complexity*, *trailability* and *observability*. Relative advantage is described by Rogers (1983) as *"the degree to which an innovation is perceived as being better than the idea it supersedes"* (p. 213). Relative advantage can be expressed in terms of economic profitability, social status or other forms of livelihood improvement (Rogers 1983). The advantages are determined by the characteristics of the innovation as well as the priorities of the adopter. Potential adopters seek information about the innovation to determine advantages over their existing practices. Subsequently, information about relative advantage is spread through various communication channels in the social system. Rogers (1983) categorizes relative advantage into multiple sub-dimensions including *"economic profitability, low initial cost, a decrease in discomfort, a savings in time and effort, and the immediacy of the reward"* (p. 217-218). All of these factors play a role in influencing the time period in which an individual decides to adopt, reject or discontinue an innovation.

Rogers (1983) defines two types of innovations and their different relative advantage characteristics that influence innovation adoption rate: *preventative innovations* and *incremental innovations*. A preventive innovation *"is a new idea that an individual adopts in order to avoid the possibility of some unwanted future event"* (Rogers 1983, p. 218). Examples of *preventive innovations* include insurance, soil-conservation practices, inoculation against diseases etc. Relative advantages of preventative innovations occur in the future and tend to be harder for the change agent to motivate adoption among their target group. On the other hand, relative advantages associated with *incremental* or *non-preventive innovations* are achieved over a shorter time period (Sahin 2006).

Secondly, Rogers (1983) defines *compatibility* as *"the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters"* (p. 223). The compatibility or incompatibility of an innovation is compared with an individual's social structure, culture, beliefs, values, previously introduced ideas and the individuals need for the innovation. The more a new idea or innovation is in line with these characteristics of an individual or social system, the more the uncertainty associated with the innovation is reduced and potential for adoption increased. However, if an innovation is too similar or compatible to existing practices, then the individual may not perceive the innovation as new or more beneficial than the preceding practices. In line with compatibility is the *complexity* attribute as Rogers defines by "*the degree to which an innovation is perceived as relatively difficult to understand and use*" (p. 230). *Complexity* negatively correlates to rate of adoption. Innovations can be viewed along a complexity-simplicity scale. The more complex or difficult an innovation is for the potential adopter to understand, the more difficult it is or longer it will take for the innovation to be adopted.

The attribute *trailability* is defined by Rogers (1983) as *"the degree to which an innovation may be experimented with on a limited basis"* (p. 231). As opposed to complexity, trailability is positively related to the rate of adoption. The ability of a potential adopter to test the innovation on a trial basis reduces the level of uncertainty and generally increases the rate at which the individual accepts the innovation. Along the scale of *adopter categorization*, which will be described in the section for the element time, early adopters place a larger importance on the trailability of an innovation than later adopters. Late adopters and laggards tend to go through a more rapid transition from trial period to full-scale implementation because they are surrounded by examples from their experienced peers.

The fifth attribute of innovations *observability* is defined by Rogers (1983) as *"the degree to which the results of an innovation are visible to others"* (p. 240). Some innovations and new ideas are easy to observe and communicate, subsequently having a positive influence on the adoption rate by reducing uncertainty. Innovations that are hardware oriented are more visible and easily observed by potential adopters than innovations that are software or knowledge focused. Innovations that are software oriented typically have slower adoption rates. Overall, innovation characteristics have a large influence on the rate of adoption or rejection (Sahin 2006). The adoption rate of an innovation can be enhanced if the relative advantage is tangible, the innovation is simple to understand and implemented in an easily observable environment.

Additionally, in early diffusion research, the notion of innovation adoption was considered a passive act by the adopter in which the individual implemented as the innovation as prescribed in the dissemination process. But in the 1970s scholars began to delve into the concept of *reinvention*. Rogers (2003) describes *reinvention* as "*the degree to which an innovation is changed or modified by the user in the process of its adoption and implementation…*" (p. 181). Thus, the innovation adoption process suggests proactive involvement from both the change agent and the potential adopter. In fact, many individuals are eager to participate in customizing and modifying innovations to suit their local conditions. Reinvention occurs during the adoption and implementation stages when an individual modifies or changes the innovation. Rogers (2003) argues that the more an innovation is reinvented, the more likely the innovation will be widely adopted, practices sustained longer and the innovation to become institutionalized.

4.3 Communication Channel

Rogers (2003) defines *communication* as *"the process by which participants create and share information with one another in order to reach a mutual understanding"* (p.18). In terms of innovation diffusion, the messages and information being portrayed is that of new ideas. Diffusion is a specific type of communication that involves an innovation, two individuals or sources – one with knowledge of and experience with the innovation and the other without – and communication channels. A *communication channel* is *"the means by which messages get from one individual to another"* (Rogers 2003 p. 18). Communication channels exists in the form of *mass media* like TV, radio, or newspaper, etc. and *interpersonal communication,* namely personal communication between two or more individuals. Diffusion is a very social process, which is highly influenced by interpersonal communication, the most powerful communication persuasion tool for changing attitudes.

According to Rogers (2003), *"a fundamental principal of human communication is that the exchange of ideas occurs most frequently between individuals who are alike, or homophilous" (*p. 305). Interpersonal communication involves actors with a degree of both *homophily*, similar personal attributes like beliefs, education, socioeconomic status and *heterophily*, differences in personal attributes. Rogers (2003) notes that heterophily characteristics between participants are one of the most difficult challenges and sources of problems in the innovation diffusion process. Issues often occur between the change agents and their clients to whom they introduce the innovation. Change agents have a higher technical understanding of the innovation, which can lead to ineffective or miscommunication. Yet, some degree of heterophily must be present in the diffusion process in order for knowledge to be exchanged. In an ideal situation, the two participants would have different degrees of knowledge relating to the innovation, but be homophilious on all other aspects such as education, culture, socio-economic status etc.

4.4 Time

Time is present throughout all activities and stages of the innovation diffusion process from first knowledge and introduction of the innovation to the adoption or rejection stage (Rogers 2003). Rogers (1983) argues that the element of time is an important aspect of locating and determining the rate at which an innovation is adopted as well as an individual's innovation-decision process and adopter categorization (the earliness or lateness an innovation is adopted in a social system).

Innovation-decision process: Adoption or rejection of an innovation involves an innovation-decision process, which Rogers categorizes into five stages: *knowledge*, *persuasion*, *decision*, *implementation*, and *confirmation* (Rogers 1983). Rogers (1983) defines the innovation-decision process as *"the mental process through which an individual (or other decision-making unit) passes from first knowledge of an innovation to forming an attitude toward the innovation, to a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision"* (p. 36). The *knowledge stage* is when the individual first learns about the innovation and enters a critical question phase asking "what," "how" and "why" about the innovation (Sahin 2006). There are three types of knowledge involved with innovation-decision making: awareness-knowledge, how-to knowledge and principles-knowledge. *Awareness-knowledge* is the individual's first contact with existence of the innovation, which can spark motivation to learn more about the innovation. *How-to-knowledge* is information about how to properly use the innovation. An individual's knowledge of how to properly utilize the innovation increases the chance of adoption. *Principle-knowledge* is knowledge about how and why the innovation works. This knowledge is not essential for adoption of the innovation, but it encourages continuous, long-term use of the innovation.

The *persuasion stage* occurs after the individual is aware of the innovation and begins to form his or her opinion of the innovation (Rogers 1983). This stage involves a more personal level of involvement with the innovation than the knowledge stage and is influenced by the innovations functions within the individuals' social sphere. Opinions and beliefs formed by peers influence an individuals' perception of the innovation and reduce uncertainties. The *decision* *stage* is when individuals decide to use the innovation. Adoption of the innovation is defined as the "*full use of an innovation as the best course of action available*" whereas rejection is the decision to not adopt the innovation (Rogers 1983, p. 21). The chance of adoption is higher if the individual is able to personally test the innovation in a quasi-trail situation. A trail phase can speed up the decision-making process for adoption or rejection. Following is the *implementation stage* in which the innovation is carried out in practice. At this stage, there is still a level of uncertainty with the outcome of using the innovation, so some degree of technical assistance, often by a change agent, is necessary. The *confirmation* stage is the final stage of the innovation adoption decision-making process. In this post-decision stage, the individual seeks support for his or her decision (Rogers 1983). The available support or enabling environment for adopting the innovation as well as the attitude of the individual determine whether the innovation gets fully adopted or use is discontinued. Discontinuation of an innovation can occur when an individual starts using another innovation or if the individual is not satisfied with the results of the innovation. Roger (2003) notes that rejection is possible at any stage.

Categorization of Innovation Adopters: Rogers (1983) defines *rate of adoption* as *"the relative speed with which an innovation is adopted by members of a social system"* (p. 23). The number of individuals who adopt the innovation over a period of time is considered the *rate of adoption*. Individuals within a social system adopt innovations at different time periods based on innovation attributes as well as the characteristics of their surroundings and personal traits. There is much discussion and debate among diffusion researchers about the number, name and classification of the adopter categories. Rogers (1983) definition of adopter categories has gained most popularity as *"the classifications of members of a system on the basis of innovativeness"* (p. 241). Individuals are categorized according to their innovativeness, which is *"the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than the other members of a system"* (Rogers 1983, p. 22). The adopter categories are classified into five groups: *innovators*, *early adopters*, *early majority*, *late majority*, and *laggards.* The adopter groups are based on the timeframe during which the individual adopts an innovation after it has been introduction to the social system.

Researchers describe *innovators* as being "venturesome" and eager to try new ideas (Rogers 1983). Innovators are in a socio-economic situation that allows them to handle a certain degree of uncertainty with the innovation and ability to incur potential setbacks or consequences. Innovators can be seen as outsiders within their social system, yet they play an important role in the diffusion process by introducing the innovation and information to their social system. On the other hand, *early adopters* are respectable, opinion leaders with a higher social acceptance. Early adopters tend to serve as role models for other members of the society to whom potential adopters go to for advice and information. Thus, early adopters are important for decreasing uncertainty and sharing their personal evaluation of the innovation with their peers via interpersonal communication networks.

The *early majority* are deliberators who adopt the innovation before the average member of society joins the adoption process. They communicate frequently with their peers, rarely hold leadership positions and as such are a communication link within the entire social system. Their deliberation process to accept a new idea is longer than innovators and early adopters, still early majority possess a willingness to adopt. Early majority play a pivotal role in the diffusion process by bridging the gap between the innovators and early adopters with the late majority. The *late majority* are skeptical and cautious of new ideas, only adopting an innovation after the majority of the members in their social system have also adopted. Their limited resources make them more vulnerable to uncertainties associated with new ideas. Their motivation for adoption is mainly driven by economic factors or social pressure. Late majority adopters only adopt if the innovation has become part of the social norm. *Laggards* are the very last group to adopt an innovation and tend to hold relatively traditional values and are often isolated from many social networks. Their economic situation influences them to be protective of their limited resources and extremely cautious of new ideas that could further jeopardize their economic situation. Laggards tend to only adopt an innovation after they have already observed its success among the other members of their social system.

Statistically, the adopter categorization is expressed by a normal distribution, bell-shaped curve for which *innovativeness* is the continuous variable (Rogers 1983). Innovativeness is a dimension of characteristics that each individual within a social system either possess more or less of. The average members in a social system and the distribution of the sampled members (standard deviation) is used to partition the normal distribution curve into the five adopter categories. Figure. 2 shows the normal frequency distribution as divided into the five categories of innovators, early adopters, early majority, late majority and laggards. The percentages of each category are based off of the standard deviations from the average time of adoption. Research has shown in typical social system scenarios, innovators make up 2.5 percent of the social system, early adopters 13.5 percent, early majority 34 percent, late majority 34 percent and laggards 16 percent (Rogers 1983).

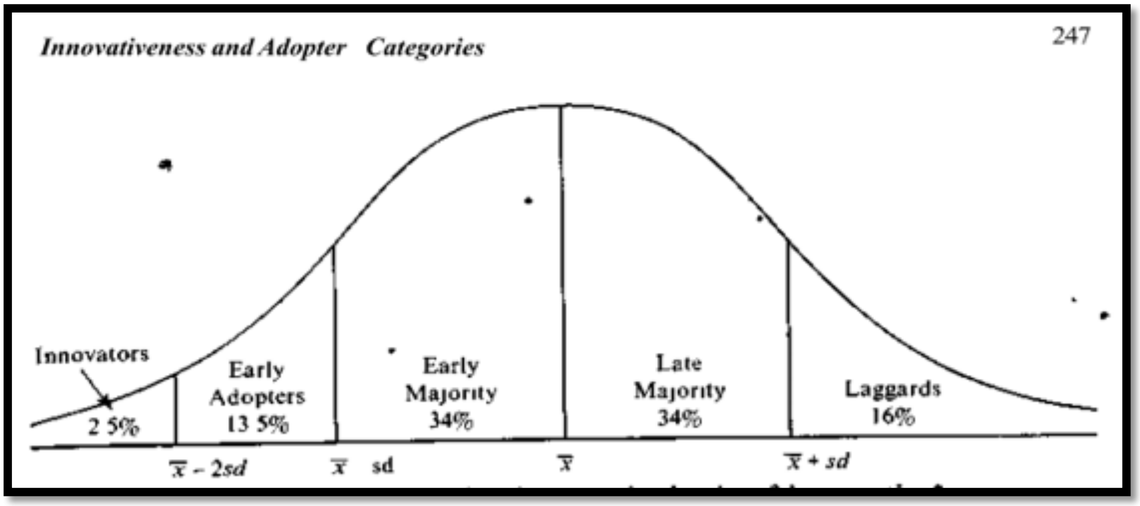

Figure 2. Shows the normal frequency distribution of the adopter categories with the dimension innovativeness as the continuous variable. The percentages are based off of the standard deviations from the time of innovation adoption within the social system (Rogers 1983, p.247).

4.5 Social System

Social system is one of the most fundamental components in the innovation diffusion process (Rogers 1983). The social system represents a boundary within which the innovation is diffused or disseminated. The social structure of a social system influences the innovation diffusion process via social norms and the roles of opinion leaders and change agents. Rogers (1983) defines social systems as *"a set of interrelated units engaged in joint problem solving to accomplish a common goal"* (p. 24). The members of social systems can be either individuals, informal groups, organizations or subsystems that are distinguishable from the other units. All of the units in the system work together towards a common objective, thus binding the units together. Rogers (1983) defines structure as *"the patterned arrangements of the units in a system"* (p. 24). Rogers argues that social structure provides stability, regularity and a degree of predictability of human behavior within a social system. *Social structure* refers to the relationship among the different units and members of a system. *Communication structure* is a more informal component of structure within a social system. Communication structure describes the interpersonal connections between members of the system and patterns of communication flow. Communication structures are often homophilious groups of individuals or cliques with similar characteristics. On the contrary, a heterophilious communication structure would be a situation in which individuals communicate with each member of the system with an equal probability. An example of heterophilious communication would be when two strangers first meet. Over time, regular communication patterns begin to occur within social systems. These patterns in communication structure allow a degree of predictability to the behavior of individuals of a social system. Social system structures greatly influence the facilitation or hindrance of innovation diffusion and affect an individual's actions and decision-making process (Rogers 1983; Sahin 2006).

System norms affect the range of acceptable behavior within social systems and serve as guidelines for individual members (Rogers 1983). Rogers (1983) defines *system norms* as *"the established behavior patterns for the members of a social system"* (p. 27). The influence of norms can be found at all levels of society from local systems to religious communities, organizations or even nations. Norms are often barriers to system changes and adoption of new ideas or innovations. Thus, the role of certain individual members of social structures is key to the diffusion process, namely the role of *opinion leaders* and *change agents*. As defined by Rogers (1983), opinion leadership *"is the degree to which an individual is able to influence other individual's attitudes or overt behavior informally in a desired way with relative frequency"* (p. 27). This describes a type of informal leadership role an individual within a social system assumes. An opinion leader is a highly regarded member of the system on his or her technical competence, social status and conformity to social norms. As part of his or her leadership role, he or she has a strong persuasion power within the social system and thus largely influences system change and diffusion. In systems where social norms are adept to change, opinion leaders tend to have more innovative characteristics. On the contrary, in social systems with more conservative norms opinion leaders tend to mirror the system conformity.

Opinion leaders reflect the structure of a system and are at the center of all interpersonal communication networks and information flow among individuals in the system (Rogers 1983). An opinion leader's status within the system and access to communication networks makes him or her the social model in innovative behavior of which other members follow and imitate. Yet, the ability of the opinion leader to maintain his or her leadership role can be removed if he or she strays too far away from social norms. Opinion leaders can also lose their status if they are perceived as being too similar to change agents. Rogers (1983) describes *change agents* as *"an individual who influences clients' innovation decisions in a direction deemed desirable by a change agency"* (p. 28). Change agents aim to promote new ideas and innovations and can also attempt to stop the dissemination process if they deem the innovation to be negative. Change agents are professionals within their technical field and incur an associated social status. Change agents' heterophilious relationship to the social systems they work with can lead to problems in communication and information exchange about the innovation. To illicit change and gain persuasion among their clients, change agents often use opinion leaders to head their campaign on diffusion of innovations.

5 Case Study: System of Rice Intensification in Ghana

5.1 Introduction to the Study Location

Ghana is located along the Guinea Coast of West Africa, bordered by Cote d'Ivoire to the west, Burkina Faso to the north and Togo to the east, see Figure 3 (USAID 2012). Ghana is a lower middle-income country with a total estimated population of 26.79 million (2014) and an annual population growth rate of 1.78 percent (The World Bank 2016; GRIB 2012). As of 2012, the national poverty rate was 24.4 percent, which decreased from 31.9 percent from 2005 (The World Bank 2016). Roughly half of the population lives in rural communities with an annual trend of 3.4 percent migration to urban areas (GRIB 2012). Currently, 16.4 percent of the national population lives in the capital city of Accra and the surrounding Greater Accra region.

Since the early 1990s, Ghana has experienced economic growth and a decrease in extreme poverty (FAO 2015). Ghana achieved two international targets for hunger reduction: the 1996 WFS goal and MDG 1c (National Development Planning Commission 2016). The proportion of the population living in extreme poverty declined from 51 percent in 1991 to 29 percent by 2005. Further, the percentage of the population living with chronic hunger or suffering from undernourishment drastically reduced from 47 percent in 1990 to below 5 percent by 2014. The agriculture sector in accompaniment with institutional reform and policies contributed to and continues to play a significant role in Ghana's economic growth. Ghana's economy is largely influenced by its agriculture sector, which contributes one-third to the country's GDP (USAID 2012). Moreover, agriculture covers over 68 percent of land use (USAID 2012). Yet, even with economic growth and agricultural vigor, Ghana still remains a food deficit country (WFP 2016). The largest hindrances to national food security are poverty, drought, floods and lack of agricultural technology (WFP 2016).

Figure 3. Ghana located within the region of West Africa (Googlemaps 2016).

5.2 Rice in the Ghanaian Agriculture Sector

The exact origin of rice domestication in West Africa is unknown, but archeological evidence suggests that the endemic variety *Oryza glaberrima* has been cultivated in the region for over 3,500 years (Kranjac-Berisavljevic 2003). In addition to *O. glaberrima* (Africa rice)*, O. sativa* (Asian rice) is the second major variety of rice grown in West Africa, both of which are the most important varieties for contributing to nutrition. In Ghana and all across the West African region, rice is becoming an extremely vital household and cash crop, with an increasing preference for rice among the population. But as of yet, no country within the region has been able to attain self-sufficient rice production. Regional demand for rice has continued to increase since the 1970s (GRIB 2012). This increase in rice consumption in West Africa is commonly called the “Rice Diet Transition.” Since the 1990s, rice imports to West Africa have increased from 4 million tons, costing 0.8 billion USD, to 8 million tons costing 1.6 billion USD in 2005 and imports are projected to reach between 6.5 and 10.1 million tons by 2020 (MoFA 2009). The expansion of rice consumption in West Africa can be partially attributed to a rise in economic status (USAID 2009).

In Ghana, other sources of carbohydrates such as maize, millet, sorghum, cassava, yam and plantain, tend to be cheaper than rice throughout most of the year (USAID 2009). Research shows that a demand shift from tubulars to rice tends to correlate with a rise in income. Rice consumption is often low in rural areas where poverty levels are high and in areas where farmers produce other sources of carbohydrates. Nonetheless, rice has become Ghana's second most important food crop falling just behind the country's most important grain crop maize (MoFA 2009). Economically, rice production in Ghana contributes 15 percent to the Agricultural Gross Domestic Product. In terms of land use, rice fields cover over 45 percent of the total land area for cereal production (Kranjac-Berisavljevic 2003). National consumption of rice dramatically increased from an annual level of less than 100,000 Mt per year in 1993 to over 600,000 Mt by 2003 (Quaye 2007). The Ministry of Food and Agriculture (MoFA) (2009) estimates the annual national rice consumption to increase to 1.4 - 1.6 million Mt by 2018.

The estimated annual rice production in Ghana is roughly 400,000 to 500,000 Mt, which covers only 30 - 40 percent of the current national demand (GRIB 2012). The remaining demand for rice is satiated by rice imports mainly from countries outside of the continent such as Vietnam, Taiwan, Thailand and the USA (USAID 2009). Ghana spends an estimated 450 million USD annually on rice imports (MoFEP 2016). Ghana's extensive dependency on rice imports has remained a concern for policy makers especially after food prices soared in 2008 (FAO 2013, MAFAP SPAAA). In May 2008, Ghana was one of the first countries within the Coalition for African Rice Development (CARD) to launch a National Rice Development Strategy (NRDS) for the decade 2009 - 2018. The main objective of the NRDS is to double domestic production of rice by 2018, implying a 10 percent annual production growth rate. In addition, the NRDS aims to enhance rice quality to stimulate the market for locally grown rice.

National rice yields are dependent on multiple variables such as cropping type, climatic conditions and the major or minor growing season (USAID 2009). Throughout the country, average rice yields are between 2.4 and 4.2 Mt/ha, which are well below the climatic potential of 6.5 Mt/ha. In comparison to other rice producing countries around the world, Egypt produces 9.8 Mt/ha, the United States an average 7 Mt/ha and an average 4 Mt/ha in Vietnam. Of Ghana's 10 regions, the major rice producing regions are the Upper East, Northern and Volta regions. Within Ghana there are three basic ecological systems in which rice is cultivated 1) irrigation schemes, typically with two crop seasons per year, 2) inland valley systems that are rainfed systems with water retention influenced by soil typology and land topography and 3) upland rice systems with limited soil water retention and a dependence on sufficient or continuous rainfall (Kranjac-Berisavljevic 2003). The majority of land for rice cultivation is covered by lowland rainfed systems (78 percent), followed by irrigated systems (16 percent) and then upland rainfed systems (6 percent) (MoFA 2009). In addition to low yields, the Ghanaian rice sector also faces challenges along the entire value chain (USAID 2009). Post-harvest loss due to lack of proper drying and storage facilities is a key issue in the rice sector throughout Ghana and all of West Africa. In addition, marketing local rice is a big challenge. Local rice is often of lower quality than imported rice leading to low market prices, a negative reputation and discouragement of consumers buying locally grown rice.

5.3 Socio-Economic Overview of Ghanaian Rice Farmers

Rice cultivation contributes roughly 10 percent of the employment in farming households in Ghana (MoFA 2009). The total national rice production area covers 118,000 hectares with an average of 0.4 hectares per household, equaling to an estimated 295,000 households involved in rice production. The socio-economic characteristics of Ghanaian rice farmers can be classified into four main typologies based on their access to resources and scale of operation: *ultra-poor rice growers*, *marginal rice smallholders*, *viable small scale rice growers* and *emergent commercial growers*.

Ultra-poor rice growers represent 15 percent of Ghanaian rice growers and operate on a pure subsistence level (MoFA 2009). Ultra-poor rice growers are mainly female headed households or ones with elderly heads of household and face major labor constraints. These households often have no reserve resources in the case of any natural disasters or external disruptions to their livelihoods. *Marginal rice smallholders* produce enough rice for their own consumption as well as a modest surplus for market sales. They represent 25 percent of the rice farmer population and tend to have a greater wealth of resources than ultra-poor rice growers in terms of physical strength, land and small savings. A large proportion of the adult household members of marginal rice smallholders migrate during the off-season to find work.

Viable small-scale rice growers represent the bulk of rice farmers making up 40 percent. Viable small-scale farmers are poor, yet possess resources like land and labor and tend to be more willing or in a position to take risks. However, their efficiency is often constrained by lack of access to markets, limited access to technology, poor infrastructure or weather-related issues. *Emergent commercial growers* produce rice as a cash crop and have more access to resources than the other farmer typologies. Some commercial farmers possess small mechanical equipment, may use hybrid seeds, apply fertilizer, can hire labor and often operate on irrigated fields. Emergent commercial growers make up 20 percent of the national rice producers.

Nation-wide, smallholder rice farmers in Ghana face similar constraints to production including high costs associated with land preparation that requires machinery, particularly for water conservation techniques such as bound building (Kranjac-Berisavljevic 2003). In terms of cultivation challenges, problems with weed control tend to surpass those caused by birds, mammals or diseases. According to Kranjac-Berisavljevic et al (2003) intensification of rice production would be important for ensuring food and cash security for farmers who cannot afford irrigation technology.

5.4 Rice Production in the Volta Region

The Volta region is Ghana's fourth largest region (20,572 km2) located on the far eastern border of the country (FAO 2016). The region shares a border with the Republic of Togo and stretches from the Atlantic Ocean to the Northern region of Ghana, see Figure 4. According to the FAO 2000 Population and Housing Census (GLSS 2000), the population is an estimated 1.7 million with the majority of the population being members of the Ewe community. The inheritance system is patrilineal meaning assets (land, money etc.) are passed down through the father. Literacy rates in the region are relatively high, with roughly 83 percent males and 58 percent females being literate and having received some form of formal education. Farming is the dominant land use and household occupation in large part due to the rural characteristics of the region as well as the abundant natural resources and fertile soils.

Farming plays an important role in the region as a means of crop production, food security, income generation and employment (FAO 2016). The most common cash crops are rice, cocoa, oil palm, tomato, shallot, cassava, maize and beans. The most common food crops grown throughout the region are cassava, maize, plantain, okra, yam, banana, garden egg, beans and peppers. Results from the GLSS 2000 survey revealed that a majority of the surveyed respondents kept part of their crop yields for household consumption and sold their remaining harvest. However, during focus discussion groups, the respondents mentioned issues of being unable to maintain food supplies and not being able meet daily nutritional needs. These issues are rooted in many different problems faced by the regional population. Land availability is becoming scarcer as it is under constant pressure from population growth and the need to produce more food. One main reason for a reduction in farm productivity is limited access to credit required for farm investments. Farm productivity is also hindered by a decline in labor due to an increasing pattern of youth and able-bodied workers migrating to urban areas.

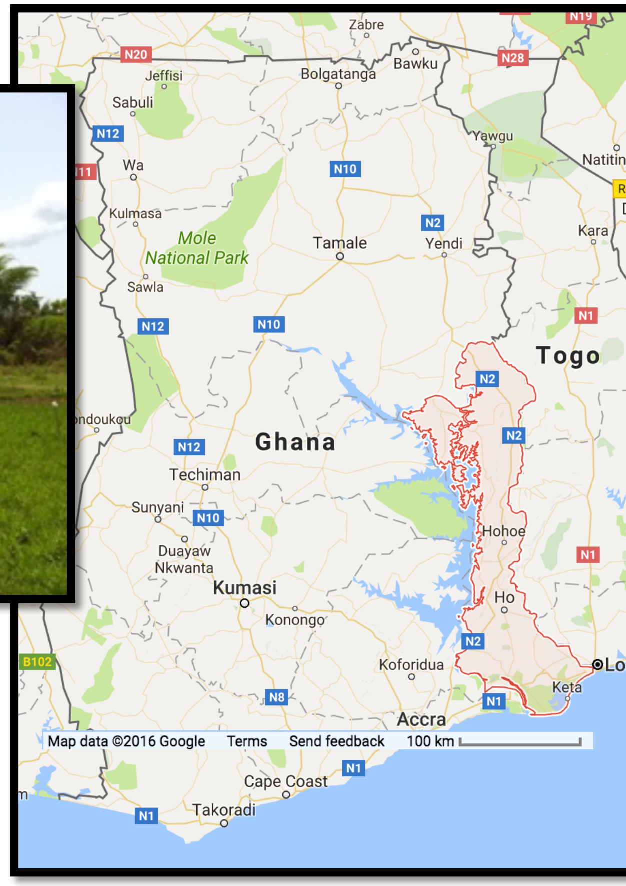

Photo 2. A rice field in fallow in the Volta Region (own photo 2016).

Figure 4. Volta Region located on the eastern border of Ghana (Googlemaps 2016).

Rice is an important cash crop for the Volta region and grown most extensively in 13 districts some of which include the Tongu districts, Akatsi districts, Afadzato South, Keta North, Ho Municipal, Hohoe Municipal, Jasikan, Biakoye and Kadjebi Nkwanta South (Rice Hub 2016). There are an estimated 43,400 rice farmers within the region, roughly 72 percent male and 28 percent female. The total area of regional rice production is 26,000 hectares with an estimated annual production of 84,000 Mt. In comparison to the other major rice growing regions, the Northern region produces 171,000 Mt on 73,400 hectares of land, the Upper East produces 109,500Mt on 51,000 hectares and Greater Accra produces 18,800 Mt on 2,900 hectares (GRIB 2012). The majority of rice farmers in the Volta region are smallholders, cultivating on average land plots of 0.6 hectares and produce an average yield of 3.2 Mt/ha (Rice Hub 2016). There are a few larger commercial rice farms such as the Brazilian Agro, GADCO, Prairie Volta Limited and Weta Irrigation. The most common rice varieties grown are Togo marshal, Jasmine 85, Sikamo, Amankwatia and Brown rice.

6 Research Methods

This research used a descriptive, qualitative research design with the case study of rice farmers in the Volta region of Ghana. Research methods used for data collection were field observations, interviews and literature review. Field research for this thesis was conducted the Ho, Hohoe, Jaskian and Kadjebi districts, see Figure 5.

Interviews were conducted with experts as well as individual farmers practicing SRI. The objective of the interviews was to gain a wider understanding and perspective of the SRI dissemination and implementation process in the study area. Throughout the research process, email, telephone and in-person correspondence was made with seven experts in the field of the Ghanaian rice and agriculture sector and SRI research field. The semi-structured expert interviews were analyzed using the same method as the individual questionnaires and are referred to as *interview 1, interview 2, interview 3* etc. The focus of the expert interviews was to gain a better understanding of the Ghanaian rice sector, SRI principles, SRI implementation, farmer reinventions (modifications) and SRI training.

In addition, pilot interviews were conducted in the Okadjakrom and Kadjebi Town communities to gain an insight into the current status of SRI in the study area and to test out the individual questionnaire format. Following the pilot interviews, questionnaires were administered to individual farmers in the Nsuta, Kasec and Akpafu Mempeosem communities, see Table 4. A total of 10 pilot interviews were conducted and 50 individual interviews. The pilot interviews and individual questionnaires were administered in the spring of 2016, before the 2016 rice-growing season.

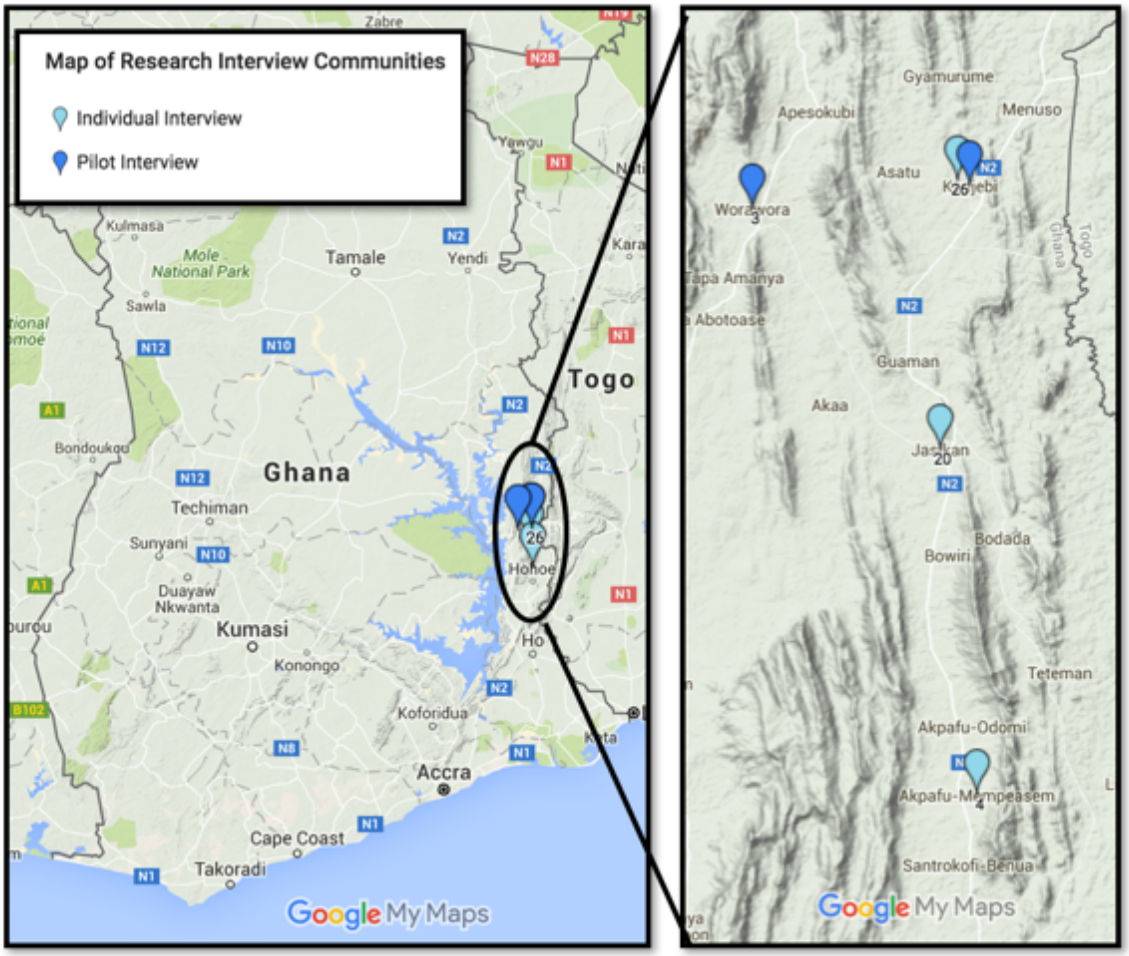

Figure 5. A map of the pilot and individual interview communities in the Volta Region. Pilot interview communities: Okadjakrom and Kadjebi Town. Individual interview communities: Nsuta, Kasec and Akpafu-Mempeasem.

Table 4. Chart showing the research pilot and individual interviewed communities.

Community	District	Interview	No. of Interviews
Okadjakrom	Jasikan	Pilot	5
Kadjebi Town	Kadjebi	Pilot	5
Nsuta	Jasikan	Individual	20
Kasec	Kadjebi	Individual	26
Akpafu Mempeosem	Hohoe	Individual	4

Five pilot interviews were conducted in the Okadjakrom community in the Jasikan District and five pilot interviews were conducted in the Kadjebi Town community in the

Kadjebi district. The questionnaire was initially a set of rigid questions, but after the first interview, it became apparent that the questionnaire format was not suitable for eliciting sufficient information. Therefore, the subsequent pilot interviewees were asked to produce a narrative of their farming practices. The interview guidelines followed these themes:

- Describe in detail the following stages you practice in rice cultivation using SRI methods: land preparation, nursery management, transplanting management, weed management and fertilizer management.
- Describe in detail the following stages you practice in rice cultivation using traditional methods: land preparation, nursery management, transplanting management, weed management and fertilizer management.
- What are aspects of the SRI methods you like?
- What are aspects of the SRI method you do not like or find challenging?
- Will you continue to use the SRI method in the next growing season?

The pilot interviews guided the structure for the individual questionnaires. A total of 50 individual interviews were conducted in three communities: Nsuta, Kasec and Akapafu Mempeosem, see Table 4. The communities were selected based on access to the location and availability of the district MoFA extension agents. The number of farmers interviewed was based on the farmer-based organization (FBO) size, availability and willingness of the farmers or available time period to conduct the interviews. The questionnaire was composed of multiple question formats: open-ended, “guided” questions with options provided (similar to a check list with the option to specify in the case of “other”) and ranking. The individual questionnaires consisted of 99 questions including sections on the themes:

A. **Socio-economic Information** (gender, age, education, occupation, land acquisition etc.)

B. **General Farm Characteristics** (types of crops cultivated, total size of plots/fields, total size of rice plot, size of SRI plot in 2015, predicted size of SRI plot in 2016)

C. **Introduction of the System of Rice Intensification** (year of introduction, introducing agent)

D. **Stages of Cultivation Practice with SRI Methods** (land preparation, seed preparation, nursery management, transplanting management, weed control management, fertilizer management, harvest and post-harvest)

E. **Constraints and Challenges with practicing SRI Methods** (including a ranking question of eight constraints to be ranked on a scale of most challenging (1) to least challenging (8))

F. **What recommended practices of the SRI method does the respondent plan to implement in the next rice growing season (2016)**

G. **Enabling Environment Needed to Implement SRI Practices**

H. **Stages of Cultivation Practice with Traditional Methods** (land preparation, seed preparation, propagation method, weed control management, fertilizer management)

The expert interviews and individual questionnaires were analyzed using the qualitative data analysis software MAXQDA and Microsoft Excel. The interviews were transcribed into formats compatible with MAXQDA and analyzed using a coding system. The coding system was created and based on the different components and categories of Rogers (1983) *Diffusion of Innovations* as an analytical guide. Code categories included: *elements of diffusion of innovation* (innovation, communication channels, time, social system), *innovation-decision process* (knowledge, persuasion, decision, implementation, reinvention, social norms), *attributes of innovations* (observability, trailability, complexity, compatibility, relative advantage), *stakeholders* (opinion leaders, change agents) and *new insights*.

7 Results

7.1 Introduction of SRI in Ghana

The introduction of the *System of Rice Intensification* to Ghana began in 2001 with a visit of representatives from the SRI International Network and Resources Center (SRI-Rice) to the country (SRI-Rice 2016). The first visit and interests in the agricultural innovation set the stage for subsequent channels of SRI dissemination. During 2007 - 2008, first trials of the SRI management practices were carried out on demonstration fields with the support of the Japan International Cooperation Agency (JICA) in the Ashaiman Irrigation Scheme in the Greater Accra region (SRI-WAAPP 2014). Since then, a continuation of experimentation and implementation spread throughout the rest of the country via different government, private and informal communication channels.

The Ghana Rice Inter-Professional Body (GRIB) started promoting SRI management practices in 2012 (interview No. 2 2016). GRIB is a national quasi-governmental "umbrella organization of rice stakeholders" with over 9,000 members across the entire rice sector (Teye 2013). GRIB established trainings of trainers (ToTs) and farmers on SRI demonstration plots in six out of the ten regions in Ghana including the Upper East, Northern, Volta, Western, Ashanti and Brong-Ahafo regions. Participating farmers reported harvests of 6.0 - 8.5 Mt/ha on their SRI demonstration plots, in comparison with the national average of 2.4 to 4.2 Mt/ha. Continuation of SRI practices and training was incorporated into the GRIB Strategic Plan 2013-2017 to *"strengthen the capacity of rice smallholder farmers in System of Rice Intensification methods and other technology to improve productivity"* (interview No. 2 2016; GRIB 2012). GRIB places a special emphasis on training women and youth rice farmers in the strategy plan (Teye 2013; Interview No. 2 2016).

In 2014, the World Bank appointed the Savannah Agricultural Research Institute (SARI) to head the SRI West Africa Project as part of the West African Agricultural Productivity Program (SRI-WAAPP) in Ghana (interview No. 6 2016; SRI-WAAPP 2014). The aim of SRI-WAAPP is to improve and scale up the adoption of SRI across the entire West African region. The project objective is to enhance regional food security by improving productivity and increasing market competitiveness (CSIR-SARI 2016). As part of SRI -WAAPP, a three-year 1 million USD grant was provided to improve local Ghanaian rice production through the use of SRI management practices. This project is being implemented in tandem with SRI-Rice (SRI-WAAPP 2014). SARI coordinates the project in the northern regions of Upper East, Northern and Upper West and the Crop Research Institute (CSIR) coordinates project activities in the Volta, Ashanti, Greater Accra, Western, Central and Brong-Ahafo regions (interview No. 6 2016).

In April of 2015, CSIR organized a WAAPP meeting and ToTs of SRI management practices for relevant national stakeholders in the rice sector (interview No. 3 2016). The trainings were conducted over a two-day period with 23 participants on the first day and 33 participants on the second day (Interview No. 7 2016). Institutions represented at the trainings were MoFA, GRIB, SARI, CSIR, Ghana Irrigation Development Authority, JICA, Wienco Ghana Limited and Ashaiman Municipal District (interview No. 3 2016). The participant members represented institutions from the north and south of the country and included regional crop officers, regional rice officers, extension officers, agronomists, technicians, project coordinators, monitoring & evaluation coordinators, organization presidents and executive secretaries and scheme managers.

In the same year, CSIR supported farmer trainings and demonstration plots on 46 sites throughout the country (Interview No. 3 2016). The demonstration plots involved both rainfed and irrigated systems in different ecological zones of the highlands, lowlands and valleys. For each of the training sites, CSIR provided the participants with poultry manure, weeders, nitrogen fertilizer, netting material and capital in the form of cash. MoFA established 90 SRI demonstration plots nationwide and supported over 12,000 rice farmers (Government of Ghana 2016). Additionally, the National Rice Development Strategy (NRDS) for 2009 – 2018 set a target to improve technology transfer across rice value chain stakeholders with the aim to improve adoption of modern techniques and agronomic practices to increase productivity. The strategy proposes to *"strengthen the capacity of rice smallholder farmers in the System of Rice Intensification (SRI) methods and other technology to improve productivity."* Actions for implementing this strategy include organization of on-field training in 12 rice-producing zones, the selection of best practice SRI farmers for demonstration sites, preparation of three demonstration sites per ecological zone for capacity building and learning and monitoring the technology adoption process by the farmers. The activity deadlines are set for December 2016 and to be carried out primarily by MoFA in collaboration with GRIB.

Table 5. Shows SRI change agent and the year of SRI introduction to the pilot interview communities and the individual questionnaire communities (Nsuta, Kasec, Akapafu Mempeosem). The chart also shows FBOs, the change agent and whether or not demonstration plots were present during trainings.

System of Rice Intensification Diffusion in Research Area (Volta region)				
Community	FBO	SRI Introduction (Year)	Change Agent	Demonstration Plot
Okadjakrom	NA	2015	GRIB	Yes
Kadjebi Town	NA	2015	MoFA	Yes
Nsuta	Edwampa Rice Farmers	2015	MoFA	Yes
Kasec	Star Rice	2015	MoFA	Yes
Akpafu Mempeosem (Respondent No. 1)	Dima Onse Association	2012	GRIB; trained in Tamale	Yes
Akpafu Mempeosem (Respondent No. 2)	Unique Rice Farmers Association	2012	GRIB	Yes
Akpafu Mempeosem (Respondent No. 3)	Dima Onse Association	2013	FBO members	No
Akpafu Mempeosem (Respondent No. 4)	Dima Onse Association	2014	GRIB	Yes

MoFA and GRIB were the dominant change agents that introduced SRI to the target communities, see Table 5. Out of the pilot interview communities, GRIB introduced SRI to the Okadjakrom community in 2015 and MoFA introduced SRI to the Kadjebi Town community in 2015. Out of the individual interview communities, MoFA introduced SRI to Nsuta and Kasec. Different change agents introduced the interview respondents from the Akapafu Mempeosem community to SRI at different times. Respondent No. 1 received training in 2012 in Tamale by GRIB through a United States Agency for International Development program. Respondents belonging to the same FBO Dima Onse Association, learned SRI management practices in subsequent years.

Respondent No. 3 learned from observations and FBO members and Respondent No. 2 and No. 4 learned from GRIB. Almost all of the respondents received trainings on demonstration plots except the Akapafu Mempeosem Respondent No. 3.

7.2 Social Economic Results

Rice production in the Volta region commonly involves both men and women, with women traditionally taking on additional household responsibilities (Interview No. 4).

Out of the 50 respondents, 32 percent were female and 68 percent were male. With regards to household relation, 66 percent were the head of household, 32 percent were the spouse of the household and 2 percent were a non-relative. The average and median of the respondents was 46 years old. The youngest respondent was 22 years old and the oldest 62 years old. Education levels varied across the respondents; see Figure 6. 19 percent of the respondents received no formal education, 2 percent had a primary education, 41 percent had a junior high school education, 12 percent had a middle school living certificate, 16 percent had a senior high school education and 10 percent had national vocational training institute education.

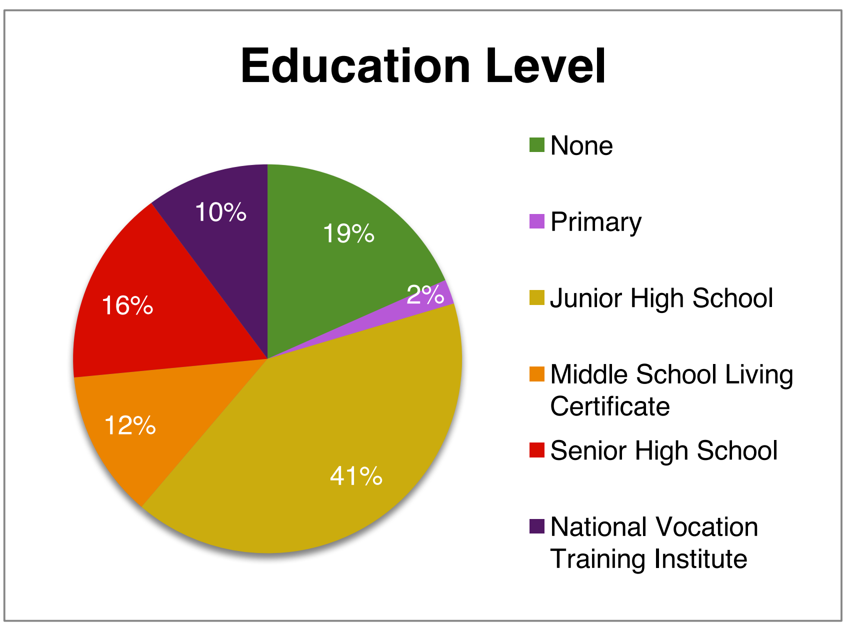

Figure 6. Shows the formal education level of the respondents: 19% none, 2% Primary, 41% Junior High School, 12% Middle School Living Certificate, 16% Senior High School and 10& National Vocation Training Institute.

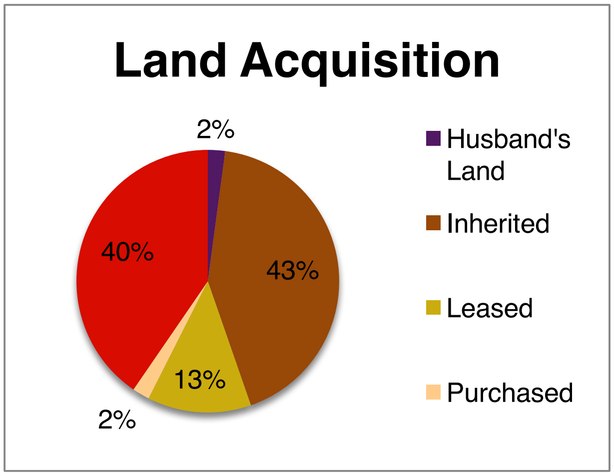

Figure 7. Shows the land acquisition for the farmers. 2% farm on her husband's land, 43% inherited land, 13% leased land, 2% purchased land and 40% share crop.

Farming is the main occupation for 80 percent of the respondents. In addition to farm work, the other 20 percent of the respondents are artisans, black smiths, carpenters or traders. Land acquisition varied across the respondents: 40 percent inherited land, 38 percent were sharecroppers, 12 percent leased, 2 percent purchased and 2 percent cultivated on their husband's land, see Figure 7. In terms of crops, 10 farmers grow solely rice on their land. The other respondents grew one or more of the following crops in addition to rice: cassava, cocoa, maize, vegetables, okra, pepper, plantain, groundnut (peanuts) and beans. 92 percent of the respondents started SRI management practices in 2015, 2 percent in 2014, 2 percent in 2013, 2 percent in 2012 and 2 percent in 2011.

The average total land size of the respondents was 2.1 ha and average rice plot size was 1.1 ha. The average SRI plot size in 2015 was 0.1 ha and the average SRI plot size planned for the 2016 crop season was 0.5 ha, see Figure 8. The percentage of the SRI plot size out of the farmers' entire rice plot was calculated for the 2016 growing season to determine the extent of innovation implementation, see Figure 9. Seventeen farmers planned to implement SRI management practices on 8 – 25 percent of their rice plot. Eleven farmers planned to implement SRI practices on 33 – 50 percent of their rice field. Five farmers plan to use SRI practices on 67 percent of their rice field and thirteen farmers plan to use SRI on 100 percent of their rice plot. Two farmers plan to incorporate SRI management practices onto to 100 percent or more meaning the expansion of their rice plots to incorporate SRI methods.

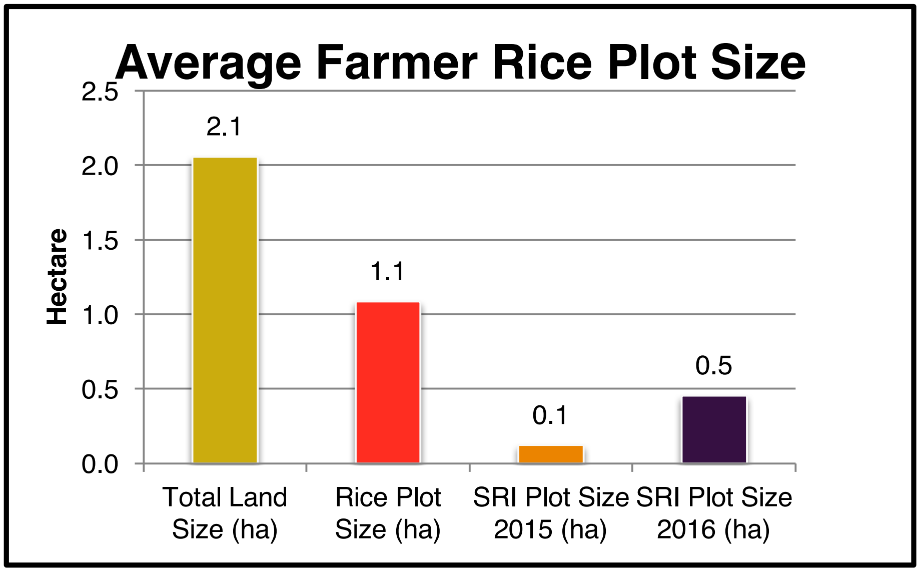

Figure 8. Shows the average land size of the respondents (2.1 ha), the average plot size (1.1 ha), the average SRI plot size for 2015 (0.1 ha) and the average projected SRI plot size for 2016 (0.5 ha).

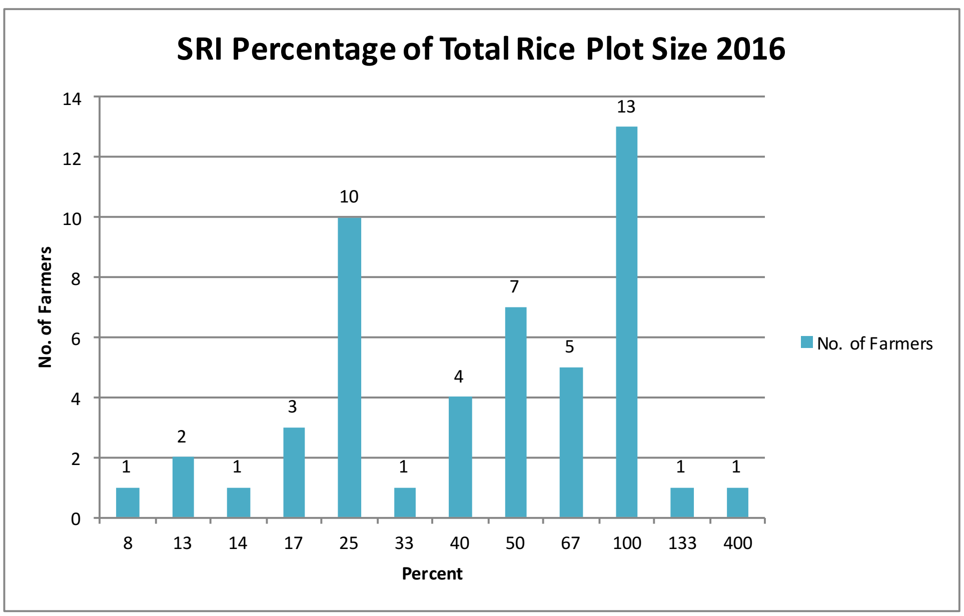

Figure 9. Shows the percentage of the farmer plots that will be cultivated with SRI management practices for 2016. The values 133% and 400% represent farmers who converted all of their farmland to rice cultivation and expanded their rice plot to incorporate SRI.

7.3 Results of Rice Cultivation Practices (SRI & Traditional)

Results from the individual questionnaires about the farmers' rice cultivation practices with implementation of SRI methods were categorized into land preparation, water management, nursery and transplanting management and weed and fertilizer management, see Table 6. The Nsuta community used a power tiller to prepare the land and built bounds on their rainfed field. The nursery was cultivated on a rubber tarp with the seeds planted in rows. Seedlings were transplanted at 8 – 10 days old, cleaned of soil particles, planted on the rice field in a spacing distance of 25 x 25 cm and 1 seedling per hill. For weed and fertilizer management, the Nsuta community applied poultry manure and weedicide in addition to using a weed pusher and selective manual weeding. The Kasec community used a power tiller to cultivate the soil in addition to using cutlasses to clear the land. The Kasec rice farmers built bounds on their rainfed fields. They grew their nursery on raised beds and rubber tarps and planted the seedlings in rows. The farmers transplanted the seedlings at 8 – 10 days old, cleaned the seedlings of soil particles, transplanted them onto the rice field at a spacing distance of 25 x 25 cm and 1 seedling per hill. Weed and fertilizer management involved poultry manure and weedicide application in addition to the use of a weed pusher and selective manual weeding.

In the Akpafu Mempeosem community all of the respondents used a power tiller to cultivate the soil; two respondents used cutlasses to clear the land; one respondent built bounds; and all of the fields were rainfed systems. The nursery was cultivated on a raised bed; three respondents broadcast the seeds and one respondent planted the seeds in rows. The seedlings were transplanted at 10 – 12 days old, uncleaned of soil particles, planted at distances of 20 x 20 cm, 24 x 24 cm, or 25 x 25 cm and 1 seedling per hill. For weed and fertilizer management, all respondents applied weedicide and practiced selective manual weeding. One respondent applied poultry manure; two respondents applied NPK; and one respondent applied poultry manure and NPK.

Results from the individual questionnaires regarding traditional rice cultivation methods are shown in Table 7. For traditional practices, farmers in the Nsuta community clear their land with a cutlass and cultivate rainfed systems. 95 percent of the respondents practice broadcasting as the traditional propagation method. For weed and fertilizer management, the farmers applied weedicide and NPK. In the Kasec community, farmers use power tillers to cultivate the soil and cutlasses to clear the land on their rainfed fields. For traditional crop propagation methods, 50 percent of the respondents practice broadcasting and 50 percent practice scatter transplanting. All of the respondents applied weedicide and NPK. In the Akpafu Mempeosem community, three respondents used a power tiller to clear their land and one respondent practiced zero tillage. All of the rice fields are rainfed systems. For traditional crop propagation methods, all of the respondents practiced broadcasting. The respondents also applied weedicide, urea, NPK and ammonium.

Table 6. Shows the results of the individual questionnaires regarding the farmers' SRI rice cultivation management practices. The Nsuta and Kasec respondents learned and practiced SRI on one demonstration plot in each community. Respondents from the Akpafu Mempeosem community practiced SRI on their individual rice fields.

Results: Rice Cultivation with SRI Management Practices			
Community	**Land Preparation & Water Management**	**Nursery & Transplanting Management**	**Weed & Fertilizer Management**
Nsuta	Power tiller to cultivate soil; build bounds; rainfed system	Nursery on rubber tarp; seeds planted in rows; seedling age 8-10 days old; seedlings cleaned, carried in container; spacing 25 x 25cm; 1 seedling per hill	Weedicide application; weed pusher; selective manual weeding; poultry manure application
Kasec	Power tiller to cultivate soil; cleared land with cutlass; build bounds; rainfed system	Nursery on raised bed and rubber tarp; seeds planted in rows on nursery; seedling age 8-10 days old; seedlings cleaned, carried in container; spacing 25 x 25cm; 1 seedling per hill	Weedicide application; weed pusher; selective manual weeding; poultry manure application
Akpafu Mempeosem	Power tiller to cultivate soil; cleared land with cutlass (2 rspd.); build bounds (1 rspd.); rainfed system	Nursery on raised bed; seeds broadcast (3 rspd.), rows (1 rspd.) on nursery; seedlings age 10-12 days old; seedlings not cleaned, carried in container or hand; spacing 20 x 20 cm, 24 x 24 cm, 25 x 25 cm; 1 seedling per hill	Weedicide application; selective manual weeding; poultry manure application (1 rspd.); NPK application (2 rspd.); poultry manure & NPK application (1 rspd.)

Table 7. Results from the individual questionnaires regarding traditional rice cultivation management practices.

Results: Rice Cultivation with Traditional Management Practices			
Community	**Land Preparation & Water Management**	**Propagation Method**	**Weed & Fertilizer Management**
Nsuta	Land cleared with cutlass; rainfed	Broadcasting (95% respondents)	Weedicide application; NPK application
Kasec	Power tiller to cultivate soil; land cleared with cutlass; rainfed	Broadcasting (50% respondents); scattered transplanting (50% respondents)	Weedicide application; N,P,K application
Akpafu Mempeosem	Power tiller to cultivate soil or zero tillage; rainfed	Broadcasting	Weedicide application; urea; NPK; ammonium

7.4 SRI Challenges & Constraints

The pilot and individual questionnaires revealed challenges and constraints that farmers faced throughout the different cultivation stages with implementation of SRI practices. The individual questionnaire included a ranking question in which the respondents were asked to rank challenges on a scale of 1 (most challenging) to 8 (least challenging). The constraint choices included labor availability, land ownership, high costs of material inputs, water availability, organic fertilizer availability, tool availability and support/training from extension agents or other institutions. As a consideration of time, the enumerators asked the ranking question to the entire group of respondents in the Nsuta and Kasec communities. The top limiting factors from the ranking question were lack of capital, tool accessibility and labor (accessibility, intensity, costs), see Table 8. For many aspects of the SRI management practices, the farmers had a lack of capital for purchasing required material and labor.

Table 8. Shows the results of the ranking question from the individual questionnaire. In the Nsuta and Kasec communities, the question was asked to the entire group.

SRI Challenges & Constraints Ranking (1 most challenging; 8 least challenging)						
Challenges & Constraint	**Nsuta**	**Kasec**	**Akpafu Mempeosem (No. 1)**	**Akpafu Mempeosem (No. 2)**	**Akpafu Mempeosem (No. 3)**	**Akpafu Mempeosem (No. 4)**
Labor Availability	3	1	1	3	1	5
Land Ownership	1	6	8	2	– –	6
Land Size	2	4	3	8	– –	4
High costs of material inputs	4	3	5	7	3	8
Water availability	6	5	2	6	4	3
Organic fertilizer availability	5	2	7	4	– –	7
Tool availability	7	7	4	5	2	1
Support/training from institution	8	8	6	1	5	2

The questionnaire revealed further constraints such as tools required for land preparation (i.e. bound building, land leveling/clearing) and inter-cultivation i.e. access to weed pushers. The farmers had difficulty finding access to and obtaining enough capital for the tools. The Nsuta and Kasec communities each share one weed pusher for the whole community. With regards to power tillers, the machines were either privately owned, hired from community members or MoFA, provided by MoFA or in some cases not used at all due to lack of capital. In addition, the farmers found bound building to be time consuming, labor intensive and costly.

A farmer from Akpafu Mempeosem mentioned, *"Leveling the land and building bounds is challenging because of the cost and limited access to machinery and equipment. Clearing ant hills is a big problem and challenge without these tools"* (Akpafu Mempeosem Interview no. 1). Another farmer from the Akpafu Mempeosem community stressed further, *"I would build bounds if money was available. Proper land preparation* *is difficult, especially land clearing and removal of tree stumps, which require a lot of labor and money,"* (Akpafu Mempeosem Interview No. 3).

Another challenge the farmers had with implementing SRI practices was the use of organic fertilizer. The farmers have difficulty accessing poultry manure in the Volta region. For the demonstration fields, MoFA and GRIB provided the farmers with poultry manure. The poultry manure is produced in the city Kumasi in the Ashanti region and must be transported to the Volta region. A farmer from the Akpafu Mempeosem community expressed she had tried organic farming, but the weed maintenance was too difficult without the use of weedicide (Interview No. 2). Additionally, the MoFA extension agent for the Jasikan District noted, *"For SRI activities in rice to be successful, the farmers need machines to prepare their land, access to inputs and water to increase rice production."* And the MoFA extension agent for the Kadjebi District commented, *"Rice gives much [income to the communities] and needs to be supported by timely release of inputs and the use of simple farm machines for good land preparation and harvesting to increase production of rice and reduce post-harvest losses."*

Some farmers also expressed challenges with nursery management and transplanting as being time consuming (requiring more labor, higher intensity or capital). Transplanting required more time than traditional practices of broadcasting. In many cases this required the farmer to pay for extra labor to complete crop propagation. Additional constraints with SRI crop propagation methods were technical challenges. *"The seedling planting distance is difficult to measure,"* noted one farmer from Kadjebi Town (Interview No. 3). Further, literature review revealed that the issue of labor is a common constraint to innovation diffusion processes in the Ghanaian agriculture sector even despite rapid population growth in the country (Nin-Pratt et al 2014). Nin-Pratt et al (2014) found *"labor costs still play a major role in limiting the adoption of labor-intensive technologies even in high population density areas in all major agroecologies in Ghana."*

Farmers from the pilot interviews in the Okadjakrom community expressed extension services and support to be the largest limiting factor. The farmers were not satisfied with the support they received from the change agent GRIB. The farmers received inputs and initial training, but trainings declined throughout the growing season, thus leaving the farmers to maneuver the SRI practices on their own. But when asked if they would continue SRI practices in the next growing season, one farmer replied, *"I* *would like to try the method out again even though it did not work well the first season. But I will only participate if MoFA and not GRIB provides training or support,"* (Interview No. 2).

Moreover, literature review revealed that SRI practitioners around the world face similar challenges with SRI management methods. Thiyagarajan et al (2013) analysis of SRI diffusion in India revealed "*factors affecting adoption of SRI by farmers*" and categorized them into three types: *farm-level conditions*, *technical interventions* and *policy support*. Challenges at the farm-level included motivation, self-interest, attitude, land ownership, land size, soil fertility, labor availability, laborers' mindset, capital, water availability, organic manure availability and tangible benefits (Thiyagarajan et al 2013). Farmer level constraints had a direct impact on adoption, variations or modifications in SRI management practices, disadoption and sustained adoption. Challenges associated with technical interventions were research support, training, exposure, technical backstopping and regular follow-up. Lastly, policy support constraints included determination, specific programs, subsidies/incentives, irrigation water supply regulation and monitoring mechanisms.

7.5 Results through Rogers (2003) Diffusion of Innovations Perspective

Results from the individual questionnaires were analyzed through the lens of Rogers (2003) *attributes of innovation* approach to explore the different factors that could influence SRI adoption or rejection. The five attributes of innovation that were analyzed include *relative advantage, compatibility, complexity, trialability,* and *observability*. In addition, attributes of the *innovation-decision process*, as described by Rogers (2003), were also observed.

***Relative advantage*:** All of the participants experienced relatively high yields or an increased crop yield with the use of SRI management practices despite a poor rainy season for 2015. The 0.1 ha SRI demonstration plot in Nsuta had a yield of 420 kg, which could be projected to 4.1 Mt/ha. The Kasec community had a yield of 504 kg on their 0.1 ha SRI demonstration plot for the 2015 season, which could be extrapolated to 4.9 Mt/ha. The yields on the individual farmers' rice plots in the Akapafu Mempeosem community varied, yet the farmers still experienced an improvement in rice yield. The yield for 2015 growing season ranged from 504 kg to 672 kg on 0.2 ha, amounting to 4.9 Mt/ha to 6.6 Mt/ha.

Farmers also used less seeding material with the use of SRI management practices. The average use of seed for traditional rice cultivation methods in the three communities ranged from 34 kg/ha - 78 kg/ha (14 kg/acre - 5 kg/acre). The average use of seeding material required for the SRI management practices reduced to between 12.2 kg/ha - 17.1 kg/ha (5 kg/acre - 7 kg/acre). Another relative advantage associated with SRI practices was water conservation. A farmer noted that he liked the bounds in the SRI land preparation practices because, *"They keep the water on the field even if there were not heavy rains"* (Kadjebi Town Interview No. 2). Another farmer noted, *"[SRI management practices] are a different method than what my forefathers used, but I see the benefit of this improved technology and get higher yields"* (Kadjebi Town Interview No. 4).

Compatibility**:** The degree of compatibility between the SRI management practices and traditional methods varied across the different target communities. The largest forms of differences occurred in the weed management control, fertilizer management and crop propagation stages. Prior to SRI introduction, the traditional methods of all the individual interview communities used weedicide and application of either NPK, urea, and or ammonium. SRI management practices encourage the use of organic (animal manure) fertilizer and the use of inter-cultivation with a mechanical weeder (Styger et al 2014). With the SRI management practices, all communities continued to apply weedicide. Nsuta and Kasec in addition used a weed pusher, Akapafu Mempeosem participants supplemented with selective manual weeding. In Nsuta and Kasec, poultry manure was used as fertilizer on the demonstration plots. In Akapafu Mempeosem, 1 farmer used solely poultry manure, 2 farmers used solely NPK and 1 farmer used both.

In terms of crop propagation, all participants from the Nsuta and Akapafu Mempeosem communities practiced broadcasting as their traditional propagation method. In the Kasec community, 50 percent of the participants broadcast and 50 percent practiced scattered transplanting with traditional methods. SRI management practices promote the use of transplanting as the mode of crop propagation (Styger et al 2014). After implementation of the SRI management practices, all of the respondents from all of the communities practiced transplanting on their SRI plots with the recommended spacing and plant density.

***Complexity*:** In terms of complexity, SRI management is a knowledge intensive innovation that requires extensive training (Uphoff 2007; Styger et al 2014). Land preparation with SRI management practices also introduces a degree of complexity. Building bounds requires access to and the use of agricultural machinery. Additionally, in comparison to traditional crop propagation methods, SRI transplanting is a degree more complex than scatter transplanting and broadcasting. Broadcasting involves throwing or scattering the seeds onto the field at random. Scatter transplanting involves planting seeds onto a nursery and then planting the seedlings on to the rice field via throwing them onto the field or random planting. SRI transplanting requires nursery management and orderly, stricter guidelines for planting seedlings than traditional propagation methods. SRI transplanting technique involves planting young seedlings (between 10 and 12 days old) onto the field with a wide-specific spacing, typically 25 x 25 cm (SRI-Rice 2016). Moreover, only one seedling per hill is planted. The farmers used various tools for measuring the distances including rope, sticks, fingers and feet.

In the case of the pilot interviews with Kadjebi Town, the farmers had been practicing "good or best practices" prior to implementing SRI management practices. The transplanting method was similar to SRI practices. For best practices methods, the farmers grow seedlings in a nursery and transplant the seedling at 14 days old and plant two to three seedlings per hill at a distance of 20 x 20 cm

***Trialability*:** SRI in the interview communities had a high degree of trialability. In all of the interviewed communities, the respondents had learned SRI management practices on small demonstration plots (except one respondent) before implementing or deciding to implement the SRI practices onto their own fields. The respondents from the Nsuta community all practiced and learned each stage of SRI practices on one demonstration plot. The demonstration plot was 0.1 ha (0.25 acre) of the FBO leader's rice plot. All respondents said they would practice SRI on a portion of their rice field for the upcoming 2016 growing season. 15 percent of the respondents plan to use SRI on 0.1 ha (0.25 acre), 55 percent plan to implement SRI on 0.2 ha (0.5 acre), and 10 percent plan to implement SRI on 0.4 ha (1 acre).

Interviewed farmers from the Kasec community practiced SRI management on a 0.1 ha (0.25 acre) demonstration field in 2015. The rice field for SRI demonstration belonged to the FBO leader. All of the farmers intended to implement SRI on their rice fields for the 2016 growing season. 19 percent plan to implement SRI on 0.1 ha, 8 percent plan to implement SRI on 0.5 ha, 46 percent plan to implement SRI on 0.4 ha, 19 planned to implement on 0.8 ha and 4 percent planned to implement on 4 ha. Two farmers from the Kasec community plan to increase their rice plot size and implement SRI practices on their entire rice field and expanded land, see Figure 9.

In the Akpafu Mempeosem community, three of the respondents learned SRI management practices on demonstration plots during consecutive growing seasons between 2012 and 2015. The other respondent learned from FBO members. For the 2016 growing season, two farmers plan to implement SRI practices on 0.4 ha, one farmer plans to implement on 1 ha and one farmer plans to implement on 1.6 ha.

***Observability*:** Respondents' participation in the demonstration plots showed a high degree of innovation observability. The participants personally tested SRI and experienced the relative advantages and consequences of implementation. In the case of Akpafu Mempeosem, one farmer decided to use SRI methods after she had observed other members of her FBO practicing SRI methods.

7.6 Results of SRI Reinvention

Literature review revealed reinventions, adaptations or modifications of SRI management practices around the world. SRI is introduced to farmers as a set of general principles and recommendations rather than prescribed rules (Uphoff 2007). This technique of diffusion allows flexibility in farmer implementation and encourages many different adaptations befitting to local conditions. According to Uphoff (2007), the central theme of SRI is "*whatever works for the farmer.*" Uphoff (2007) further notes, the main question with the SRI method is "*How much and how well are these different practices utilized?"* and not "*Is this SRI or not?*"

Around the world farmers have reinvented the SRI principles with their own modifications for different stages of cultivation. For instance, SRI principles recommend making a "garden" nursery for growing rice seedlings before the transplanting stage (Uphoff 2007). In the Philippines, some famers have reinvented this principle by planting seeds in sand, which makes it easier to uproot and separate the seedlings at transplanting time. In the region Tamil Nadu of India, famers grow their nurseries on small trays of banana leaves, making the seedlings easier for transport to the field. Different forms of raised beds and zero-tillage are also common modifications for nursery management. And in many cases, farmers have created their own devices for measuring and marking the recommended spacing for transplanting. In the Tripura state of India, farmers use a bamboo rod notched with the appropriate space markers. In Madagascar, many farmers have created "rake-markers" that slightly indent the soil with the correct planting distance. Some farmers in Cuba, India and Thailand surpass the nursery and transplanting stages by practicing direct-seeding onto the rice field. Uphoff (2007) notes that direct-seeding may replace transplanting as the main method for crop establishment in the future. Many farmers have also created different types of rotating hoes or cono-weeders out of available local materials including heavy nails, wooden axles and iron rods.

SRI was originally developed for irrigated rice systems in Madagascar, yet a majority of the world's smallholder farmers and poorest households do not have access to irrigation (Uphoff 2007). Despite lack of water resources, many NGOs have worked closely with farmers to adapt and incorporate SRI techniques into rainfed rice cultivation, with water conservation techniques such as bound building (Uphoff 2007; Kranjac-Berisavljevic 2003). During the 1999 rice-growing season in Madagascar, government rice specialists, research centers and the local NGO Tefy Saina worked closely with rice farmers around the Ranomafana National Park to adapt SRI practices for rainfed rice fields. The results of their trail and replicated trails were a success with increases of 2.5 to 5 times more yield, from the average 0.8 - 1.5 Mt/ha to 4.02 Mt/ha. In these examples and many others around the world, experts and farmers reinvented the SRI management practices to tailor to their own needs and capacities.

This research observed two cases of reinvention; one from a change agent and one from a farmer. As a means to expand SRI training throughout the country, the change agent GRIB plans to create an SRI hub or information network center for SRI in Ghana (Interview No. 2). The SRI center will be located in the Greater Accra region and serve as a training facility center with demonstration plots and ToT sessions. To address challenges associated with SRI management practices, GRIB plans to promote two solutions: community-based farming and "transplanting services." Community-based farming involves a change in practice and mindset of farming community members to work together during the nursery establishment and transplanting stages of SRI practices via staggered timing or nursery rotation planning. Secondly, GRIB proposes to establish a "transplanting service" that would be composed of specialist farmers trained in nursery management and transplanting activities. The transplanting specialists would be available for hire by farmers around the country. These projects could alleviate the issue of labor availability and difficulties associated with SRI crop propagation.

Additionally, for the next growing season a farmer from the Akpafu Mempeosem community plans to establish his nursery on small pieces of tarp or blanket that could be carried onto the field during the time of transplanting. This is a similar reinvention to that of SRI farmers in Tamil, India who practice growing their nurseries on banana leaves.

7.7 Insights

The semi-structured expert interviews revealed a deeper insight into the global innovation diffusion process of SRI. The topics of gender and women in agriculture as well as health impacts associated with rice cultivation were repeatedly mentioned in association with *relative advantages* of adopting SRI management practices (Interview No. 5 2016).

In many developing nations, there is typically a strong gender-based separation of labor tasks in the agriculture sector (Vent et al 2015). Women are often charged with tedious, mundane and repetitive tasks such as weeding, nursery management and transplanting. On the other hand, men are responsible for heavy laborious duties such as land preparation and any operation of machinery. In developing countries, rice cultivation is carried out primarily by manual labor with the use of rudimentary tools like hoes, cutlasses, sickles and requiring repetitive motions as well as bent and crouched postures that are physically taxing and painful. Extensive research conducted by Sabarmatee (2015) with women farmers from communities practicing SRI in the Odisha State in India revealed that women farmers experienced a lessening in "pain and drudgery" after switching to SRI management practices. The women experienced a reduction of labor spent in painful postures with the use of SRI methods. For instance, the use of less seeding material and seedlings decreased the time needed for nursery management as well as time spent in bending postures or sitting in flooded fields and carrying heavy seedling bundles.

Moreover, rice farmers are extremely vulnerable to water-borne diseases due to spending extensive amount of time in flooded conditions. Women are particularly vulnerable to diseases as they spend long periods of time working in standing water performing weeding and transplanting tasks. One expert noted, *"Working in flooded fields is a major contributor to the scourge of female genital schistosomiasis in Africa"* (Interview No. 5 2016). The non-flooded water management practices of SRI reduce rice farmers' vulnerability to water-borne diseases and urinary-genital issues. Additionally, the introduction of weeders in SRI management has shifted the typically traditional female responsibility of weeding to a male responsibility in many countries due to mechanization of the task (Interview No. 5 2016). Yet, an expert also commented, *"This can be both a benefit —relieving women of this task to do something else —and also some have argued that in countries like India, it takes away low-wage jobs from women"* (Interview No. 5 2016).

8 Discussion through *Diffusion of Innovations* Perspective

The discussion section analyzes the research results through the four elements of diffusion as described by Rogers (2003): *innovation, communication channels, time* and *social system*. The interconnected characteristics of the four elements blur the lines between where one element ends and the next begins. The elements *time* and *communication channels* permeate throughout the diffusion process and are interwoven between the elements *innovation* and *social system*.

8.1 Innovation & Social Systems Discussion

The study communities showed to be composed of relatively homogenous social systems. The majority of the farmers were in their forties and had received a junior high school level education. A facile dissemination process may be attributed to the farmers having more or less alike socio-economic backgrounds of similar age, education level and farming as a main occupation. Further, land acquisition, did not seem to affect the farmers' motivation for experimenting with SRI. The majority of farmers had either inherited their land or were share croppers. While land acquisition did not seem to affect farmer attitude, it may have influenced the extent to which the farmers planned to implement SRI for the 2016 growing season. Farmers who own more assets, like those who inherited land, may be in a more secure position to risk implementing SRI on a larger scale than their counterparts who sharecrop or lease land.

The literature review and expert interviews revealed the System of Rice Intensification to be a *software* information heavy innovation with necessary *hardware* information components. SRI is a management practice that suggests recommended agroecological methods to improve natural resource efficiency with limited required amount of inputs to produce increased crop yields. The SRI management practices and so-called *software knowledge* require an extensive amount of information sharing and communication. Communication channels via information campaigns, informational meetings and trainings as well as hands-on practice or trials at both the national and local level are vital for a potential candidate to consider SRI adoption.

Although the SRI method boasts the notion of "fewer external inputs with higher outputs," the management practices still do require the use of some specific *hardware* information components (tools, materials etc.) for the full potential of the SRI method to be achieved. The study results revealed tools required for optimum SRI implementation to be organic fertilizer in the form of poultry manure; power tillers for land clearing and bound building; weed pushers; farm labor; and training. Organic fertilizer and tools (weeders, tractors, etc.) are important external inputs for SRI implementation. This research also argues that "training" is also an essential external input without which the SRI diffusion process could not exist or would progress at an extremely slow rate. In this sense, SRI requires more external inputs in the initial introduction stage, yet the requirement for training should diminish overtime as farmers adopt and integrate SRI methods into their regular practices. Additionally, a certain amount of labor is required for each stage of SRI implementation, particularly for the transplanting stage. Training and labor are necessary "tools" that the farmers expressed as being limiting factors with implementation of SRI methods. Without access to all of these key hardware components, the farmers expressed having difficulty in being able to carry out SRI management practices.

However, it should also be recognized that software and hardware information are intrinsically linked. Information not only about the SRI management practices, but also about how to properly use the hardware tools is vital for proper innovation utilization. Here this element touches on Rogers (2003) described attributes of innovations including *trialability* and *observability*. Farmers in the study communities were able to test the innovation on small demonstration plots on which they "learned by doing" both the software and hardware components of SRI practices. As such, they were also able to observe the results and relative advantages of the innovation. Consequently, experimentation of SRI required continual information input and guidance from change agents to enable the farmers to fully implement the innovation. As seen in the case of the Okadjakrom community, the farmers did not receive adequate support from the change agent and could not successfully implement SRI. However, despite lack of informational support, the farmers still perceived some benefits (*relative advantages*) of the innovation and would consider continuation under the condition of receiving sufficient support.

The interviewed farmers observed *relative advantages* of the SRI innovation, with the most prominent benefit being a higher crop yield. When extrapolating the demonstration plot yields to metric tons per hectare (Mt/ha), the SRI yields of the study communities (4.1 - 6.6 Mt/ha) match or exceed the national average (2.4 - 4.2 Mt/ha). In some cases, the SRI yields were still below the climatic potential (6.5 Mt/ha). In terms of improving national self-sufficiency in rice production and national food security, further research is needed to examine the yield potential of SRI management practices. Yet, this research is another example of how rice yields can increase without the need to increase cultivated land size and also shows an example of reduced seeding material requirement. The farmers noted a reduction of seeding material with the SRI method from of 34 - 78 kg/ha to 12.2 - 17.1 kg/ha. Farmers also noted water conservation benefits of building bounds. Further research would be needed to examine in a more global context, the impact SRI water management practices have on water conservation and greenhouse gas emissions and the impact of SRI on soil biota.

8.2 Communication Channels Discussion

Multiple communication channels and active stakeholders in the Ghanaian rice sector played a key role in SRI diffusion throughout the country. From the literature review and expert interviews it can be concluded that the majority of the important governmental and non-governmental relevant actors are involved in national SRI dissemination projects and trainings. However, there is the possibility for other key stakeholders to have been unintentionally excluded. The dominant change agents driving the innovation diffusion process at the national and local levels are CSIR, SARI, MoFA and GRIB, with the latter two being more active at the farmer level. SRI has been communicated through predominately interpersonal communication channels involving training sessions between experts and trainers (for ToTs) and between trainers and farmers. The original training material for the CSIR WAAPP SRI training session and MoFA and GRIB extension agent training material was not available for this research. Therefore, not a full analysis can be given on the training material itself or how this could affect the diffusion process. But, from the information that was gathered, it seems SRI could be expanded to emphasize SRI adaptation to location-specific conditions.

The change agents established demonstration plots in different rice growing ecologies throughout the country, but the ToT sessions did not seem to reflect this location-specific adaptation. Further encouragement of SRI flexibilities during ToT sessions would encourage training officers and extension agents to adapt SRI practices to local socio-economic and ecological conditions. For example, poultry manure is not easily accessible throughout the country and farmers could benefit more from localized solutions for alternative fertilizer sources. However, SRI is still a relatively newly introduced innovation in Ghana. Demonstration plots and trials by farmers are still being carried out across the country in all the different rice growing ecologies and water management systems, so more local specific adaptations may still be in experimentation and exploration stages. These new modifications to the general SRI principles could be shared at a later time with the national SRI community. Thus, the learning and communication phases of SRI diffusion are a continuous process.

8.3 Time Discussion

Results from the individual questionnaires in which the farmers were asked to indicate what size their SRI plot would be for the next growing season, revealed a continuation of the innovation trial period. 2016 would be the first growing season that the farmers in the Nsuta and Kasec communities would implement SRI practices by themselves on their own fields. The majority of the farmers opted to test SRI on a small portion of their rice field, while still practicing traditional methods on the remainder of their field, see Figure 9.

Moreover, if the SRI plot size percentage is to be taken as a proxy for innovation diffusion time, the farmers have adopted SRI at various rates and could be sorted into the different adopter categories according to Rogers (2003). *Innovators* represent the two farmers who plan to expand their rice fields for SRI implementation. The farmers may have more capital or flexibility in converting their farming operations to focus solely on rice and the SRI method. But by converting all of their farmland to rice cultivation, they may be foregoing other benefits from farming diverse crops such as dietary diversity in household food provision. On the other hand, higher crop yields with SRI practices could increase their crop sales and income. *Early adopters* would be the farmers who plan to implement SRI on 50 - 67 percent of their rice field. *Early majority* are farmers are those who plan to use SRI on 25 - 40 percent of their land and *late* *majority* would be those who plan to implement on 13 - 14 percent. The *laggards* are the farmers who plan to implement on 8 - 13 percent of their land. It is important to note, that all of the respondents chose to continue SRI management practices.

However, there are some limitations to the questionnaire results. The interviews were conducted before the 2016 rice-growing season. Therefore, the farmers could have experienced changes in their socio-economic status from the time of the interview to the growing season that could affect their initial response to continue SRI practices. Secondly, the questionnaire did not provide information that could give an in-depth explanation for the enabling factors that encourage or support each farmer to implement SRI. Although it is still too early in the diffusion process to concretely discern whether SRI has fully been adopted by these practitioners.

8.4 Challenges & Constraints Discussion

In addition to relative advantages, this research observed *relative disadvantages* farmers faced with SRI implementation in the form of *challenges* and *constraints*. As a result of the pilot and individual questionnaires, the main identified challenges related to the SRI innovation were associated with *hardware information* such as land availability, costs of material inputs, water management, input availability and tool availability as well as *software information* like support and training by extension agents or institutions. In terms of hardware related challenges, the results were also an indication of general challenges associated with rice cultivation. Land and water related issues could be associated with both SRI and traditional methods, especially in rainfed systems where water is dependent on the climate and weather patterns. Land availability and acquisition is dependent on various socio-economic and ecologic factors. The availability and cost of material inputs i.e. organic fertilizer is specifically related to SRI implementation. In the case study, the farmers used poultry manure that needed to be transported from Kumasi, a city over 430 km away. While the use of poultry manure could decrease dependency on chemical inputs and enhance soil biota or promote other ecological benefits, it does not appear to be compatible for the Volta region. The farmers expressed challenges with access and costs associated with poultry manure. In most cases, MoFA or GRIB provided the manure, but this is not a long-term, sustainable solution as the farmers could become dependent on input provision. In other examples from the research results, farmers opted to forego the use of poultry manure because they did not have the capital to pay for it.

Other major challenges farmers faced with SRI management practices were labor and support or training. The farmers found the SRI transplanting method to be more time consuming than traditional methods and the SRI planting distance specificities to be complicated. Majority of the respondents and rice farmers in Ghana traditionally practice the simple crop propagation method of broadcasting. Transplanting is rather incompatible and complex in comparison to traditional techniques, thus the learning process requires adequate support, training, time and a change in mindset. However, over time as farmers become more familiar and well-practiced, they could become faster at implementing SRI transplanting techniques, thus decreasing the required amount of labor.

As the literature and interviews have repeatedly conveyed, SRI is a software knowledge-based intensive innovation that requires extensive communication and training. In most cases of the study communities, farmers expressed support and training to be one of the least concerning challenges associated with learning SRI practices. However, this research also recognizes that the SRI training officers (change agents) were also the enumerators for the majority of the individual questionnaires, thus some bias may be present in the results. Yet, all of the farmers did plan to continue SRI practices, so this can be taken as an indication they were satisfied with the results and felt adequately trained or equipped to continue on their own. On the other hand, the rice farmers in the Okadjakrom community did not feel they received enough support from their trainers and would only continue SRI practices under the condition they received improved training support. This highlights the importance of communication channels and change agents in disseminating an innovation, particularly one that is knowledge-intensive like SRI.

9 Recommendation Themes

Results from the literature review and findings from the interviews informed recommendations for the SRI diffusion process in Ghana. The recommendations are characterized by three key themes: *'global phenomenon, localized solutions'* (information & knowledge exchange), '*WAY – women, age, youth*' (social system & target group) and *inclusion of a value chain perspective*.

In addition to recommendations, this research also notes that in-line with Rogers (2003) *Diffusion of Innovations* theory, change agents should be aware of the *pro-innovation bias* critique of innovation diffusion. Rogers (2003) defines the *pro-innovation bias* as *"the implication in diffusion research that an innovation should be diffused and adopted by all members of a social system, that it should be diffused more rapidly, and that the innovation should be neither re-invented nor rejected"* (p. 106). This critique cautions against overlooking or underemphasizing reasons for innovation rejection or discontinuation. The concept and word itself 'innovation' conjures a positive image and notion of improvement. Yet, not every innovation is appropriate for every individual or social system, thus negative consequences could arise from promotion of innovations that are actually damaging or not suitable to the social system. Change agents should be aware of challenges farmers face with SRI implementation and assess whether the method is appropriate for targeted social systems.

9.1 "*Global Phenomenon, Localized Solutions*"

A key concept behind the SRI methodology is that the principles can be adjusted and modified to best accommodate local conditions (SRI-Rice 2016). Thus, SRI is a *'global phenomenon, [requiring] localized solutions'* for improving rice yields and natural resource conservation. Access to the original training material from the CSIR SRI-WAAPP training session and from MoFA and GRIB was not available for analysis. But, from the available information gathered, it seemed the national level SRI disseminators (CSIR, MoFA, GRIB) recognized the importance of adapting SRI management practices to local conditions. The change agents established demonstration plots in the different rice growing ecologies across the country, but these activities fell short in the implementation process.

The CSIR ToTs in 2015 seemed to still approach SRI as a "one-solution fits all" for all rice systems across the country. It is important for the trainers receive full information of *how* the SRI innovation works and SRI management practices that have worked for other SRI practitioners around the world. Yet, it is critical to adapt these practices to local conditions throughout the country. Rice is grown in at least three different ecologies throughout Ghana, with different water management systems. Furthermore, each location may have different soil fertility, microclimates, environmental degradation etc. In addition, the socio-economic conditions most likely vary across each rice community. Trainers and practitioners would benefit to recognize the potential need to modify recommended practices to suit the local conditions of their target social systems. In this light, a recommendation is for the ToT sessions is to stress and expand upon teaching alternative SRI techniques that are more compatible to local conditions. This would create awareness of challenges change agents might face or changes they may need to make during the implementation and dissemination process. A further recommendation is continued documentation and annual meetings or gatherings of SRI practitioners from across the country. These gatherings could provide a platform for information exchange to increase awareness and knowledge of how other SRI practitioners have adapted the methods to their local conditions. In this way, peer learning from first-hand experiences could reduce uncertainties about the innovation for potential adopters and promote ways in which farmers can make SRI more appropriate for their own circumstances.

A concrete recommendation is for a new or local source of organic fertilizer. The CSIR trainings promote poultry manure as the primary source of organic fertilizer. The individual questionnaires revealed that access to poultry manure is not feasible for all rice growing ecologies in the country. In this regards, a recommendation is to find suitable sources of organic fertilizer in accordance with the local ecologies and the use of locally available materials, for example in the form of homemade compost or use of rice bio-waste, etc. More research is needed to find a suitable organic fertilizer that is local and still provides adequate nutrients.

9.2 "*WAY – women, age, youth*"

Another recommendation is for SRI trainings, strategy plans and policies to specifically and concretely address the target group *WAY – women, age, youth*. Analyzing the impact of SRI social systems is important for understanding and continuation of the diffusion process. Though women are main producing stakeholders in agriculture, they are often marginalized and tend to be the last to access innovations. The diffusion process should be seen through a gender lens to increase access for women (training, credit, tool use etc.). Women are tasked with household responsibilities in addition to farm production or agriculture-related roles. These dual job responsibilities leave women with limited time to attend extension services or trainings. Furthermore, some cultural norms may prohibit or limit women from participation or full participation in such. Past and current SRI research around the world has already alluded to potential benefits SRI management practices offer for women in terms of improving labor status, health impacts, body pains and drudgery associated with rice cultivation (Interview No. 5; Vent et al 2015). For example, research is being conducted by organizations like AfricaRice in testing different types of weeders that are suitable for farmer use and particularly women (Interview No. 6). Weeders could introduce a potential change in the Ghanaian social structure of rice cultivation as seen in examples in India where the mechanization of weeding transformed it into a male task (Interview No. 5; Vent et al 2015). Further research is needed to analyze gender-related topics of SRI.

Gender distribution of the individual questionnaires included 32 percent of the respondents being female and 68 percent being male. The uneven gender representation in the interviews could be a result of various factors: number of female farmers in the community, number of female farmers in the FBO, female farmers available for interview etc. Nonetheless, policy makers and rice sector stakeholders should analyze their activities through a gender lens to consider the full social impacts of SRI diffusion. Trainings and support throughout the growing season should put a specific emphasis on being accessible for women, taking their household tasks or additional time consuming responsibilities into consideration.

Similarly, the two social groups of the *elderly* and *youth* should also be included in SRI diffusion strategies and plans. Like the *global phenomenon, localized solution* recommendation, social structures of every rice farming community have different nuances even within the same region or district and therefore should be treated as similar, but separate entities. As indicated in the literature review and interviews, the *age* of farmers is a growing issue and concern in the agriculture sector. A trend in Ghana and around the world is the aging of farming communities. Young and able-bodied workers in rural communities are migrating to urban areas in droves, leaving farming activities to an elderly and aging population. The average age of the individually interviewed respondents was 46 years old, with the oldest respondent being 62 and the youngest being 22 years old. In a nation where the average life expectancy is 61 - 64 years, 46 years old is a ripe age (WHO 2016).

An aging farmer population, decline in able-bodied labor and youth migration to urban areas are key issues in social systems of the Ghanaian rice sector (Interview No.

2). SRI promoters and disseminators should take into consideration *who* they are training and *how* they are training their target groups. Simply increasing the numbers of youth in trainings and the rice sector is only a short-term solution to a long-term and perpetuating problem. A long-term solution requires a change in mindset and social norms across the region and country to refresh the agriculture sector for new generations. Change agents should be aware of this issue. Perhaps a structural change of the agriculture sector and farming is needed to reflect the lifestyle and opportunities rural youth seek in urban areas. This would require promotion of entrepreneurial thinking and further innovative systems or structural change in the current traditional agriculture model.

9.3 Inclusion of a Value Chain Perspective

SRI is an agricultural innovation that focuses on crop production; yield increase and its contribution to ensuring self-sufficiency and food security. However, the production stage is not the only phase of a commodity life cycle. The final recommendation is for policy makers, institutions and all key rice sector stakeholders to include a *value chain perspective* in the SRI diffusion process. As proven in demonstration fields in the research areas, throughout Ghana and around the world, SRI has the potential to increase crop yields, but it does not address post-production activities. Some of the interviewed farmers expressed challenges associated with higher yields and management of increased harvest. As a farmer from the Kadjebi Town pilot interviews commented, *"The yield is higher, but we do not have enough labor to harvest all of the grains in time. So some gets left on the plant and goes bad,"* (Interview No. 4).

In addition to receiving training on *production* with SRI practices, farmers would benefit from receiving extra support for post-production activities such as harvesting, processing and storage. The capacities of each of these post-production activities should be analyzed in order to decrease the amount of post-harvest loss due to lack of man-power, machinery or facilities. Post-harvest loss is already a major bottleneck in agricultural systems in sub-Saharan Africa (Alder et al 2012). Any introduction of agricultural innovations that perpetuates this problem would be counter-productive in achieving food security and alleviating poverty. Additionally, research revealed the marketing of local Ghanaian rice to be a main obstacle. In Ghana, there is a negative stigmatism towards local rice as being of poor quality with broken grains or containing stones (Interview No. 2). To improve the entire rice sector, SRI trainings would benefit to include quality control issues. Marketing strategies for locally grown rice also should be taken into consideration. The benefits of rice yields with SRI can only be fully realized if other aspects of the rice value chain such as post-harvest activities, marketing and consumer demands be included with SRI up-scaling projects. Zooming out at a global level, this begs the question, whether these are similar issues being faced by other SRI practitioners around the world. If so, how do change agents approach these issues? Do other countries have adaptive capacities to accommodate the impact of SRI in its entirety along the commodity value chain? Are there lessons to be learned from best management practices around the world? Further research would be needed to address these questions.

10 Research Limitations and suggestions for further research

This paper recognizes limitations and constraints of the research process. The scale and scope of the field research and data collection was restricted due to limited time and funding. The researcher had a limited time frame in which she could visit the case study region. The researcher conducted a larger number of pilot interviews in multiple communities in the Volta Region than was documented in the paper. These interviews gave the researcher a greater insight into the rice sector from the farmer perspective and allowed her to make improvements and adjustments on the questionnaire format. However, not all of the pilot interviews were documented in the paper results because some of the communities were practicing “good practices” methods and not SRI.

Additionally, biases could be associated with the pilot interviews and individual questionnaires; in some cases, a translator was required. The translator was often either the MoFA extension agent or a member of the community. The presence of the MoFA extension agent could have influenced the respondent’s answers. Due to limited time and funding, the researcher was only able to conduct the individual questionnaires in the Akpafu Mempeosem community. The individual questionnaires for the Nsuta and Kasec communities were administered by the district MoFA extension agents. The researcher recognizes that the enumerators were a non-neutral and potentially biased party that could have affected the questionnaire results. This research would have benefited more if the researcher had conducted all of the individual questionnaires and had a neutral translator.

Another limitation with the research was the timing in which the field research was conducted. The researcher was only available to visit the communities and collect data after the 2015 growing season had finished and before the 2016 growing season had started. Thus, the farmers could only share what they intended to do for the next growing season and the researcher did not have the opportunity to observe farming activities in the field. The researcher was not able to observe first-hand how the farmers implement SRI techniques. Additionally, the research does not reflect the entire adoption phase of SRI and whether or not some farmers decided to discontinue or disadopt the innovation. Any matter of socio-economic or ecological factors could have occurred between the time of the survey period and the start of the 2016 growing season that could have influenced the implementation and farmer adoption rate.

This research focused on the diffusion process of SRI in the Ghanaian rice sector, yet the rice sector would benefit from further research into the impacts of SRI implementation. More research would be needed to calculate the potential yield increase of SRI implementation and associated benefits in terms of food security and poverty alleviation. In addition, further research would be useful for analyzing the potential ecological benefits associated with SRI practices in terms of soil microbiota, soil nutrients and water conservation. Lastly, more research is needed to examine the potential impacts SRI implementation has on social structures such as gender roles in agriculture and community dynamics.

11 Conclusion

Since its establishment in Madagascar in the 1980s, the agroecological method of the *System of Rice Intensification* has spread to rice communities around the globe (SRI-Rice 2016). The attraction of SRI adoption lies in its adaptable management practices; its reduction in external input requirements; and most importantly high yields potential. In a global context where hunger and poverty are rampant throughout rural communities and developing nations, increases in rice production with the use of SRI practices offers a potential solution for ensuring food security and natural resource conservation.

SRI was introduced to Ghana in the early 2000s as a strategy for improving the national rice sector. The Ghanaian rice sector currently relies heavily on imports to cover the gap between sub-marginal production and an ever-increasing consumer demand (Teye 2013). SRI offers a strategy for improving the rice sector and enabling Ghana in achieving self-sufficiency in rice production. This research is an ex-post analysis of the dissemination process of SRI in Ghana in the case study area of the Volta Region. Analysis of SRI dissemination process through Rogers (2003) *Diffusion of Innovations* theory perspective procured further insights for improvement and continuation of SRI expansion throughout the country.

Rogers (2003) argues the key elements for the innovation diffusion process are the innovation, communication channels, time and social system. This research examined the System of Rice Intensification as an agricultural innovation within the social system of rice farming communities in the Volta Region. SRI is a software information, knowledge-based innovation that requires an extensive amount of training provided by change agents via interpersonal communication and hands-on learning with demonstration fields. The study revealed that most of farmers practicing SRI in the research area had received adequate support and training to carry out implementation. Additional attributes of SRI that lent to its acceptance among practitioners are its high degree of trialability and observability. The case study farmers decided to implement SRI methods after having participated on or having observed SRI demonstration fields. Demonstration fields and trainings allowed the farmers to test the innovation and personally observe its relative advantages such as higher yields, less seeding material and water conservation.

Further findings revealed that labor availability and costs, tool availability and organic fertilizer accessibility were key challenges and constraints farmers faced with SRI implementation. The SRI propagation method of nursery management and transplanting is a degree more complex, tedious and time-consuming than traditional methods of broadcasting or scatter transplanting. In addition, many farmers lacked capital and accessibility to tools recommended for SRI methods such as machinery for bound building for land preparation and mechanical weeders for inter-cultivation. Similarly, farmers expressed difficulty accessing and affording organic fertilizer.

Based on literature review, questionnaire results and field observations this research suggests recommendations characterized by three themes: *global phenomenon, local solutions, WAY – women, age, youth* and *inclusion of a value chain perspective*. SRI is a *"global phenomenon, [requiring] localized solutions"* to adapt SRI techniques for all rice growing ecologies across the country. SRI trainings and experimentations should continue to stress the need to modify SRI management practices to adjust to local conditions; SRI is not a "one-size fits all" solution. SRI practitioners and change agents could benefit from a continuous exchange network of communication, knowledge and lessons-learned platform. Additionally, this research found that poultry manure was not a feasible source of fertilizer for the Volta region farmers in terms of accessibility and affordability. Sources of organic fertilizer should be modified according to local availability and conditions i.e. local composting, re-use of rice bio-waste products etc. Further research is needed to determine appropriate organic fertilizer sources that are both locally available and provide sufficient nutrients.

Secondly, the SRI dissemination process would benefit from specific inclusion of the social groups *WAY – women, age, youth* – in strategy planning. Though they are key actors in the agriculture sector, women are often marginalized, underrepresented and tend to benefit last from the introduction of innovations. Moreover, the agriculture sector in Ghana is experiencing an aging farmer population and trend of rural youth migrating to urban areas. This leaves an uncertain future for how the agriculture sector and rice production can continue to expand and improve. Changes in the social structure are required to either encourage more youth into agriculture or a structural change in the agriculture system.

Lastly, SRI change agents and stakeholders in the rice sector would benefit to analyze the impact SRI has on the entire value chain such as inclusion of post-harvest management and activities such as processing, marketing and storing. SRI is a technique that focuses on the production stage of rice cultivation, yet all capacities of the rice value chain should to be improved in order for benefits of SRI to have a long-term effect. Improvements are needed to include boosting farmer capacities in handling increased yields at harvest time and grain storage facilities to decrease post-harvest loss. Moreover, quality control should also be taken into consideration to increase the market competitiveness of Ghanaian rice and address the negative stigmatism of local rice.

In conclusion, SRI is steadily spreading throughout all rice growing regions in Ghana and farmers have experienced benefits of its practices such as higher crop yields. SRI offers a potential strategy for boosting the Ghanaian rice sector, yet more observations and documentation is needed to follow the adoption process. Moreover, the dissemination process would benefit from further research on the environmental and social impacts of SRI implementation, specifically in terms of food security, natural resource conservation and social structure.

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A. Mark

14 Appendices

Appendix 1 Individual Questionnaire Sample 2016

Questionnaire
The System of Rice Intensification (SRI) method, a solution to ensuring food security? How smallholder farmers in selected countries have adopted and adapted the SRI method and its related challenges, constraints and opportunities: Case study of the Volta Region in Ghana

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The main objective of this study is to assess how smallholder farmers in selected countries have adopted the System of Rice Intensification (SRI) method and assess how they have adapted recommended practices to suit their socio-, economic and ecological conditions. In addition, this research aims to highlight key challenges, constraints and opportunities that result from SRI practices. Fieldwork data will be collected from communities in the Volta Region of Ghana where first trainings in SRI have been given and demonstration plots established. Furthermore, this study aims to determine the enabling environment required for farmers in the Volta Region to implement SRI practices. Results from the fieldwork will be compared with other findings from studies in selected countries (for example India, Mali, Cambodia).

This research is carried out for a master thesis and conducted with the help of the *Deutsche Gesellschaft für International Zusammenarbeit (GIZ)/ Green Innovation Centre Project Ghana (GIC), the Ministry of Food and Agriculture Ghana, Ghana Rice Inter-Professional Body (GRIB) and the University of Sustainable Development Eberswalde, Germany. This exercise is for academic purposes only, thus details provided by all respondents will be kept confidential. The results of this research will be included in a report and available to whoever is interested.*

The interview will take about 40 – 60 minutes.

Survey No.: _ _ _ _ _ _ _ _ _

SURVEY INFORMATION

Region:			
District:	_ _ _ _ _ _ _ _ _ _		
Village:	_ _ _ _ _ _ _ _ _ _		
Name of enumerator:	_ _ _ _ _ _ _ _ _ _		
Email/Telephone:	_ _ _ _ _ _ _ _ _ _		
Translator required?:	Yes [ ] No [ ]		
Date of interview:	/ /	Start time:............	End time:.......

GENERAL INFORMATION

Name of Farmer:	
Farmer's Contact Number/Email (if applicable):	_ _ _ _ _ _ _ _ _ _

SECTION A: SOCIO-ECONOMIC INFORMATION

1. Gender of respondent Female [ ] Male [ ]	2. Age of respondent (years)		
3. Educational background	[ ] Primary [ ] JHS/JSS [ ] SHS/SSS [ ] Tertiary [ ] None [ ] other (specify).............................		
4. The number of household members?	Total.........	Female......	Male..........
5. What is your relationship to the head of household? (see household relation codes)	....	**Household relation codes** Head...01 Spouse (Wife/Husband).................................02 Child (Son/daughter).......................................03 Grandchild...04 Parent/Parent-in-law.......................................05 Son/Daughter-in-law..06 Other relative...07 Adopted/Foster/step child.................................08 Househelp..09 Non-relative..10 Other (specify)..11	
6. Is farm production your only work? Yes [ ] No [ ]	7. If no, which is your other major work?	Teacher [ ] Miller [ ] Trader [ ] Artisan [ ] Other (specify)...	
8. Farmer Based Organization (FBO) membership? Yes [ ] No [ ]	9. If yes, what is the name of the FBO?		
10. Marital Status Single [ ] Married [ ] Widowed [ ] Other (specify)...			
11. How many years have you been cultivating rice?			
12. Access to extension services?	2015 Yes [ ] No [ ]	2016 Yes [ ] No [ ]	
13. If yes, what was the number of visits? If no, please state why?	2015................................	2016..................................	
14. Access to farm credit?	2015 Yes [ ] No [ ]	2016 Yes [ ] No [ ]	
15. If yes, what type of farm credit?	2015 Cash credit [ ] In-kind [ ] Both [ ] Other (specify).............	2016 Cash credit [ ] In-kind [ ] Both [ ] Other (specify)...............	

16. Acquisition and ownership of farmland Total No. of plots:…………	
Plot 1	Inherited [ ] Purchased [ ] Leased [ ] Share cropping [ ] Other (specify)……………………………………
Plot 2	Inherited [ ] Purchased [ ] Leased [ ] Share cropping [ ] Other (specify)……………………………………
Plot 3	Inherited [ ] Purchased [ ] Leased [ ] Share cropping [ ] Other (specify)……………………………………
Plot 4	Inherited [ ] Purchased [ ] Leased [ ] Share cropping [ ] Other (specify)……………………………………

SECTION B: GENERAL FARM CHARACTERISTICS

17. What crops do you grow? (see crop codes)	Plot 1	Plot 2	Plot 3	Plot 4

Crop codes			
None……………………………00	Coffee………………………09	Maize………………………19	Rubber……………………32
Avocado pear……………01	Colanut……………………10	Mango………………………20	Sheanut……………………33
Bananas…………………02	Cotton………………………11	Millet………………………21	Sugarcane…………………34
Beans/Peas………………03	Garden egg/Egg pla………12	Okro………………………23	Tiger nut……………………35
Cashew nut………………04	Ginger………………………13	Onion………………………24	Tobacco……………………36
Cassava…………………05	Groundnut/Peanut…………14	Oranges/tangerine…………25	Tomatoes……………………37
Cocoa………………………06	Guinea corn/Sorghu………15	Pawpaw……………………26	Water melon………………38
Coconut……………………07	Kenef………………………16	Pepper………………………27	Wood lot……………………39
Cocoyam…………………08	Leafy vegetables…………17	Pineapple…………………28	Yam…………………………40
	Lime/Lemon………………18	Plantain……………………29	Other crops…………………41
		Potatoes/Sweet potatoes…. 30	Other fruits…………………42
		Rice…………………………31	Other vegetables……………43
			Moringa……………………44
			Star apple…………………45

	Plot 1	Plot 2	Plot 3	Plot 4
18. What is the water management?	Rainfed [ ] Irrigated [ ]	Rainfed [ ] Irrigated [ ]	Rainfed [ ] Irrigated [ ]	Rainfed [ ] Irrigated [ ]
19. What was the plot size in 2015? (Unit: ha/acre)	……………………	……………………	……………………	……………………
20. What size was your SRI plot in 2015? (Unit: ha/acre)	…………………	…………………	…………………	…………………
21. What will your SRI plot be the size in 2016? (Unit: ha/acre)	………………..	…………………	………………….	…………………

SECTION C: INTRODUCTION OF SYSTEM OF RICE INTENSIFICATION (SRI) METHOD

22. How were you introduced (training) to the SRI method? Extension agent [ ] NGO [ ] Other farmers [ ] Other (specify)…………………………………………………………	23. What year did you first start practicing the SRI method? ………………………
24. Were the first trainings and practices on a demonstration plot? Yes [ ] No [ ]	25. If yes, was the demonstration plot on your land? Yes [ ] No [ ]
26. If no, please describe how you received trainings on SRI. ……	

SECTION D: STAGES OF CULTIVATION PRACTICE WITH SRI METHODS – *What did the respondent learn or remember from the trainings?*

Land Preparation (SRI) – *check all that apply, record additional activities and/or variations under "other"*	
27. How did you prepare your rice plot? Weedicide [ ] Power tiller [ ] Cutlass [ ] Other (specify)…………………………………………………	
28. If you used a power tiller, how many times did you till the land? ……	
29. Where did you obtain the power tiller? Ministry of Food and Agriculture (MoFa) [ ] Private owned [ ] Other (specify)………………………………………	30. Do you build bounds? Yes [ ] No [ ]
31. Did you apply fertilizer? Yes [ ] No [	32. If yes, what kind? Poultry manure [ ] N, P, K [ ] Other (specify)…………………………………
33. Who was responsible for clearing the land? Respondent [ ] Family [ ], please indicate number of **Male**……. **Female**…… Hired labor [ ], please indicate number of **Male**…… **Female**……. Other (specify)………………………………………………………….	

Seed Preparation (SRI) – *check all that apply, record additional activities and/or variations under "other"*
34. What variety of rice do you grow? ……………………………………………
35. How did you obtain seeds? Old harvest [ ] Crop Research Institute (CSIR) [ ] Other (specify)………………………………………………

36. What quantity of seeds did you use for your SRI plot? (Unit: kg/acre) …………………………………………………………	37. If seeds were purchased, how much did it cost per unit? (Unit: kg/acre) …………………………………………………………
38. Did you soak or pre-germinate the seeds? Yes [ ] No [ ]	

Nursery Management (SRI) – *check all that apply, record additional activities and/or variations under "other"*

39. How did you prepare your nursery plot?
Raised bed [ ] Plastic/Rubber tarp [ ] Cleared land with cutlass [ ] Cleared land with weedicide [ ]
Cleared land with power tiller [ ] Till the land with a hoe [ ]
Other (specify)……………………………………………………………………

40. How did you plant the seeds?
Broadcasting [ ] In lines or rows [ ] Other (specify)…………………………………………………………

41. Who was responsible for nursery management?
Respondent [ ]
Family [ ], please indicate number of **Male**……. **Female**……
Hired labor [ ], please indicate number of **Male**…… **Female**…….
Other (specify)…………………………………………………………..

Transplanting (SRI) – *check all that apply, record additional activities and/or variations under "other"*

42. How old were the seedlings when transplanted (days)? ………..

43. How were the seedlings picked and prepared for planting?
Cleaned, all soil removed [ ] Partially cleaned, still some soil remaining [ ] Not cleaned [ ]
Other (specify)……………………………………………………………………

44. How were the seedlings transported from the nursery to the field?
In a container [ ] In bundles [ ] In the hand [ ] On a cutlass [ ] Other (specify)……………………..

45. What was the planting arrangement of the seedlings on the field?
In row spacing [ ] Random [ ] Other (specify)……………………………………

46. What distance were the seedlings planted?
20 x 20cm [ ] 25 x 25cm [ ] 30 x 30cm [ ] Other (specify)………………………………

47. How many seedlings were planted per hill?
1 seedling [ ] 2 seedlings [ ] 3 seedlings [ ] Other (specify)………………………………

48. What tools were used for marking the lines or spacing?
Rope [ ] Rope attached to sticks [ ] Other (specify)…………………………………………

49. Who was responsible for transplanting?
Respondent [ ]
Family [ ], please indicate number of **Male**……. **Female**……
Hired labor [ ], please indicate number of **Male**…… **Female**…….
Other (specify)…………………………………………………………..

50. After transplanting, did you apply fertilizer? Yes [ ] No [ ]

51. If yes, what kind of fertilizer? Poultry Manure [ ] N,P,K [ ] Ammonium [ ] Other (specify)………………..
52. Who was responsible for apply fertilizer? Respondent [ ] Family [ ], please indicate number of **Male**……. **Female**…… Hired labor [ ], please indicate number of **Male**…… **Female**……. Other (specify)…………………………………………………………..

Weed Control (SRI) – *check all that apply, record additional activities and/or variations under "other"*
53. How did you control the weeds? Weed pusher [ ] Hand picking (manual) [ ] Mechanical weeder [ ] Weedicide [ ] Other (specify)……………………………..
54. If a tool was used for weeding, how was it obtained? Purchased [ ] Provided by MoFa [ ] Borrowed [ ] Other (specify)……………………………………………
55. How often did you weed? Every 10 days [ ] Every 4 weeks [ ] Other (specify)…………………………………………………………
56. Who was responsible for weeding? Respondent [ ] Family [ ], please indicate number of **Male**……. **Female**…… Hired labor [ ], please indicate number of **Male**…… **Female**……. Other (specify)…………………………………………………………..

Harvest and Post-harvest (SRI)		
57. What the yield of your SRI plot (if applicable)? (Unit: kg)	2014 ……………………………………….	2015 ……………………………………….
58. What tools are used for harvesting? Manual (cutlass, sickle) [ ] Mechanical harvester [ ] Other (specify)………………………………………		
59. Who is responsible for harvesting? Respondent [ ] Family [ ], please indicate number of **Male**……. **Female**…… Hired labor [ ], please indicate number of **Male**…… **Female**……. Other (specify)…………………………………………………………..		
60. What is the method used for threshing? Manual [ ] Mechanical [ ] Other (specify)……………………		
61. Who is responsible for threshing? Respondent [ ] Family [ ], please indicate number of **Male**……. **Female**…… Hired labor [ ], please indicate number of **Male**…… **Female**……. Other (specify)…………………………………………………………..		
62. What is the method used for winnowing? Manual [ ] Mechanized [ ] Other (specify)………………………………………………………………..		

63. What do you do with the rice paddy after harvest? Sell the paddy [ ] Mill the paddy yourself before selling [ ] Take the paddy to the mill before selling [ ] Other (specify)…………………………………………………………		
64. If you mill the paddy before selling, who is responsible for milling? Respondent [ ] Family [ ], please indicate number of **Male**……. **Female**…… Hired labor [ ], please indicate number of **Male**…… **Female**……. Other (specify)……………………………………………………… .		
65. How much harvest from your SRI plot did you sell? (Unit: kg)	2014 …………………………………….	2015 …………………………………….
66. How much harvest from your SRI plot did you keep for household consumption? (Unit: kg)	2014 …………………………………….	2015 …………………………………….
67. Who is responsible for selling? Respondent [ ] Family [ ], please indicate number of **Male**……. **Female**…… Hired labor [ ], please indicate number of **Male**…… **Female**……. Other (specify)………………………………………………………		

SECTION E: CONSTRAINTS AND CHALLENGES WITH SRI METHODS– *check all that apply, record additional activities and/or variations under "other"*

68. Please identify the main challenges or constraints you have with land preparation. Labour availablilty [ ] Labour costs [ ] Tool accessibility [ ] Organic fertilizer availability [ ] High costs of material inputs [ ] Water availability [ ] Other (specify)…………………………………………………………………………………………….. ………………………………………………………………………………………………………
69. Please identify the main challenges or constraints you have with nursery management. Labour availablilty [ ] Labour costs [ ] Tool accessibility [ ] Water availability [ ] Weeding [ ] Seedling mortality [ ] Time consuming [ ] Other (specify)…………………………………………………………………………………………….. ………………………………………………………………………………………………………
70. Please identify the main challenges or constraints you have with transplanting. Labour availablilty [ ] Labour costs [ ] Time consuming [ ] Body pains/drudgery [ ] Other (specify)…………………………………………………………………………………………….. ………………………………………………………………………………………………………
71. Please identify the main challenges or constraints you have with weeding. Labour availablilty [ ] Labour costs [ ] Time consuming [ ] Body pains/drudgery [ ] High costs of material inputs [ ] Tool accessibility [ ] Other (specify)…………………………………………………………………………

72. Please rank the challenges/constraints associated with practicing the SRI method on a scale of one (1) to eight (8), with (1) being the most challenging or largest constraint.

Constraint	Ranking
Labour availability	
Land ownership	
Land size	
High costs of material inputs	
Water availability	
Organic fertilizer availability	
Tool availability	
Support/training from extension agents or other institution	

SECTION F: WHAT RECOMMENDED PRACTICES OF THE SRI METHOD DOES THE RESPONDENT PLAN TO IMPLEMENT NEXT SEASON (2016) – *check all that apply, record additional activities and/or variations under "other"*

73. What recommended SRI practices of land preparation do you plan to do this season (2016)?
Power tiller [ ] Application of poultry manure [ ] Building bounds [ ] Other (specify)............................
....

74. What recommended SRI practices of seed preparation do you plan to do this season (2016)?
Use of improved seeds [ ] Seed soaking/pre-germination [ ] Other (specify).....................................
....

75. What recommended SRI practices of nursery management do you plan to do this season (2016)?
Seed on a raised bed [ ] Seed on a tarp/material [ ] Planting seeds in rows [ ]
Other (specify)...
....

76. What recommended SRI practices of transplanting do you plan to do this season (2016)?
Picking seedlings with soil on the roots [ ] Planting seedlings 8-10 days old [ ]
Planting 1 seedling per hill [ ] Planting distance 25 x 25cm [ ] Using marker tools [ ]
Other (specify)...
....

77. What recommended SRI practices of weed control do you plan to do this season (2016)?
Use of a weeder [ ] Weeding every 10 days [ ] Other (specify)..
....

78. What recommended SRI practices of fertilizer use do you plan to do this season (2016)?
Use of poultry manure [ ] Other (specify)...
....

SECTION G: ENABLING ENVIRONMENT NEEDED TO IMPLEMENT SRI PRACTICES- *What do the farmers need or is required in order for them to implement the SRI recommended practices for the next crop season (2016)? – check all that apply, record additional activities and/or variations under "other"*

79. What factors will influence whether or not you use the SRI practices this crop season (2016)? Further training and/or monitoring support (by MoFa or another actor) [ ] Provision of poultry manure or other organic material [ ] Accessibility to a weeder [ ] Labour accessibility [ ] Accessibility to a power tiller [ ] Access to credit [ ] Other (specify)………………………………………………………………………………………………… ………

SECTION H: STAGES OF CULTIVATION PRACTICE WITH TRADITIONAL/CONVENTIONAL METHOD

Land Preparation (Traditional/Conventional) – *check all that apply, record additional activities and/or variations under "other"*	
80. How did you prepare your rice plot? Weedicide [ ] Power tiller [ ] Cutlass [ ] Other (specify)…………………………………………………	
81. If you used a power tiller, how many times did you till the land? …………………	82. Where did you obtain the power tiller? Ministry of Food and Agriculture (MoFa) [ ] Private owned [ ] Other (specify)…………………………………………………
83. Did you apply fertilizer? Yes [ ] No [ ]	84. If yes, what kind? 'Poultry manure [ ] N, P, K [ ] Other (specify)………………………………………………………………
85. Do you build bounds? Yes [ ] No [ ]	
86. Who was responsible for clearing the land? Respondent [ ] Family [ ], please indicate number of **Male**……. **Female**…… Hired labor [ ], please indicate number of **Male**…… **Female**……. Other (specify)…………………………………………………………..	

Seed Preparation (Traditional/Conventional) – *check all that apply, record additional activities and/or variations under "other"*	
87. What variety of rice do you grow? …………………………………………	
88. How did you obtain seeds? Old harvest [ ] Crop Research Institute (CSIR) [ ] Other (specify)……………………………………………	
89. What quantity of seed did you use? (Unit: kg/acre)…………………………………	90. If seeds were purchased, how much did it cost per unit? (Unit: kg/acre) ………………………………………………………………
91. Did you soak or pre-germinate the seeds? Yes [ ] No [ ]	

Planting method (Traditional/Conventional) – *check all that apply, record additional activities and/or variations under "other"*
92. How did you plant the seeds on the field? Broadcasting [ ] Dibbling [ ] Transplanting [ ] Other (specify)…………………………………………………..
If transplanting was practiced, continue to ask the following questions:
93. How did you prepare your nursery plot? Raised bed [ ] Plastic/Rubber tarp [ ] Cleared land with cutlass [ ] Cleared land with weedicide [ ] Cleared land with power tiller [ ] Till the land with a hoe [ ] Other (specify)…………………………………
94. How did you plant the seeds? Broadcasting [ ] In lines or rows [ ] Other (specify)………………………………………………………
95. Who was responsible for nursery management? Respondent [ ] Family [ ], please indicate number of **Male**……. **Female**…… Hired labor [ ], please indicate number of **Male**…… **Female**……. Other (specify)…………………………………………………………..

Weed Control (Traditional/Conventional) – *check all that apply, record additional activities and/or variations under "other"*
96. How did you control the weeds? Weed pusher [ ] Hand picking (manual) [ ] Mechanical weeder [ ] Weedicide [ ] Other (specify)……………………………..
97. If a tool was used, how was it obtained? Purchased [ ] Provided by MoFa [ ] Borrowed [ ] Other (specify)………………………………………….
98. How often did you weed? Every 10 days [ ] Every 4 weeks [ ] Other (specify)…………………………………………………………….
99. Who was responsible for weeding? Respondent [ ] Family [ ], please indicate number of **Male**……. **Female**…… Hired labor [ ], please indicate number of **Male**…… **Female**……. Other (specify)…………………………………………………………..

Thank you for your participation! Medasse! Akpe kaka!

Additional Comments & Notes (if applicable)
………
………

Appendix 2 Expert Interviews (Correspondence)

Interview No. 1: In-person meeting on 30 March 2016 with a senior lecturer of the Agricultural Economics Department at the University of Ghana.

Interview No. 2: In-person meeting on 25 February 2016 with the executive secretary of a nation-wide organization of the rice sector stakeholders

Interview No. 3: Telephone correspondence on 1 April 2016 with a head research scientist at a research institute for the food and agriculture sectors in Ghana

Interview No. 4: In-person and email correspondence from February to June 2016 with an expert and consultant in the rice sector

Interview No. 5: Email correspondence throughout February and March 2016 with an SRI technical expert at an international rice company based in the United States

Interview No. 6: Email correspondence throughout February and March 2016 with an SRI technical expert at an SRI research center based in the United States

Interview No. 7: In-person, telephone and email correspondence from March to July 2016 with an agricultural extension agent based in the Volta Region

Appendix 3 Photo Documentary of SRI stages

These photos show the different stages of rice cultivation with the SRI management practices in the Nsuta community on the demonstration plot in 2015.

Land preparation

Land preparation with a tractor to build bounds and clear the land and a power tiller to till the soil (own photo 2016; Dunyo 2015).

Nursery and Transplanting

Farmers in the Nsuta community picking seedlings from the nursery for transplanting in the rice field (Dunyo 2015).

Weed Management

Farmers in the Nsuta community using push weeders to control weeds (Dunyo 2015).

Harvest

Farmers from the Nsuta community manually harvesting their SRI field with sickles and cutlasses, threshing the tillers and drying the paddies (Dunyo 2015).