UNIVERSITY FOR DEVELOPMENT STUDIES, TAMALE

ADOPTION AND DISADOPTION OF IMPROVED RICE VARIETIES AMONG FARMERS IN THE NORTHERN REGION, GHANA

CLEMENT YAW LAMPTEY

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BY

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(UDS/DIC/0003/18)

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DECLARATION

STUDENT'S DECLARATION

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this University or elsewhere.

Candidate's Signature:...**Date:** ....

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SUPERVISORS' DECLARATION

We hereby declare that the preparation and presentation of the thesis was supervised in accordance with the guidelines on supervision of thesis laid down by the University for Development Studies.

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ABSTRACT

Rice Farmers in Ghana have benefited from the dissemination programmes of high-yielding crop varieties in addition to other complementary technologies to enhance productivity, food security and welfare of farmers, among others. Despite the expected gains from the numerous interventions, there are low levels of adoption and high levels of disadoption of rice varieties among many farmers in Ghana. The main objective of this study was to investigate the factors that influenced adoption and disadoption of improved rice varieties among farmers in the Northern Region of Ghana. The study used both qualitative and quantitative data. The data was primarily collected from 404 rice farmers using multi-stage sampling procedure. The data was analyzed using descriptive and inferential statistics, narratives, and estimation of a generalized multivariate regression, and propensity score matching models. The empirical results show that fellow farmers, researchers and extension agents as well as certified seeds and input dealers were the commonest channels of innovation communication among the rice farmers. Farm and home visits, technology demonstration farms, and radio broadcasts were the main innovation dissemination methods used to educate farmers. Generally, there were lower levels of improved rice variety adoption in the study area, with the most adopted varieties being Agra (77.33%), Sakai (50%), Jasmine (40.64%) and Afife (23.17%) in that order. The disadoption levels were much higher for improved rice varieties such as GR-18 (94.23%), Nerica (94.18), Digang (87.72%), Tox (87.18%), Mandee (81.82%) and Faro-15 (80.90%), also in that order. The main reasons for the disadoption of improved rice varieties in the study area were the high input requirements for some of the varieties, lack of ready market for the produce, and unfavourable climatic conditions. The estimation results of the generalized multivariate regression revealed that factors that influenced initial adoption and current adoption of improved rice varietieties positively, also influenced their disadoption negatively, and vice versa. Such factors include farmers' age, family labour, and membership of Farmer Based Organizations (FBO), extension, input market, farm size, telephone, field demonstrations, and temperature. In all, FBO membership was the single most important factor that significantly affected the initial adoption, current adoption and disadoption decisions of all the rice varieties modelled, either negatively or positively. Adoption also had a positive impact on farmers' rice output, implying that maximum output could be achieved if efforts are made to increase adoption rates of improved rice varieties among the farmers. The study recommends that the extension directorate of Ministry of Food and Agriculture (MoFA) should target younger farmers, through a combination of individual, group and mass media methods, as the surest way of educating farmers. For continuous adoption of improved rice varieties and sustainability of agricultural innovations, the government, Non-Governmental Organizations (NGOs) and FBOs in the rice value chain must ensure that improved rice varieties disseminated have low input requirements, ready markets and less susceptibility to the prevailing climatic conditions, pests and diseases of the study area. The government could also promote the adoption of newly improved rice varieties such as Agra, Jasmine and Nerica through its flagship programmes including *Feed the Future* initiative, *Planting for Food and Jobs, the National Food Buffer Stock Company* and *School Feeding Programme*. Savannah Agricultural Research Institute (SARI) and Centre for Scientific and Industrial Research (CSIR) should also step up their efforts at developing and disseminating new improved rice varieties to overcome the challeneges of climate change, pests and diseases infestations. Finally, MoFA could subsidice mobile phones for farmers to enable them have easy access to AEAs, weather information as well as information about government's policies and programmes.

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DEDICATION

I dedicate this thesis to God.

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LIST OF ABBREVIATIONS

ATC:	Average Treatment Effect on the Control
ATE:	Average Treatment Effect
ATT:	Average Treatment effect on the Treated
ATS/CA:	Agricultural Technology Systems/ Conservative Agriculture
CDT:	Cognitive Dissonance Theory
CSIR:	Council for Scientific and Industrial Research
DTPB:	Decomposed Theory of Planned Behaviour
EAS:	Extension and Advisory Services
ECT:	Expectation Confirmation Theory
EDT:	Expectation Disconfirmation Theory
ETMs:	Extension Teaching Methods
EUCORD:	European Cooperative for Rural Development
FAO:	Food and Agriculture Organization
FGD:	Focus Group Discussion(s)
GSS:	Ghana Statistical Service
ICAR:	Indian Council of Agricultural Research
ICM:	Innovation Communication Methods
IDM:	Innovation Dissemination Methods
IDT:	Innovation Diffusion Theory
KIIs:	Key Informant Interviews
MiDA:	Millennium Development Authority
MMDAs:	Metropolitan, Municipal and District Assemblies

MoFA:	Ministry of Food and Agriculture
MRM:	Multivariate Regression Model
MVP:	Multivariate Probit Model
NGOs:	Non-Governmental Organizations
NRDP:	NERICA Rice Dissemination Project
NRDS:	National Rice Development Strategy
OLS:	Ordinary Least Squares
PBC:	Perceived Behavioural Control
PEOU/PU:	Perceived Ease of Use/ Perceived Usefulness
PSM:	Propensity Score Matching
SAP:	Structural Adjustment Programme
SARI:	Savannah Agricultural Research Institute
SCT:	Social Cognitive Theory
SET/ SIT:	Social Exclusion Theory/ Social Inclusion Theory
SRI:	System of Rice Intensification
SSA:	Sub-Sahara Africa
TAM:	Technology Acceptance Model
TPB/ TRA:	Theory of Planned Behavior/ Theory of Reasoned Action
USAID:	United States Agency for International Development
UTAUT:	Unified Theory of Acceptance and Use of Technology
WARDA:	West African Rice Development Authority
WIAD:	Women’s Rights in Agricultural Development.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Rice is one of the staple food crops in the world (Belayneh and Tekle, 2017). More than 90% of rice produced in the world is from South and East Asia with China as the leading producing country. According to the European Cooperative for Rural Development (EUCORD, 2012), 3% of rice produced globally is from Africa. This means Africa contributes abysmally to the world rice market. The reason being that rice has been a neglected crop in Africa with consumption by far exceeding production. There is therefore the need to boost rice production in Africa, particularly Ghana. The 2008/9 global food-price crisis triggered production increases of rice in Sub-Saharan Africa (SSA) from 16-18% and a further 4.5% in 2009 alone (Science Council, 2007).

Demand for rice is therefore on the rise due to rapid population growth. For instance, about 501,201 thousand metric tons of rice produced globally in 2020/2021 is from South and East Asia. In Africa, 19,613 thousand metric tons of rice were produced in the 2020/2021 cropping season (FAO, 2021). That is, Africa currently contributes approximately 4% to the global rice basket, which is still below expectation. The reason is that there are poor marketing opportunities for rice producers in Africa, which leads to poor adoption decisions of improved rice varieties coupled with other agronomic practices among farm households. This makes Africa the net importer of rice from the developed countries. High importation of rice to Africa increases governments' debt stock, which slows down economic growth and socio-economic transformation in the rural economy. There is therefore the need to boost rice production in Africa, particularly Ghana, to minimize rice importation through the adoption of improved rice production varieties.

Although huge public resources have been allocated to the generation and dissemination of improved crop varieties in SSA for the past three decades, the general levels of adoption of improved innovations have been relatively low compared to other regions (World Development Report, 2008). This trend can be reverted if the innovations are disseminated to commercial and large-scale farmers rather than the pro-poor and smallholder farmers as has been the case in SSA over the past three decades. The adoption of about twenty improved rice varieties disseminated in Ethiopia since 1999 has faced enormous challenges including high competition from imported rice, poor roads and market infrastructure, inadequate mechanization services, and post-harvest losses, inadequate skilled labour and research facilities, and bottlenecks in transport and communication channels (Tamirat and Jember, 2017).

The diffusion of improved rice varieties across Africa is sometimes hampered by a lack of readily available literature on the nutritional characteristics and the approved agronomic practices. Available literature on such innovations is quite scattered and scanty, which reduces their value to research and extension staff, as well as crop producers and consumers (WARDA, 2008). Kasirye (2013) observed that peer pressure contributes immensely to influence crop producers to either adopt or not to adopt certified seeds and recommended fertilizers. Rice is an important cash crop in Ethiopia, which is used locally and for export (Belayneh and Tekle, 2017). Therefore, innovative farming practices are essential for peasant farmers in ensuring food security (Kasirye, 2013).

The largest producer of rice on the African continent is West Africa, with Nigeria in the lead, producing an optimum of 3 million metric tons of paddy rice annually, over the past 30 to 40 years (Ayedun and Adeniyi, 2019). Nigeria has increased in rice production lately, by producing 8.44 million tonnes of paddy rice in 2019 and over five million metric tons of milled rice in 2020 respectively (FAO, 2021; Kamai, Omoigui, Kamara and Ekeleme, 2020). Rice is widely cultivated under several ecosystems and a wide varietion of environmental conditions such as rain-fed lowland, irrigated lowland, mangrove swamp and upland with a total annual production of about 2 million metric tons (MT) in Nigeria (Obayelu, Dontsop, and Adeoti, 2016). This strategic commodity is next to sorghum, millet and maize in Nigeria (Obayelu et al., 2016). Improved rice variety adoption in Nigeria significantly increased the total farm size, output, and income of farmers. Rice is next to maize among all the cereals grown and consumed in Ghana (Agricultural Production Survey, APS, 2015). It is therefore very important for consumption and commercial purposes in Ghana.

The agricultural sector in Ghana is one of the pillars for sustainable economic growth and development. The sector has devrived benefits from a myriad of multi-national assistants aimed at improving yield, reducing poverty and increasing incomes (Ragasa, Dankyi, Acheampong, Wiredu, Chapoto, Asamoah, and Tripp, 2013). Rice Farmers have also received assistance from the promotion of improved crop varieties together with other complementary innovations (Faltermeier, 2007; Langyintuo and Dogbe, 2005; Al-hassan, Sarpong, and Al-hassan, 2004; Jatoe, 2002). The aim of promoting green technologies, like high-yielding rice varieties, is to increase rice production to meet domestic demand and also create market opportunities for farm households and other rice value chain actors. Increasing rice production and market opportunities have a positive impact on sustainable job creation in rural areas. However, rice production in Ghana is dominated by small scale farmers, who mostly use low farm inputs and technologies. Adoption of Agricultural innovations is aimed at enhancing productivity, increasing incomes, reducing poverty and ensuring equity among adopters (Asante, Appiah, Ofori-Frimpong, and Afrifa, 2004). So, in support of Ghana's resolve to enhancing food security by boosting production and facilitating growth of the agricultural sector in a sustainable way, USAID/Ghana implemented its Feed the Future (FtF) initiative. The initiative had a focus and high-impact method of transforming the rice value chain, with particular reference to Ghana's Northern Region (McNamara, Dale, Keane, and Ferguson, 2014).

Many farmers in Northern Ghana operate at low levels of productivity (Langyintuo and Dogbe, 2005), primarily because they do not adhere to modern farming methods and technologies. Inspite the numerous benefits to be derived from several interventions, the adoption rates of innovations among many farmers in the Northern Region of Ghana keeps dwindling. Almost all of these farmers use traditional crop varieties and outmoded farming methods (Azumah, 2019).

Obayelu, Dontsop, and Adeoti (2016) noted a positive impact of improved rice variety adoption on yields and incomes of rice farmers, which shows that improved rice varieties have the innate ability to increase rice production, minimize poverty and food insecurity in Ghana. Awotide, Diagne, and Omonona (2012) suggest that adoption of improved rice varieties greatly improves the living standards of farmers but Wiredu, Asante, Martey, Diagne, and Dogbe (2010), report that the record of the impact of improved rice variety adoption on farmers' output and welfare in the Ghana is minimal. That not withstanding, Wiredu et al. (2010) found that improved rice variety adoption in Ghana had positive impact on farmers' rice yields and estimated 46% level of modern rice variety adoption in this country. Nevertheless, the introduction of improved rice varieties in Ghana did not achieve its intended purpose of creating employment because the innovations were disseminated to existing rice farmers (Ministry of Food and Agriculture, MoFA, 2010). The innovations also did not diffuse among rice farmers as expected because most of the farmers who adopted those innovations were those who participated in the dissemination projects. The adoption rates of improved rice varieties in Ghana have therefore been continuously low due to incomplete adoption and diffusion of agricultural innovations (Lamptey, 2018).

Low adoption levels of agricultural innovations among farmers in Ghana has contributed to reduced agricultural production levels in the country (Akudugu, Guo, and Dadzie, 2012). Interventions aimed at minimizing food insecurity and poverty but increasing incomes by improving farm-level performances have not yielded the needed results (Lamptey, 2018; Norton, 2004). Yet, improved rice variety adoption is supposed to raise rice production and income levels of potential adopters. There is therefore the necessity to understand the peculiar modes of improved rice variety adoption in Ghana.

As Oster and Thorton (2009) highlighted, understanding the process of innovation adoption in developing countries can help to: (i) predict adoption patterns; (ii) support adopters to maintain their adoption decisions inspite of the relatively higher levels of disadoption; and (iii) know the most favourable ways of promoting innovations. This is because many agricultural innovations suffer disadoption partly due to poor sustainability and incompatibility of the innovations in the social system.

Lamptey (2018) observed that rice farmers in the Tolon and Kumbungu Districts in the Northern Region of Ghana were no longer cultivating an improved rice variety called NERICA because they claimed "NERICA time had passed." So, they had moved on to adopt other improved varieties of rice. This phenomenon is known in adoption literature as disadoption or discontinuous adoption of agricultural innovations (Rogers, 2003). A key informant at SARI confirmed Lamptey's (2018) findings on NERICA disadoption and added that there was little or no adoption of NERICA in the other regions of Ghana. Since so much resources were invested in the promotion of improved rice varieties in the Northern Ghana, reasons for farmers' disadoption decisions need to be investigated. That would help to send appropriate feedback to the government of Ghana, researchers and donour agencies about the fate of similar projects in the near future.

1.2 Problem statement

Adoption of innovations has been studied extensively (Azumah, 2019; Bruce, Donkoh and Ayamga, 2014; Wiredu et al. 2014), but none of them focused on the disadoption of of improved rice varieties in the Northern Region of Ghana, which is equally an important subject. Similarly, Odeniyi et al. (2018) researched into the disadoption of improved rice varieties in Nigeria and found that there was no prior research to find out why Nigerian native farmers disadopted modern rice varieties. Though a few disadoption studies (Odeniyi et al., 2018; Kasirye, 2013; Kijima, Otsuka, and Sserunkuuma, 2011; Oster and Thorton, 2009), have been conducted recently, researchers have not focused much attention on studying disadoption as a general subject so as to formulate a unified "theory" of disadoption (Donald and Parker, 2012).

Again, most of these researchers studied adoption or disadoption of gricultural technologies separately. None of them combined adoption and disadoption of agricultural innovations, parcularly modern and traditional rice varieties among farmers in the Northern Region. Looking at adoption and disadoption in a single study would add impetus to the strengths of adoption research. This study therefore intends to make progress in that direction and look at the adoption and disadoption of improved rice varieties in the Northern Region of Ghana.

Besides, most studies investigate the impact of adoption of improved rice production technologies when the dissemination projects are still ongoing or immediately the projects end (Obayelu et al., 2016; Wiredu et al., 2014; 2010; Kijima et al., 2011). This study, however, sought to examine the determinants of improved rice variety adoption and its effect on rice output among farm households in the Northern Region of Ghana, by considering rice projects which have ended for over five years. The outcomes of this study would give policy directions to policymakers, along the rice value chain, to enhance rice productivity and incomes.

1.3 Research questions

The main research question to be answered by the study is, what factors influence the adoption and disadoption of improved rice varieties among farmers in the Northern Region of Ghana?

The specific research questions are as follows:

1. What are the main innovation communication channels and methods used to educate farmers on improved rice varieties in the Northern Region of Ghana?
2. What are the levels of adoption and disadoption of the main rice varieties in the Northern Region from 2009 to 2019 cropping seasons?
3. What are the reasons, processes and types of improved rice varity adoption and disadoption in the Northern Region?
4. What are the factors affecting initial adoption, current adoption and disadoption of improved rice varieties in the Northern Region?
5. What is the effect of improved rice variety adoption on rice output among farm households in the Northern Region?

1.4 Research objectives

The principal objective of the study was to investigate the factors influencing the adoption and disadoption of the improved rice varieties among farmers in the Northern Region of Ghana. Specifically, the study sought to:

1. Identify the main innovation communication channels and methods used to educate farmers on improved rice varieties in the Northern Region of Ghana.

2. Identify the levels of adoption and disadoption of the main rice varieties in the Northern Region from 2009 to 2019 cropping seasons.
3. Analyze the reasons, processes and types of improved rice varity adoption and disadoption among farmers in the Northern Region.
4. Analyze the factors affecting initial adoption, current adoption and disadoption of improved rice varieties in the Northern Region.
5. Evaluate the effect of improved rice variety adoption on rice output among farm households in the Northern Region of Ghana.

1.5 Justification of the study

This study is a follow-up to previous adoption studies. It seeks to bridge a unique adoption gap in the adoption literature. The reason being that many researchers do not venture into the disadoption aspects of agricultural innovations. This work is therefore novel in terms of combining adoption and disadoption behaviours of rice farmers. If the farmers discontinue the adoption (disadopted) of some improved rice varieties despite their unique characteristics but continue the adoption of other improved rice varieties, then the latter are superior. Those with superior qualities, from the farmers' perspective, rather than what researchers think, would be made known to the government of Ghana, donors, researchers and other stakeholders such as NGOs and FOBs in the rice value chain. That would go a long way to help the researchers breed preferable improved rice varieties for farmers. It would also help the government to formulate and implement appropriate policies for the breeding, disseminations, adoption, marketing and consumption of those varieties. Donor agencies and other stakeholders in the rice value chain would then see the relevant and appropriate ways to partner the government, through MoFA, to promote the breeding, disseminations, adoption, marketing and consumption of those improved rice varieties in Ghana. These reasons make the determination of the adoption and disadoption levels of the main rice varieties in the the Northern Region worthwhile.

Knowing the main innovation communication channels and methods used to educate farmers on improved rice varieties in the Northern Region of Ghana would also help MoFA, NGOs and FOBs to adopt such chnnels and methods when promoting improved rice varieties in future. Knowing the factors affecting adoption and disadoption of improved rice varieties in the Northern Region would as well help send appropriate feedback to researchers and policy makers on the best possible ways to generate, disseminate and sustain the adoption of improved rice varieties. Understanding the effect of improved rice variety adoption on rice output among the farm households would likewise help rice farmers to intensify and maintain their adoption decisions, maximizing rice output and improve farmer-welfare in the region. These would in turn help to salvage the low adoption and high disadoption rates of improved rice varieties in the region.

1.6 Significance of the study

In spite of the significant role of adopting improved rice varieties in enhancing production outcomes and ensuring food security in Ghana, many rice producers in the Northern Region have disadopted some of these improved rice varieties for reasons best known to them (Lamptey, 2018). Although FARO 15-21, GR 18-20, DIGANG and other improved rice varieties have been promoted among smallholder rice farmers in Ghana about three decades ago, many farmers are still aware and adopting these old improved rice varieties but are disadopting newly improved rice varieties like JASMINE 85, NERICA and AGRA, which were introduced to them about a decade ago (Lamptey, 2018; APS, 2015; Ragasa et al., 2013). Some farmers even cultivate MANDII (MENDEE), which was introduced in the early 1970s. The reasons for the continuous adoption of some improved rice varieties and the disadoption of the other improved rice varieties are worth investigating from the farmers' point of view.

While improved rice variety adoption can increase farmers' output, income and welfare, disadoption can thwart governments' development efforts in farming communities. The reasons for disadoption of some rice varieties can guide researchers to come out with appropriate varieties that would stand the test of time and not be disadopted by farmers shortly after adoption. The reasons can also guide agricultural extension agents and other promoters of improved rice varieties to employ the most effective innovation communication methods to disseminate the varieties to farmers. The reasons would as well inform government and other stakeholders in the rice value chain to devise pragmatic measures to sustain adoption and limit disadoption of improved rice varieties. It would likewise inform donor agencies to channel their resources into sustainable and profitable agricultural innovations in Ghana. Also, disadoption studies of this kind can help in predicting rice varieties that are likely to be adopted by farmers for a very long time.

1.7 Scope of the study

This study is limited to the Northern Region of Ghana where the improved rice varieties have been largely introduced. A sample survey was conducted to elicit responses from smallholder rice farmers in the study area who cultivated improved rice varieties from 2009 to date. The survey was supported by focus group discussions with farmers as well as key informant interviviews with researchers at the Savannah Agricultural Research Institute (SARI) and Agricultural Extension Agents (AEAs) of the Ministry of Food and Agriculture (MoFA). That helped to determine the main rice varieties that were adopted initially, currently or disadopted by the farmers.

1.8 Delimitations of the study

Time, material and financial constraints have limited the scope of this research to only the Northern Region of Ghana where improved rice varieties have been largely promoted, adopted and disadopted instead of the whole country or outside. The time frame for farmers' recall was limited to the past ten years. The researcher would have liked to look beyond the last ten years but the fear was that farmers would not be able to do proper recall of their adoption or disadoption behaviours. The researcher would have likewise liked to look at the adoption and disadoption of complementary agricultural technologies such as recommeneded agronomic practices, but that would have broadened the scope of this study beyond its focus. Besides, several researchers including Donkoh (2020), Azumah (2019), Ehiakpor et al. (2019), Donkoh, Azumah and Awuni (2019), Donkor et al. (2016), Langyintuo and Dogbe (2005), and Asante et al. (2004), have extensively studied the adoption of those technologies in the region.

This study therefore focused on the adoption and disadoption of the main rice varieties, and the effect of adoption on rice output in the Northern Region of Ghana.

1.9 Organization of the study

This thesis comprises of seven chapters. The first chapter contains the background of the study. It is where the research problem, research questions to be answered, the research objectives, and justification and significance of the study are stated. Chapter two discusses and provides information on the rice production, consumption and constraints patterns in Ghana. The third chapter gives a review of literature relevant to the study and the research gap identified. The fourth chapter presents the theoretical, conceptual, and empirical frameworks of the study. The fifth chapter elaborates the methodology adopted for the study and how it was used, as well as the basic information on the study area relevant to the study. The sixth chapter contains details of the main findings and discussions of the research. A summary of the findings and conclusions drawn from the study vis-a-vis the author's contribution to the body of literature and recommendations made for further study are presented in chapter seven.

CHAPTER TWO

RICE PRODUCTION, CONSUMPTION AND CONSTRAINTS IN GHANA

2.0 Introduction

This chapter presents the nature of rice production, consumption and constraints in Ghana. It is divided into eight different sections. The first section discusses and provides information on the rice production and consumption patterns in Ghana. The second section looks at the rice production regions in Ghana. The third section considers the improved rice varieties in Ghana while section four discusses the unique characteristics of those improved rice varieties. The fifth section highlights recommended agronomic practices for rice farmers in Ghana. Section six discusses the challenges to commercial rice production in Ghana whereas the next section looks at constraints to availability of improved rice seeds in Ghana. The chapter ends with a conclusion on the nature of rice production, consumption and constraints in this country.

2.1 Rice production and consumption patterns in Ghana

This section discusses and provides information on the rice production and consumption patterns in Ghana. Rice is next to maize among the most important edible cereal and grain crops in Ghana (MoFA-SRID, 2018). Rice is rich in carbohydrate and provides 9% of total caloric food intake (Food and Agricultural Organization, FAO, 2016). Rice cultivation worldwide takes place in six main ecosystems comprising rain-fed, irrigated, upland, lowland, deepwater and tidal wetlands, but the first four ecosystems are the most popular in Ghana.

Rice consumption in Ghana is on the ascendancy due to rapid urbanization but the country is self-insufficient in rice production. Rice importation exceeds local production in Ghana (MoFA-SRID, 2018). Ghana used to be self-sufficient (but not secured) in rice production between 1974 and 1975 (Seini, 2002), due to government intervention in the rice sector in 1972 that provided incentives and impetus for farmers to boost local rice production.

However, all incentives and subsidies for agricultural inputs, notably fertilizers and insecticides were removed during the Structural Adjustment Programme (SAP) in the 1980s. That led to a 40% increase in the prices of most agricultural inputs such as herbicides used in rice production from 1986 to 1992 (Asuming-Brempong, 1998). The government's trade liberalization agenda at the time had a dire consequence on the local rice sector. Rice production in this country started to decline in the absence of subsidies to support the sector. Imported rice then flooded the rice market in Ghana, during the trade liberalization. Rice production in Ghana began to increase significantly from year 2000, making the local rice sector to compete favourably with imported rice (Azumah, 2019). The total land area used for rice production in Ghana increased from 123, 000 hectares in 2002 to about 189, 000 hectares in 2012 (MoFA, 2013). The mean yield per hectare was 2.5, which was less than the expected yield of 6.5 MT/Ha, resulting in a yield deficit of 4.0 MT/Ha per annum. Until 2008, the sum of paddy rice produced in this country was less than 300, 000 (MoFA, 2013).

Demand for rice in Ghana far exceeds production. Hence the consumption deficit is catered for by rice imports with hard currency. We end up spending much money on imported rice than local rice in this country**.** Rice imports into Ghana ranged from 384,000MT in 2009 to 414,000MT in 2014 (MoFA-SRID, 2016). The rice consumption rate has since been on the ascendency (APS, 2015). There had therefore been over 20 rice development projects in Ghana, including the multinational NERICA Rice Dissemination Project (NRDP), between 2001 and 2014, aimed at revamping the local rice sub sector and enhancing adoption of improved rice varieties (Ragasa et al., 2013; MoFA, 2010). There were also about ten national and agricultural development plans and strategies from 2001 to 2014, with rice as one of the food security crops targeted. They comprised the Ghana Poverty Reduction Strategy (GPRS 1), and Growth and Poverty Reduction Strategy (GPRS 2). The rest were Food and Agricultural Sector Development Policy (FASDEP) 1 and 2, Medium Term Agriculture Sector Investment Plan (METASIP), and Accelerated Agricultural Growth and Development Strategy (AAGDS), (Ragasa et al., 2013).

The introduction of improved rice varieties such as NERICA, JASMINE, AFIFE, and AGRA among others, from 2009 to date, boosted rice production in Ghana (APS, 2015; Bruce, Donkoh, and Ayamga, 2014). Favourable rainfall patterns, and government interventions in the rice sub-sector might have also accounted for the increase in the national rice output. Otherwise, the expansion in rice cultivation was influenced by the expansion in area under production (Ragasa et al., 2013). Jasmine appears to be the most popular variety because of its nice taste and aroma. Other vital characteristics farmers looked out for in adopting rice varieties included plant height, threshing ability, pest and disease resistance, and ability to outgrow and smother weeds in a particular location.

The majority of consumers prefer imported rice to rice produced locally since the imported rice appear nicer, cook better and easy to consume. Interestingly, most consumers perceive the various grain quality charateristics of traditional rice varieties to be generally lower as opposed to the ways farmers perceive them. However, both farmers and consumers share a common view when considering the quality attributes of rice varieties of their choice. Most rice consumers and farmers have preference for soft, fluffy and long grain aromatic rice. There is therefore the need for rice breeders in Ghana and across the West African sub-region to consider breeding of improved grain quality rice that are high yielding and tolerant to bio-physical stresses.

Like other crops in Ghana, rice is mainly produced by smallholder farmers whose farms sizes are not more than one hectare. About 80% of the rice produced in Ghana is therefore by small scale farmers, mostly on farmlands that do not exceed one hectare in size (Angelucci, Asante-Poku, and Anaadumba, 2013). Past projects and government interventions such as the Millenium Development Authority (MiDA) Commercial Development of Farmer Based Organisations were not successful in commercializing the rice sector of Ghana.

Increase in farm sizes and rice yields are usually attributed to Governmental and donour interventions. Average rice yields in Ghana are about 2.75 MT/ha compared to potential yields of about 4.0 to 8.0 MT/ha (MOFA, 2014). Rwanda and Cote D'Ivoire have the highest rice yields in SSA (above 5 MT/ha) each of which doubles the yields in Ghana. Blast and rust are the main diseases associated with rice production in Ghana (MoFA, 2014). Currently, about 84% of rice farmers in Ghana depend on rainfall to produce between 1.0 to 2.4 MT/Ha of paddy rice annually while the remaining 16% irrigate their farms to produce higher average paddy rice yields of about 4.5 MT/ha (CARD, 2010, MoFA-SRID, 2016). Paddy rice production in Ghana has increased by 160% between 2007 and 2012 with a corresponding yield increase of about 59%, due to governmental interventions (MoFA, 2013). There has also been a phenomenal improvement in the finishing and the quality of the local rice produced over the years. However, only about 20% of rice produced in this country is consumed by the urban dwellers due to their inclination towards long grain aromatic rice also known as perfume rice (Danso-Abeam, Armed, and Baidoo, 2014). The most commonly planted improved rice variety in the 2012 major cropping season in Ghana was Jasmine 85, (27% of rice area) followed by Mandii (19% of rice area), Togo Marshall (11% of rice area), and Jet 3 rice (4% of rice area) (Ragasa et al., 2013).

The government's flagship programme, "Planting for Food and Jobs", has also led to a slight increase in the national averages from 2.64MT/Ha in 2013 to about 3MT/Ha in 2017 (MoFA-SRID, 2018). It presupposes that improved rice variety adoption may increase farmers' output (Angelucci et al., 2013). Nevertheless, improved rice variety adoption alone without the corresponding technologies and the associated inputs such as fertilizers cannot result in the needed output in rice for this country. Although the government has subsidized fertilizers prices for farmers since 2008, their effects on improved rice variety adoption remain little, due to the absence of an effective scheme to monitor and evaluate subsidy programmes (MoFA-PFJ, 2017). This means that subsidies and incentives in themselves cannot salvage the low levels of output in rice production and subsequent disadoption of improved rice varieties in Ghana. A comprehensive approach to providing certified seeds and other inputs, quality extension services and marketing channels, as well as adoption of modern agricultural technologies such as e-agriculture can help remedy the situation.

2.2 Rice production regions in Ghana.

Rice is produced in all the sixteen regions cross the main agro-ecological zones in Ghana. The zones are suitable for the cultivation of upland and lowland rice. They include the interior savannah, the high rain forest, the semi-deciduous rain forest and the coastal savannah zones (Bruce, Donkoh, and Ayamga, 2014). There are five distinct rice ecosystems in each agro-ecological zone in Ghana, comprising rain fed dry lands, rain fed lowlands or hydromorphic, inland swamps, valley bottoms and irrigated paddies. According to Oteng (2000), the rain fed dry lands and lowlands account for about 69% of the production area while the irrigated fields constitute 16% and the inland swamps together with the valley bottoms constitue the remaining 15%.

Rice is the fourth major crop produced in Northern Ghana, which is cultivated by about 279,000 farmers (APS, 2015). Northern Ghana is better placed in terms of rice production and has about 70 percent of the total land mass for rice cultivation in Ghana. The Northern and Upper East regions dominate the rice production regions in this country, followed by the Volta Region (MoFA-SRID, 2016). Proportionally, 37% of rice produced in Ghana is from the Northern Region. The Upper East and Volta regions respectively produce 27% and 15% of Ghana’s rice (Ragasa et al., 2013).

The average rice yield from the three main rice producing regions of this country stands at 2.96 MT/Ha. This figure is higher than the national mean yield of 2.5 MT/Ha yet essentially lower than the Greater Accra regional mean yield of 5.48 MT/Ha. The greatest production volumes of rice ranging from 150,000 MT to 200,000 MT come from the Northern and Volta Regions. The Northern Region records an average rice yield of 2.12 MT/ha annually relative to the national annual average yields of 2.65 MT/ha and 4.41 MT/ha in Volta region (AGRA-SSTP, 2016). This could be as a result of the lesser use of certified seeds together with high levels of soil infertility in the North. The performance in the Volta Region is attributed to better technical support, effective mechanization services and high levels of certified seed usage among farmers in the out-grower production schemes. Only 16% of rice produced in this country is from irrigated farmers (Nedelcovych, 2012). Most rice produced in Ghana are not well sorted and packaged due to lack of expertise in that regard. Many farmers also rely on poor quality seeds that are not always true to type, with different maturity at harvest dates. That posses a challenge to the harvesting, milling and processing of rice for the Ghanaian market (FAO, 2016).

2.3 Improved rice varieties in Ghana

Rice is the second most produced commercial seed in Ghana, after maize, and there are over 20 improved rice varieties released in Ghana, since 1970 (AGRA-SSTP, 2016; Ragasa et al., 2013). The most popular varieties among them are Agra Rice, Gbewaa or Jasmine 85, Nerica, Digang (Abirikukuo or Aberikukugo), Katanga (Tox 3972), Nabogo (Tox 3233), Bodia (ITA 320), Sakai (ITA 324), Faro 15-20, GR 18-21 and Afife (Togo Marshall). Mandii (Mendee) was initially introduced in Sierra Leone and later promoted in Ghana by MoFA in the early 1970s, and is still being cultivated by some Ghanaian farmers. A total of 578 MT of certified rice seeds produced and distributed in Ghana in 2016, of which AGRA Rice constituted about 74% (478 MT). Until then, certified seed production in Ghana had been dominated by Jasmine 85, GR 18, and Tox 3107. These three varieties constituted 91 percent of certified seed produced in this country at the time (Ragasa et al., 2013).

AGRA Rice is resistant to rust and lodging, which makes it gain much acceptance in the farming communities. It is a long grain, aromatic rice with good milling yields. Certified rice seeds are normally produced and sold by accredited farmers and dealers. Certified rice seeds become scarce when government interventions in their production and distribution come to an end. Government initiatives like Block Farms, Rice Sector, Inland Valley and Nerica Rice Projects have helped a great deal with certified seeds production and availability in Ghana (AGRA-SSTP, 2016). Farmers who obtain certified rice seeds are expected to use and reproduce the seeds for about four years or more but this objective has not been well achieved due to seed contamination. In effect, some farmers resort to the cultivation of traditional or local rice varieties instead of contacting researchers or certified seed dealers for new improved seeds, as a result of the perceived high cost of certified seeds. The reason is that in spite of these improved rice varieties, indeginous varieties still abound in Ghana, especially the Northern Region

(Ragasa et al., 2013). The indeginous rice varieties therefore serve as alternatives to the improved varieties.

2.4 Unique Characteristics of improved rice varieties in Ghana

This study focuses on ten improved rice varieties namely Mandii, Faro 15-20, GR 18-21, Digang, Jasmine 85, Nerica and Agra Rice as well as Tox (3233 and 3972), Sakai and Afife. Mandii has low-input requirements, can withstand prolonged flooding, and can compete very well with weeds (Ragasa et al., 2013).

Faro 15-20 was released in 1980. It matures in 145-150 days, approximately 5 months and it yields 5.0 tonnes per hectare. It is good for food and it is not aromatic, has long and bold grains with a milling rate of 65%. It has high resistance to pest and diseases. It does well in deep lowland areas. "GR 18-21" was promoted in 1983. It matures between 125 and 132 days (approximately 4 months). It yields 6.5 tonnes per hectare and it is good for food. It resists pests and diseases infestation. It is not aromatic and has medium and bold grains with a milling rate of 65%. It does well in lowland and irrigated fields (AGRA-SSTP, 2016).

Digang was introduced to rice farmers in 2003. It matures in 115 days and yields 4.8 tonnes per hectare. It is a long, slender grain nonaromatic rice with a milling rate of 65%, suitable for food. It has good resistance to pest and diseases infestations. It grows well in different rice ecologies, especially hydromorphic and lowland areas. Jasmine 85 (Gbewaa/Lapez/Saa Rice 2) became available for cultivation in 2009. Before then, some farmers had access to it and cultivated it in different parts of the country (Ragasa et al.

2013). It matures in 110-115 days, yields 5-6 tonnes per hectare and has long and slender grain, nice aroma, good ability to resist pests and diseases. It has a milling rate of 62%. It is a lowland and irrigated rice (AGRA-SSTP, 2016). An incomplete strain of Jasmine 85 on trial became known as Salma-Saa in the Northern Region and it is considered as a local rice among farmers (MoFA, 2020).

Tox 3233 was released in 2009, it matures in 120-130 days and yields 6-7 tonnes per hectare. It has long slender grains and it is nonaromatic, good for food, resistance to pest and diseases. It is lowland and irrigated rice, which has a milling rate of 60%. Tox 3972 was also promoted in 2009, it matures in 130-140 days and yields 6-8 tonnes per hectare. It has long slender grains, resistance to pest and disease infestations. It is a nonaromatic, deep lowland rice variety with a milling rate of 62%, which is good for food (AGRA-SSTP, 2016).

Nerica was released in 2009 and it has a maturity period of 90-100 days. It yields 3-4 tonnes per hectare and it is drought tolerant. It is an upland rice that produces average grain size, nice aroma with high levels of amylose (AGRA-SSTP, 2016). Nerica has the combined effect of the high yielding characteristics of *Oryza sativa* rice species and the resistant ability of the indigenous *Oryza glaberrima* to withsatand various bio-physical stresses of the African ecological system (Somado, Guei, and Keya, 2008). It also has the ability to produce acceptable yields with low input use situations prevalent in upland rice farming on the Africa continent (Spencer et al., 2006).

Sakai is a white rice variety released in 2010 with a maturity period of 135-140 days, which yields 8.0 tonnes per hectare. It produces long and slender grains with a milling yield of 66% (less grain breakage). It is a lowland rice variety resistant to lodging, blast, which is suitable for food. It has no aroma but good taste and is sticky after cooking (Ragasa et al., 2013; AGRA-SSTP, 2016). AGRA rice on the other hand was released in the year 2013 and it is suitable for the forest, guinea savanna, and coastal savanna zones of this country. Its grain is white in colour and good for food. The plant is resistant to blast, iron toxicity and lodging (AGRA-SSTP, 2016).

There are four known varieties of AGRA rice, developed from local crosses of the Crops Research Institute (CRI) in Ghana and funded by African Agriculture (AGRA). The locally-developed varies are AGRA-CRI-LOL-2-27, CRI-1-11-15-5, AGRA-CRI-LOL-1-7, and CRI-1-11-15-21. All the four varieties are good for lowland and irrigated rice cultivation fields or ecologies. They have higher yields, and tolerance for Rice Yellow Mottle Virus Disease and Iron toxicity. They are also easy to cook and have nice aroma preferable to most farmers and consumers (MoFA, 2020).

AGRA-CRI-LOL-2-27 matures in 120-125 days and is capable of yielding 9.0 MT/ha. CRI-1-11-15-5 matures in 125-130 days and can yield 8.0 MT/ha. AGRA-CRI-LOL-1-7 matures in 115-120 days with a yielding potential of 8.0 MT/ha. CRI-1-11-15-21 has a maturity period of 125-130 days and can yield 9.5 MT/ha. Thus, the AGRA rice varieties mature between 115 and 130 days (4 months) and can produce between 8.0-9.5 MT/ha.

Farmers are not familiar with all these technical names and differences between the Agra rice varieties. So, all Agra rice varieties would simply be referred to as Agra in this study. An Agra rice variety therefore has an average maturity date of 125 days and a yielding ability of 8.5 MT/ha, similar to Nerica (https://agra.org). Afife (Togo Marshall) is an aromatic variety from Togo, which was breeded by the University of Ghana, Legon and released by MOFA in 2010. It yields 6–8 tonnes/ha and matures in 115–120 days. It is tolerant to blast, very aromatic, has long grains, better milling recovery with a low percentage of broken grains (Ragasa et al., 2013).

Nerica appears to be outstanding among all other improved rice varieties because of the way it has been praised on the African continent, due to its early maturity. However, Jasmine yields higher than Nerica and Agra is specifically known for its resistance to blast, iron toxicity and lodging. Although Faro 15-20, GR 18-21 and Digang have been in existence about three decades ago, they are still being cultivated by rice farmers. They appear to have stood the test of time in spite of the fact that they have longer maturity dates, especially Faro 15-20, which matures in 5 months. They may have adapted to the agro-climatic requirements of the farmers as well as met the tastes and preferences of consumers. The unique characteristics of these improved rice varieties that have made them survivedisadoption are worth investigating.

2.5. Recommended agronomic practices in Ghana

The recommended agronomic practices for rice farmers in Ghana include land preparation and weed control, seed priming, row planting and planting density, fertilizer application, sawah system, and roguing, among others.

2.5.1 Land Preparation and Weed Control: It is recommended that the farmers *plough their land twice* before sowing or planting rice. The first is the actual ploughing while the second is harrowing but the farmers consider both of them as ploughing (MoFA, 2020), which are recommended land preparation methods in rice farming. Another land preparation method is Zero tillage with herbicide, which helps to conserve soil moisture and improve soil fertility as well as suppress weeds. The use of herbicide is a recommended land preparation method that is a substitute to weeding, before and after planting. Farmers are advised to apply pre-emergence herbicide 2 or 3 days after sowing, and apply postemergence herbicide 21 to 25 days following planting.

2.5.2 Seed Priming: This is the act of soaking seeds for 12 to 24 hours in clean water and allowing them to dry for 24 to 48 hours prior to planting. Ragasa et al. (2013), reported that primed seeds yield 25 to 40% higher than non-primed seeds. A study by Bam, Kumaga, Ofori, and Asiedu (2006), showed that soaking or priming of rice seeds with water containing a small amount of potassium and phosphorus facilitates seed germination, increases rates of seedlings emergence, and results in faster seedlings growth than primed seeds without fertilizer. When seeds are treated with chemicals during storage and before planting, it protects them from insects and diseases infestations (MoFA-SRID, 2016).

2.5.3 Row Planting and Planting Density: Planting rice plots in rows or lines is one of the recommended practices in rice farming. The recommended crop density for transplanted plots is 35 to 45 kg/ha, with a planting distance of 20 cm x 20 cm and two plants per stand (Ragasa et al, 2013). It could also be 20 x 25 cm as recommended by SARI. Transplanting is expected to be done 21 to 28 days following seeding. The prescribed planting density for direct seeding is 45kg/ha in the case of dibbling or drilling, and 100 kg/ha for broadcasting. Adequate soil moisture is a prerequisite for transplanting to ensure a more reliable plant stand. Dibbling, drilling, or row planting is preferred to broadcasting in the north of Ghana (Ragasa et al, 2013).

2.5.4. Fertilizer Application: The minimum rate of fertilizer application is twice per cropping season. There are two separate applications. The first one is called basal application, whereby a compound fertilizer is used and the second one is called top dressing, which involves the use of sulfate of ammonia or urea. It is advisable that between 200 to 400 kg/ha of NPK 15-1515 be used for the initial application and 150 kg/ha of sulfate of ammonia or 95 kg/ha of urea be used for the second application, based on farming history of the land. The basal application is normally done a week after transplanting of seedlings but two to three weeks following direct sowing. The top dressing is expected to done five or six weeks following planting. However, it is advisable for farmers in the north of Ghana to do top dressing seven to eight weeks after planting (Ragasa et al., 2013), due to the perculiar environmental conditions in the north.

2.5.5 Sawah System: This is an innovative practice adopted for lowland fields and it involves bunding, puddling, and leveling to achieve better soil water control and effective nutrient management (Ragasa et al., 2013). Rice production in the sawah system has given rise to massive enhancement in soil and water management in inland valleys. Buri, Issaka, Wakatsuki, and Kawano (2012) show appreciable increase in rice output for farmers who shift from adopting only bunding, to using bunding and puddling, to practicing bunding, puddling and leveling (sawah), in different locations and with different rice varieties (Buri et al., 2012).

2.3.6 Roguing**:** Is the method of identifying and removing unwanted plants by the hand from rice fields. The unwanted rice plants and other weeds are removed from the rice farms to maintain the quality or genetic purity of the rice varieties under cultivation (MoFA, 2020). Roguing is another term for hand picking of weeds in crop and marine farming.

2.6 Challenges to commercial rice production in Ghana

The production of rice in Ghana is dominated by small scale farmers who use low farm inputs and technologies. Inadequate access to rice markets, poor roadnetwroks and market infrastructure, issues with land tenure system, effects of climate change, risk aversion and low levels of innovation adoption are some of the major hinderances to successful commercial production of rice in Ghana (National Rice Development Strategy, NRDS, 2009). About 50% of smallholder rice farmers in Ghana are potential commercial rice producers (NRDS, 2009) but unavailability of improved rice seeds is a challenge to large scale rice production in Ghana. As such, most small scale rice farmers use hybridized seeds for cultivation, with minimal amounts agrochemicals like fertilisers and herbicicdes. Inneffective promotion of newly improved rice varieties, lack of awareness of their complementary agronomic practices, lack of credit for seeds and the other farm inputs and lack of ready markets for paddy rice hinder the adoption of new varieties. These varieties have higher demands and better yields with corresponding incomes among farmers. Farmers also use poor methods to process their rice, leading to the production of brittle grains that require extensive par boiling to reduce their rates of brokenness. This decreases the value and price for processed rice of Ghana made rice.

Rice production in Ghana is laborious, following the recommended agronomic practices such as nursing, transplanting, fertilizer and chemical application in the absence of mechanization. Ghanaian farmers depend more on unkilled labour than mechanization. The use of unskilled labour is more prevalent in Ghana than in other countries. Cheap labour is provided by the poor and vulnerable, especially women. Peasant farmers mainly use family and communal labour for their rice farming. Commercial farmers depend on hired labour for their farm operations including irrigation. The poor and vulnerable derive income from offering their services to rice farmers (Directorate of Agricultural Intensification, DAI, 2015).

2.7 Constraints to availability of improved rice seeds in Ghana

Challenges of availability to improved rice seed in Ghana include: supply bottlenecks for foundation seeds; limited ability of private sector; demand constraints limiting market presence; ineffective systems of distributing rice seeds; unwidened scope of rice seeds availability; low awareness levels of improved varieties and a case for business investment (AGRA-SSTP, 2016). Ragasa et al., (2013) reported few modern rice varieties in the region that were unpreferred by consumers. The reason being that most consumers prefer *polished rice* from abroad to Ghana made rice (Bruce, Donkoh, and Ayamga, 2014).

2.7.1 Supply Bottlenecks for Foundation Seeds: SARI was responsible for rice Foundation Seed production together with its breeding work in 2014. Limited production facilities at SARI coupled with lack of seed conditioning vis-a-vis storage facilities exerted normous strain on the institution, which saddled her breeding agenda (DAI, 2015).

2.7.2 Limited Ability of Private Sector: Technological problems in rice seeds production together with limited storage facilities for harvested seeds result in seed contamination, adulteration and rejection. Sometimes only 25% of rice seeds presented for asssessment at the Ghana Seed Inspection Division (GSID) in Northern Ghana meet the required specifications for certified seeds.

2.7.3 Demand Constraints Limiting Market Presence: Only a few agricultural input dealers have adequate storage facilities for certified rice seeds. That limits the number of of certified seeds dealers in Ghana. The small numbers of certified seeds dealers available in this country imply that they would not be able able to undertake their retail mandates as expected of them. Such dealers are also mostly far from the farming communities, making it difficult and expensive in terms of transportation for farmers who buy certified seeds for cultivation.

2.7.4 Ineffective Systems of Distribution: Rice Early Generation Seed (EGS) production is mainly done in Northern Ghana but rice is produced throughout the country. The systems of handling and distributing EGS are inefficient and ineffective. The use of public transport to convey certified seeds undermines product quality and increases costs of delivery.

2.7.5 Unwidened Scope of Seeds Availability: The production and delivery of certified rice seeds are mostly done by rice seed generation and dissemination projects. Unavailability of open market for certified seeds make it difficult for farmers to obtain good quality rice seeds at their doorsteps.

2.7.6 Low Awareness Levels of Improved Varieties and A Case for Business Investment: Awareness of improved rice varieties are mostly created by national and donour funded projects in conjunction with MoFA, and they are normally limited to selected communities (MoFA-PFJ, 2017; Lamptey, 2018). Little private sector participation in the promotion of improved rice varieties implies that the income derived from the public/private promotion efforts are confined to the domains of the actors. The majority of farmers remain unaware and are not bothered about the potential benefits of using improved seeds (AGRA-SSTP, 2016). It is therefore incumbent on the business community to take advantage of the private-public sector partnerships to invest in the promotion of certified seeds in Ghana.

2.8 Conclusions on rice the production, consumption and constraints in Ghana

Though rice production and consumption in this country dates back to the colonial era, the consumption far outweighs production. Though local rice production in Ghana has increased over the years, most Ghanaians, especially urban dwellers prefer aromatic, long-grain and imported rice to locally produced rice in this country. Rice importation in this country has therefore been on the rise over the years, except during the operation feed yourself era in the mid-1970s, when we became self-sufficient (but not secured) in rice production. We need a comprehensive approach to rice production, marketing and consumption, as well as adoption of modern agricultural technologies such as e-agriculture in this country to help make us self-sufficient in rice production and consumption.

All the sixteen regions in Ghana, especially the Volta, Ashanti, and the Northern Regions, are noted for rice production due to the presence of vase arable land. There are over twenty improved rice varieties in Ghana currently, all of which are suitable to the agro-ecological growth conditions of this country. However, not all the varieties are suitable to the same geographical locations and soil conditions, due to differences in the ecological and climatic conditions across the country.

Farmers who adher to recommended agronomic practices enhance their rice productivity. The constraints to commercial and improved rice production in Ghana can be overcomed when all the stakeholders in the rice value chain adopt a compressive approach with a determination to ensuring maximum promotion, production and consumption of Ghana made rice.

CHAPTER THREE

REVIEW OF LITERATURE

3.0 Introduction

This chapter provides a review of the literature relevant to the study. The working definitions of some key terminologies on innovation adoption and disadoption used in the study are first presented. The second section broadly discusses adoption and disadoption of agricultural innovations. It delves into the types, causes and effects of agricultural innovation adoption and disadoption. The third section presents the constraints and disadoption of improved rice varieties in Africa, while the agricultural innovation communication channels and methods in Ghana are considered in section four. The fifth section then considers the factors that affect adoption and disadoption of agricultural innovations, followed by the determinants of rice yields and output.

3.1 Working definitions of terminologies

Terminologies defined in this section include innovation, innovation characteristics, innovation diffusion, society, time, adoption, categories of respondents, adoption rates, agricultural extension and advisory services, and communication channels.

3.1.1 Innovation

Innovation is the principle, practice or an object that is considered as new by a person or a group of persons who adopt(s) it. Innovations that people consider to have greater relative advantage, compatibility, observability, trialability and less complexity (with the possibility of re-invention) stand the chance of being adopted faster than other innovations (Rogers, 2003). For Rogers (2005), an innovation might have been churned out for a while, but if people consider it as new, then it might still be a novel invention for them. The novel nature of an adoption is often related to three levels of knowledge acquisition, persuasion about the innovation, and decision making concerning the innovation.

An obvious hinderance to the adoption of innovations is uncertainty. The consequences of an innovation may create uncertainty in the minds of potential adopters. The term *Consequences* are the changes that take place in people or society due to the acceptance or rejection of an innovation (Rogers, 2003; Braak, 2001). People need to know about the merits and demerits of innovations to become aware of all the consequences of adopting or not adopting them. That would help to reduce the uncertainty associated with adopting those innovations. According to Rogers (2003), consequences can be categorized into desirable and undesirable, functional or dysfunctional, direct and indirect, immediate result or result of the immediate result, expected and unexpected, recognized and unrecognized, intended or unintended.

3.1.2 Innovation characteristics

Perceived characteristics of innovations that enhance their usage are relative advantage, compatibility, trialability, observability, complexity and adaptability. Rogers (2005) defined these perceived characteristics as follows:

Relative Advantage: This is the degree to which the innovation being communicated is perceived to be better than the prevailing technology or practice.

Compatibility: This is the degree to which the new idea is seen as compatible with the prevailing practice or environmental conditions, socio-cultural aspirations and indigenous technology.

Triability: Is the degree to which the new technology being introduced can be tried on pilot basis before its subsequent adoption and diffusion.

Observability: Is likewise a positive attribute of innovations, which indicates the level at which the outcomes of an innovation can be observed, with time, so as to decide whether to adopt or reject it.

Complexity: Is a negative attribute of innovations that indicates the angle at which the new technique is considered to be complex with regards to its adoption.

Adaptability: Is the sixth attribute of innovations that enhances their rates of adoption if they have the possibility of re-invention to suit the farmers' local conditions.

Hence, innovations that are perceived to have high degrees of relative advantage, compatibility, triability, observability and less complexity with the possibility of re-invention are more likely to be adopted than those that do not. There are also other attributes of agricultural innovations that affect their adoptability by farmers.

Other Attributes: Crop attributes such as grain quality, straw yield, grain yield, and input requirements are all factors farmers consider in assessing a new technology, like improved rice varieties (Taxler and Byerlee, 1993). If the crop quality is poor, farmers would have low inclination towards its adoption. There is therefore the need to improve the crop variety to suit both climatic and demographic factors of the farming community.

3.1.3 Innovation diffusion

Diffusion is the spread or communication of innovations through certain channels or media with time, among the members of a given society. Diffusion is a type of communication, in the sense that the messages convey new ideas. The novelty of the idea in the message confers unigue characteristics on diffusion. It therefore implies that some level of uncertainty is inherent in diffusion (Rogers, 2005). Diffusion is also considered as the dispersal of technology in a community (Abdul-Hanan, Ayamga, and Donkoh, 2014). Diffusion is likewise defined as aggregate adoption (Rogers, 2005). This means diffusion of an innovation can only occur when individuals in a group or in a given society have collectively adopted that innovation. The diffusion theory, attributed to Rogers (2003) can be traced to a French sociologist by name Gabriel (Couros, 2003) and it portrays several other theories that together describe the ways of accepting and using innovations. Four different termnologies are associated with the diffusion process. Namely, the innovation, channels of communication, time, and the society. These terminologies can be identified in any diffusion research study, campaign or programme (Rogers, 2003). They have accordingly been defined and explained in this section (3.1) of the chapter.

3.1.4. The Society

The society, otherwise known as the social system, is the fourth terminology associated with the diffusion process. The society is made up groups of people who relate and collaborate in many ways to jointly solve problems and achieve common goals or objectives. Groups in the society may be units of individuals, informal unions, registered organizations, and/or sub-systems. The society also includes institutions that define how people relate or groups come together to solve problems and achieve common goals (Rogers, 2003).

3.1.5 Time

Time is the period or duration within which a phenomenon occurs. The time dimension is often taken for granted in most behavioural studies (Rogers, 2003). Including the time dimension in diffusion studies shows one of the strengths of such studies (Rogers, 2003). The time dimension caters for the processes of innovation diffusion, categorization of adopters, and adoption rates. The time dimension involved in the diffusion of innovation measures;

1. The processes a person undergoes in making decisions on innovations from getting to know about an innovation to accepting, using or rejecting it.
2. How innovative a person is or a group of people are with regards to adoption compared to other members of the society.
3. The rate of adoption of an innovation in a social system, which is normally considered as the number of people of a given society who adopt the innovation in a certain time period (Rogers, 2003).

3.1.6 Adoption

The term adoption refers to the acceptance, use and continuous use of a new idea or technology (Doss, 2006; Rogers, 2005). Adoption can also be defined as a unified, unique, and general phenomenon that is multifaceted with many inputs, actors, and consequences (Donald and Parker, 2012) with an aim of improving toproductivity. Adoption is also considered as the degree of usage of a new idea, practice or technique

(Abdul-Hanan et al., 2014). Adoption is an individual affair involving five mental processes ranging from becoming aware, getting persuaded, making decisions, implementing decisions and confirming decisions made. The individuals first get knowledge about the innovations though exposure and awareness creation, possibly by change agents such as Agricultural Extension Officers. The individuals then become interested in the innovation and seek more information on it until they are persuaded. They then evaluate the innovation to see how relevant, applicable or beneficial it would be to them and decide whether to try it or not. The trial stage is what Rogers (2003) refers to as the implementation stage. This is where the individuals make full use of the innovation to ascertain its potential benefits. The final stage is the confirmation stage where the individuals seek affirmations from families and friends to help them confirm or reject their adoption decision. Where the potential gains are higher and affirmations are positive, the individuals finally confirm their adoption decisions and stick to them. Rogers (2003) therefore refers to the confirmation stage as the real stage of adoption where the individuals decide to continue to make full use of the innovation. Rejection of the innovation normally occurs at the confirmation stage when the adoption decision is negatively affirmed by families and friends of the potential adopters. Individuals who so decide to adopt or reject the innovation then try to stay away from contrary views about the innovation in other not to be persuaded or dissuaded further about it. Rogers (2003) further indicated that rejection of an innovation can take place at any stage in the decision process.

Many adopters and researchers also take the trial period of an innovation as the adoption period, which is far from the truth. Adoption is only deemed to have occurred only when the adoption decision has been affirmed and maintained for a maximum period of about five years (Ayedun and Adeniyi, 2019). So, farmers who try an innovation and truncate the process can best be described as non-adopters of the innovation.

3.1.7 Categories of respondents

This study identifies three groups of respondents, namely; initial adopters, current adopter, disadopters and non-adopters. The adopters were farmers who cultivated any of the rice varieties for a minimum of three years during the past decade (Doss, 2006; Doss, Mwangi, Verkuijl, and de Groote, 2003). They are categorized into initial adopters and current adopters (those adopting the varieties as at the time of data collection), disadopters and non-adopters.

(a) **Initial Adopters:** These are farmers who adopted each of the rice varieties, from 2009 to the 2014 cropping season. That is, farmers who adopted each of the rice varieties within the first five years following their dissemination. The reason being that, almost all the rice varieties under study were disseminated in the study area before 2010. Therefore, farmers who adopted any of the rice varieties before 2009, and from 2009 to 2014 were considered initial adopters. That is because all the farmers in this study have a minimum of ten years' experience in rice farming.

(b) **Current Adopters:** The current adopters are the adopters who had continued to adopt the rice varieties after their dissemination periods till the 2019 cropping season. They include farmers who started adopting any of the rice varieties from 2014 and have not stopped cultivating them till the 2019 cropping season, even if they have plans to stop cultivating them in future. Since adoption means continuous use of an innovation over time (Rogers, 2005), this study considers the current adopters as the real or actual adopters of the rice varieties in the study area. Adoption decisions are very likely to be rampant and massive in homogenous societies than heterogenous societies, due to similarities in socio-economic and demographic charatersitics of the potential adopters.

(c) Disadopters and Non-Adopters

Disadopters: They also include farmers who adopted any of the rice varieties from 2009 to 2014 and have stopped cultivating them even if they have plans of cultivating them again after the 2019 cropping season. The disadopters are, thus, those who have abandoned the innovations and are no longer adopting any of the rice varieties as at the 2019 cropping season. The reason being that five years is enough period for any farmers to re-adopt any of the rice varieties, since the farmers claimed that they change the types of rice they cultivate on their fields every four years (Lamptey, 2018). The practice of rejecting, stopping and discontinuing the use of an innovation after it has been adopted is referred to as disadoption. Disadoption of innovations starts from the confirmation stage in the decision making process of adoption (Rogers, 2005). Individuals who decide to adopt the innovation can later change their minds when they are constantly exposed to contrary views about it or they face serious changes about the continuous use of the innovation or when the innovation has outlived its usefulness. Individuals seek affirmations about their adoption decisions because they are social beings in a social system. Disadoption decisions are therefore very likely to be rampant and massive in heterogenous societies than homogenous societies, due to differences in the socio-economic and demographic charatersitics of the potential disadopters.

Non-Adopters: These are the farmers who have not adopted any of the rice varieties for a minimum of three years, from 2009 to the 2019 cropping season. They include farmers who are aware of the rice varieties but have not adopted them, or those have tried the varieties for about a year or two and decided not to adopt them, due to one reason or the other. By this definition, farmers who are not aware of the innovations cannot be classified as non-adopters. Since, every farmer in this study is aware of the rice varieties, any farmers who are yet to adopt any of the rice varieties are considered non-adopters. That is, whether such farmers have ever tried any of the varieties, are still trying them or yet to try them.

3.1.8. Adoption rates

Adoption rate is the extent to which an innovation is accepted and used by its intended beneficiaries in the society (Rogers, 2005). It is a measure of the proportion of the intended beneficiaries who have actually adopted the innovation at a given point in time (Sahin, 2006; Doss and Morris, 2001). Rogers (1962) found that the rate of innovation adoption in the community or nation (rate of diffusion) initially increases and finally decreases, the curve looking like an *S* in Figure 3.1 below where the y-axis measures the number of adopters and the horizontal axis measures time. The main driving force underlying the spread of innovation was argued to be the role of communication. Rogers (1962) gives a comprehensive account of adoption/diffusion of innovation.

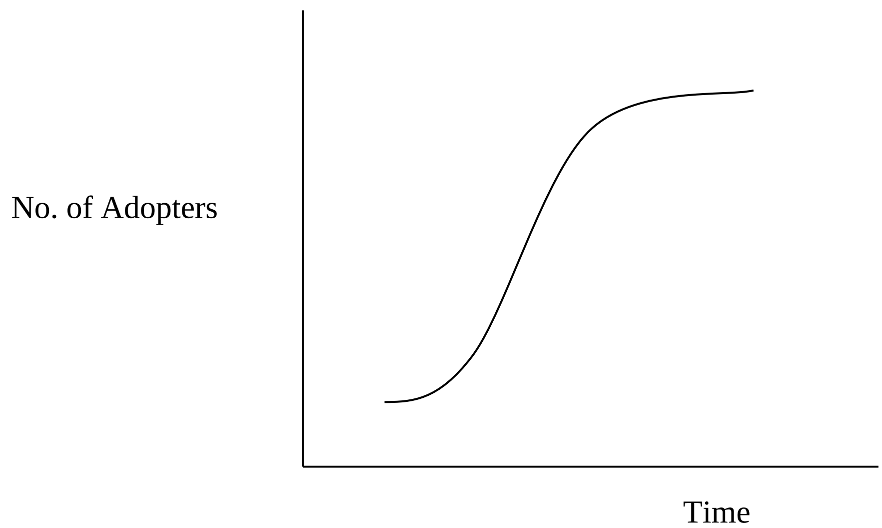

Figure 3. 1: The comprehensive adoption/diffusion curve. ***Source: Rogers, 1962***

In as much as the definitions of innovation usage encompass a variety of unrelated practices, including the degree at which farmers use farm complementary technologies acceptably or perfectly to derive maximum benefits, Doss (2006) advised that adoption studies should clearly and succinctively define these termnologies. It means adoption can be defined in unique and unambigious terms depending on the technonology or complementary technology in question. Therefore, the adoption rates in this study are the proportions of the farmers who adopted each of the rice varieties over the past ten years in the Northern Region. They are categorized into four. Namely, initial adoption rates, current adoption rates, disadoption rates, and non-adoption rates.

(a) **Initial Adoption Rates:** The initial adoption rates are the proportions of the farmers who adopted each of the rice varieties from 2009 to 2014 cropping season or adopted each of the rice varieties within the first five years after their dissemination periods.

(b) **Current Adoption Rates:** The current adoption rates are the proportions of the farmers who adopted the rice varieties from 2015 to 2019 cropping season, or farmers who adopted any of the rice varieties before 2015 and continued with their adoption decisions till the 2019 cropping season. Since adoption means continuous use of an innovation over time (Rogers, 2003), this study therefore considers the current adoption rates as the real rates of adoption of the rice varieties in the study area.

(c) **Disadoption Rates:** The disadoption rates are the proportions of initial adopters who have abandoned the innovations after 2014 and are no longer adopting any of the rice varieties as at the 2019 cropping season.

(d) **Non-Adoption Rates:** These are the proportions of the farmers who have not adopted any of the rice varieties for a minimum of three years, either before 2009 or from 2009 to the 2019 cropping season.

3.1.9 Agricultural extension and advisory services

These are ways and means by which the capacities of farm families and other stakeholders in agriculture are enhanced by agricultural extension service providers through the provision of information and technologies. The capacity building also takes the form of improving farmers' technical know how and farming methodologies, ability to invent, and solve various rural development problems. These are achieved via training programmes, enhanced managerial and organizational skills.

3.1.10 Channels of communication

The channels of communication are the media through which information flow from one person to another in the social system. Communication therefore becomes the process of sharing information, ideas or messages from a source through a channel to a receiver and vice versa. Rogers (2003) defined communication as a process by which people generate and share ideas among themselves for their mutual benefits. The information flow from sources through channels to receivers and feedback is given from the receivers through the same or similar channels to the sources for the needed actions to be taken. These channels include telephone, television, radio, computers, internet, newsletters, magazines, leaflets, bulletins, journals, person-to-person contacts, and community fora. Person-to-person contacts and community fora are more appropriate to farmers because they afford participants the opportunity to clarify the messages they receive on the spot and accordingly give appropriate feedbacks. Intra and interpersonal contacts as well as community fora are also considered more credible and trustworthy communication channels because the farmers can easily relate and identify with such channels than the sophiscated ones like internets and magazines.

3.2 Adoption and disadoption of agricultural innovations

Much of the “success story” we read in the adoption literature about agricultural innovations are recorded during the trial periods, normally at the peak of the dissemination process. Ayedun and Adeniyi (2019) recorded 57% level of awareness of improved rice seeds and 43% levels of adoption among farmers in Nigeria. That indicates low level of adoption of improved rice seeds in Nigeria. Many adopters do not keep their adoption decisions forever. Doss, Mwangi, Verkuijl, and de Groote, (2003) therefore opined that adoption studies could be improved if adoption definitions are standardized across studies and by using sampling methods that permit generalization of results. Alternatively, adoption studies could be improved by providing explanations rather than definitions of termnologies.

Innovations adoption studies are many but evidence of continuous adoption of innovations are rare. This is because many researchers simply examine initial adoption and non-adoption of innovations using adhoc measures and binary models such as logit and probit to analyse their data. The findings of such studies are often not comprehensive enough to warrant generalization on adoption and disadoption. There is therefore no unified "theory" of innovation disadoption (Mateos and Dadzie, 2014). It means there is no guarantee for continued use of innovations once adopted. This lack of continued use of technologies leads to abandonment (disadoption) of innovations. Innovation disadoption is generally referred to as technology abandonment in development literature (Mateos and Dadzie, 2014).

Donald and Parker (2012) broadly defined disadoption as the process of stopping or a marked reduction in the adoption intensity of innovations previously adopted, which can occur either instantly or gradually with time. The process of disadoption can be fairly complex and protracted. Disadoption can be catalyzed by a number of external factors such as availability or social pressure and internal factors like new perspectives or objectives. The outcomes of disadoption can be cumulative and involving. Disadoption can be a permanent or temporary change but the aftermath reaction to it may be positive and reinforcing or negative and regretful (Donald and Parker, 2012). Temporal disadoption can result in re-adoption when individuals regret their disadoption decision or when they are able to overcome the challenges associated with continuous adoption.

Table 3. 1: The complexity of innovation disadoption

Disadoption							
Factors		**Processes**		**Nature**		**Reactions**	
External	Internal	Abrupt	Gradual	Permanent	Temporary	Positive	Negative
Social Pressure	Personal goals	Instant	Withdr-awal	Long term	Short term	Reinforc -ing	Regretting
Effects		**Cumulative**				Dis-adoption	**Re-adoption**

Source: Author's construct based on literature, 2020

3.2.1 Types of innovation disadoption

Disadoption of agricultural innovations can be categorized into three as shown in Table 3.2: farmer initiated disadoption of unsustainable innovations, nature initiated disadoption as in disengagement of human relationships and institutionally initiated disadoption of undesirable innovations (Lastovicka and Karen, 2005). It means disadoption can be farmer initiated, institutional initiated, or by natural and environmental factors. These are discussed below.

Table 3. 2: Types of innovation disadoption

Type	Reason	Example
Farmer Initiated	Unsustainable Innovations	High cost of inputs, outmoded, no subsidy
Institution Initiated	Undesirable Innovations	Hazardous, ineffective, unproductive, change in policies and practices
Nature Initiated	Disengaged Relationships	Death, migration, occupation, termination, dissolution, divorce

Source: Author's construct based on literature, 2020

3.2.1.1 Farmer Initiated Disadoption of Unsustainable Innovations

Farmers normally disadopt innovations that are not sustainable: Either they do not have what it takes to keep practicing the innovation or the innovation simply cannot stand the test of time. Such innovations fade out with time, especially when they outlive their usage and are no more relevant to current trends of events. Innovations that are outmoded fall into this category. According to Rogers (2005), innovations are inventions that people consider as new. So, if people in the society consider a technology as a new invention, it becomes an innovation to them. On the other hand, if they consider the same technology as an old fashion model of a brand, then such a technology is no more considered as an innovation by the same users. Innovations that have high input requirements also become unsustainable to peasant and pro-poor farmers who lack production capital and access to credit facilities. Similarly, innovations that are associated with juicy and attractive incentives like subsidies easily outlive their usefulness when the incentive packages are removed (Lamptey, 2018).

A dimension on disadoption shows that discontinuing something imply starting another thing (innovation/behaviour), which suggests that disadoption and adoption are two sides of the same coin. They can be categorized, conceptualized, and analyzed in similar fashion. It presupposes that, when one has to choose between A and B, choosing “A” becomes synonymous to rejecting “B”. This makes adoption as a dichotomous variable, but other unique aspects of the phenomenon make disadoption complex with many extraneous variables (Donald and Parker, 2012).

It implies that, when individuals disadopt an innovation, there is relatively little uncertainty about what they are missing, compared with adoption processes in which uncertainty is inherent. Also, adoption is mostly modeled in a binary fashion (yes or no), but disadoption is more liminal and can happen gradually and partially, occur over a long period of time or in several stages. Besides, adoption of a product demands taking hold of it, but it is possible to disadopt a product without getting rid of it. For example, divorce separates couples but it does not permanently terminate their relationship, especially when there are offspring in the union. Moreover, surrendering something brings to the fore several psychological processes such as loss phobia and possession utility which perform an insignificant role in adoption decisions. Further, the psychology of choice is markedly different from the psychology of rejection (Lastovicka and Karen, 2005). Considering the trajectory of usage and abandonement of innovations, the present study centers on the adoption and disadoption of the main varieties of rice in the Northern Region of Ghana.

3.2.1.2 Nature Initiated Disadoption as in Termination of Human Relationships

Innovation disadoption can be compared to the natural process of ending human relationships. Several words can be used to describe the process of ending human relationships. The process could be described as *desertion, separation, termination, dissolution, withdrawal, disengagement, abscondment, divorce, discontinuity, abandonment, decline, exit, break-up, or rejection.* Each of the terminologies has a process phenomenology that can be investigated as an entity (Duck, 1982). Phenomenology is protracted research that requires participant observation for a long time period, usually about one or more years. For example, it takes about a decade to understand human behaviour or unravel a protracted chieftaincy dispute, or to study the climate of an area. It means the disadoption terminologies describe a temporary or permanent termination of human engagements to the point of no return or reunion. Disadoption follows a similar trend: some disadopters may switch off from a particular innovation to others either to come back to the one they have disadopted or never to return to it. Normally, farmers return to the old technologies after comparing the performances or suitability of the old and new ones. When they realize that the existing technology is better than the new one, they may resort to the old technology or look out for more promising ones. Sometimes, the old technology can be repackaged or rebranded to suit farmers' tastes and preferences better than the current competitive technologies. Farmers can also modify old technologies to suit them better than new technologies that they are not so much conversant with or when they realize that they cannot adapt the new technology like they would do (to) the old one.

Farmers appear to prefer innovations that are compatible and adaptable to their local contexts than technologies that are not. This phenomenon is what Rogers (2005) refers to as adaptability or possibility of re-invention of innovations. Similarly, in human relationships, some people sometimes prefer to stay in old relationships in which they can adjust and adapt rather than new and promising relationships they are not so sure of. People in this bracket appear to adopt a conservative approach to relationships by quoting the adage that, "the devil you know is better than the angel you do not know". This people appear to be risk averters because they are not innovators. Normally, innovators risk the uncertainty aspects of innovations in favour of the potential benefits of those innovations. However, innovators can also return to innovations they have disadopted when they realize that the new technology is not worth adopting after all.

Some people on the other hand, are also of the view that, "if you fear a break-up, you cannot enter into new and better relationships". Such people are always on the move. They move from one relationship to the other, looking for better opportunities elsewhere. Such people can be described as risk lovers because they keep trying different relationships until they get what their hearts desire and they stick to it. However, because of their tendency of opting for better options in relationships, they are likely to disengage with relationships in which they previously thought they were secure just as they would do agricultural innovations. Rogers (2005) called such people innovators. This concept of abandoning an existing innovation for a new one is the subject matter for this thesis. Sometimes, abandoning one innovation does not necessarily mean opting for a better one but to mean that that particular innovation has outlived its usage, just like in a human relationship where one partner is no more in existence or his or her existence is no more relevant to the relationship (Lastovicka and Karen, 2005). For Donald and Parker (2012), seeing disadoption from a relationship perspective can shift basic conceptions of a process that does not always involve termination and dissolution, but rather gradual separation or a more liminal state of discontinuity and withdrawal with time.

Termination and dissolution of human relations can involve third parties who directly serve as stakeholders in the relationship whereas gradual separation or a more liminal state of discontinuity and withdrawal with time may not involve third parties. Instances where third parties may be involved in a gradual separation or a more liminal state of discontinuity and withdrawal with time would normally happen indirectly. In the same vain, farmers decide on their own accord whether to continue to adopt or to discontinue the adoption of agricultural innovations. Rarely do governments and institutions tell farmers to disadopt a particular innovation unless they are recalling that particular innovation from existence (possibly due its undesirable characteristics) or a more improved version of that innovation has been discovered and introduced to the farmers. Governments can also ban innovations that are not reliable, compatible or adaptable to the social system into which they have been introduced (Rogers, 2005). Otherwise, the farmers would naturally advise themselves to disadopt such innovations. The disadoption process becomes faster and prominent in homogenous societies as opposed to heterogenous societies similar to the adoption process (Rogers, 2003). This is because the socio-economic characteristics of farmers are similar in homogeneous societies than in heterogenous societies. So, when one contact farmer, adopter or an influential person disadopts a particular innovation, many farmers in the community who take inspiration from such a person also follow suit and the process continues like a wild fire during a harmattan. In heterogenous societies each farmer decides whether to adopt or disadopt an innovation based on the individual's intuitiveness and not necessarily because other famers are doing so.

Like phenomenology, Relationship Theories help to unearth the experiences of people (Donald and Parker, 2012). Many researchers have not explored what happens when something is disadopted. There is therefore inadequate exposition of the experiences and consequences of abandonment from the disadopters' perspectives (Lastovicka and Karen, 2005). This means the effects of disadoption on disadopters need to be studied. It is sometimes assumed that a disjointed relationship is a *failed* one, and that breakups are themselves bad. However, abrogation of contracts may rescue people from abusive engagements and provide ways for people to mature in isolation than in their relationships (Lastovicka and Karen, 2005). The same can be said of disadoption when continuous adoption of an existing innovation would be at the disadvantage and to the detriment of the adopters. Specher and Fehr (1998) looked at dissolution of relationships as an integral and inseparable part of a person's life projects, activities and processes. Donald and Parker (2012) are of the view that disadoption can be seen as a social process that involves several people including the disadopters as well as their families and friends. It means many people are implicated in a disadoption process. This is because relationships occur within a social system and their terminations affect or are affected by the experiences and influences of other people. The possible intermediaries in innovation adoption or disadoption processes could either be the disseminators or the innovators who normally introduce similar innovations to the same group of farmers, or the researchers who generate new innovations for dissemination into the social system. The role of third parties in innovation disadoption can be direct or indirect.

Perrin-Martinenq (2004) portrays relationship disengagement as a multifaceted exit process like Duck's (1982) four-phased construct of deterioration, refusal, disengagement and annulment in divorce. Innovation disadoption can be likened to divorce, which is a devastating, prolonged, and comprehensive experience through which relationships becomes dis-integrated and truncated in society (Simpson, 1987). Theories on disadoption of brands of relationships are numerous but the nature of the termination experiences would be basically different based on the kinds of relationships disengaged (Lastovicka and Karen, 2005). For certain types of relationships, disadoption performs a different function altogether. For example, separation of customers and products does not terminate a given customer-product-relationship but rather serves as an adjective for relationship initiation. In the case of product opponents, it creates brand enemies and former friends (Johnson, Maggie, and Matthew, 2011). The separation of brand and person then defines the parameters for future engagements of the two.

3.2.1.3 Institutionally Initiated Disadoption of Undesirable Innovations

Institutions, firms, organizations and government agencies that come out with innovations or brands of products can cause the disadoption of those innovations in many ways. It can happen when the companies cease from producing those items and their complementary goods, withdraw those items from the public especially if they are custom-bound goods, terminate the contracts that ensure the production of those technologies or when a project responsible for that innovation comes to an end. Adopters of those innovations react to the situation in ways that lead to disadoption (Lamptey, 2018; Donald and Parker, 2012).

Many companies normally consider their reputations and perceived integrities when neglecting clients who patronize their goods and services (Lastovicka and Karen, 2005). So, they are very careful when disengaging with their clientele, rebranding their products or relocating their companies. No matter how the companies go about it, there are users of those innovations who would feel dejected, peeved, disenchanted or disappointed for the non-availability of those goods and services at their disposal. In response, they switch on to other complementary goods and services from different organizations as a matter of necessity. This phenomenon is based on social exclusion theory, which shows that the relationship between how companies disadopt clients and why firms disadopt them influences consumer response (Lastovicka and Karen, 2005). This research suggests that farmers' perception of company integrity and anger are intertwined in farmer response to institutional-initiated farmer abandonment of agricultural innovations.

When governments change their policies and institutions change their practices, individuals also change their habits and behaviours (Price, Eric, and Carolyn, 2000). The behavioural change comprises abandonment of innovations an individual has adopted or is adopting. That disadoption demands a different theoretical perspective of the process than that of adoption (Perrin-Martinenq, 2004).

3.2.2 Why Farmers Disadopt Agricultural Innovations

The reasons for agricultural technologies disadoption are two-fold: replacement discontinuance and disenchantment discontinuance (Rogers, 2003). The former occurs when a farmer discontinues a technology to adopt a better one with promising features. The latter takes place when a farmer discontinues an innovation without necessarily replacing it with another technology, due to loss of interest in the performance of the technology abandoned (Rogers, 2003).

Kehinde and Adeyemo (2017) discovered that the reasons for abandoning innovations among cocoa farmer in south-west of Nigeria included financial constraints, insufficient land available for farming, poor performances of the innovations, extra costs associated with the innovations, technicalities involved in uing the prescribed technologies, waste of time, unuseful nature of the innovations, and technology failure. The farmers in that region discontinued adoption of various innovations without replacement, meaning they were dissatisfied with those innovations. This follows Rogers (2003) disenchantment theory of discontinuance. Donald and Parker (2012), also outlined a range of specific reasons for innovation disadoption, which are exemplified by five general determinants. Namely, life transitions, negative aspects or social pressure, irritation, variety seeking, and future viability.

3.2.2.1. Life Transitions

When people move from one stage of growth to another, their tastes and preferences do change. Teenagers normally adopt certain life-styles and habits, especially when they are students. They usually drop some of those habits and life-styles like bushy hair-cuts, skinny or casual dresses, use of army type of school bags among others, to a more decent and formal life-styles when they are in their twenties or out of college. Their life-styles become more formal when they join the working class in society. Office wears, use of official cars and staff quarters, and bungalows become the order of the day as people progress in the working environment as opposed to the use of dormitories, school buses, and school uniforms while in school. Then when people approach retirement, they tend to own or build their personal houses, cars, and other assets which they may not have considered when they were much younger and perhaps did not have the means to do so. So, when the opportunity presents itself, they usually would drop some items and technologies they used to cherish and go for the ones that match their current social status. A typical example is a means of transport. A toddler may use a baby sitter to aid his or her walking, a child may use a simple bicycle for fun at home or as means of transport to school. Similarly, a teenager may use a mountain-bike either for hiking or school whereas an adult may prefer a motor-bike or a private car for work beside public means of transport. A chief executive of an organization may not go to work in a company bus loaded with his workers or wear the same types of dresses (uniform) his casual workers or employees put on to work, even if he used to wear those dresses or enjoy those rides when he was an employee or ordinary staff of the company. Rising through the ranks and stages of growth in life makes a person do away with certain habits and life-styles, which constitutes disadoption.

3.2.2.2 Negative Aspects/Social Pressure

People disadopt innovations when the innovations are no longer compatible with their societal norms and values (Rogers, 2003) or when they realize there are lots of disadvantages of using them. The rearing of a highly prolific breed of pig would not be accepted in a Moslem dominated community compared to a prolific sheep. This is because the Holy Quran prohibits Moslems from eating pork. So, adherants of Islam would normally patronize innovations that promote sheep or goats than pigs.

Similarly, a typical Ghanaian who rides a motor bike as his or her official means of transport would normally dicontinue the practice when s/he becomes a minister of state, even if s/he prefers to ride motor bikes. This is because ministers of state in Ghana use four wheel drives as their official means of transport, not motor biokes. The use of motor bike as as official means of transport for such a minister of state then becomes a thing of the past as his/her social status changes. That in itself constitutes disadoption of the motor bike as his/her official means of transport.

In the same way, Ghanaians in rural communities who produce and consume local (unpolished) rice would likely abandon local rice for imported (polished) rice when they migrate to urban areas. The use of imported rice then becomes a matter of necessity and choice for urban dwellers who consider local rice as inferior to the imported rice.

3.2.2.3 Irritation

People can also disadopt innovations if they are irritated by the practices associated with them or how to use the technologies (Donald and Parker, 2012). They can also choose to disadopt an innovation when they have a score to settle or a bone to pick with the service providers or disseminators of the innovation. This normally happens when farmers do not trust or like agricultural extension officers who introduce the innovations to them or assist them in the use of the innovations (Rogers, 2003). The extension agents may have certain undesirable personal characteristics like dishonesty, biasness, favouritism, lateness, mannerisms, or money-consciousness that may irritate the farmers (Rogers, 2005). Farmers also become irritated with certain innovations they adopted but did not benefit from the adoption. The idea of continuous adoption of the innovations annoys them so they disadopt the innovations (Donald and Parker, 2012).

3.2.2.4 Variety Seeking

Farmers normally seek ways and means to help themselves to improve their standards of living (Rogers, 2005). One way they do this is by seeking for improved technologies that would enhance their production activities. So, they resort to the use of mechanization and irrigation of their farms as well as the use of organic or inorganic fertilizers and other agro-chemicals to facilitate the farming activities. They also look for improved varieties of the crops they cultivate so as to increase their outputs and derive other benefits from the improved varieties of crops, which their local varieties do not have. Farmers therefore disadopt agricultural innovations when they get improved and better crop varieties than those they are used to.

3.2.2.5 Future Viability

Farmers easily adopt innovations that have relative advantage over other innovations that do not have such advantages (Rogers, 2005). So, they tend to adopt innovations that have higher prospects for the future and disadopt those that do not. For example, most cereal crops have inherent recessive traits that show up in the fourth year when they are cultivated in four successive years, especially on the same piece of land (Lamptey, 2018; Doss, 2006; Doss et al., 2003). So, the farmers would normally disadopt the variety either in the fourth year or after the fourth year when they see those recessive traits like low yielding, susceptibility to pests and diseases infestations among others, and go for other varieties with higher or better prospects of seed viability. The case in point was disadoption of NERICA in Ghana (Lamptey, 2018). According to Doss et al. (2003), farmers are rational beings who choose to adopt aspects of innovations they are comfortable with. For example, some may choose to adopt the improved seeds and ignore the complimentary agronomic practices or use hybridized seeds from their own farms rather than the certified seeds from input dealers, year after year.

Farmers also prefer producing viable seeds from their own farms to buying improved or viable seeds from seed sellers year after year. So, when they get a crop variety from which they can produce their own seeds for future cultivation, they stick to that one rather than the one that has to be purchased from seed sellers every planting season. Sometimes, the farmers can produce their own seeds from the crops they produce but if the seeds cannot survive under the prevailing environmental conditions of the farmers' farms or storage facilities, such seeds become unviable at the next planting season. So, they tend to disadopt those seeds that lose their viability in storage and stick to or opt for better ones that are hardy and highly viable in all weather.

3.2.3. Effects of innovation adoption

A number of studies reveal that increase in output is one of the effects of adopting innovations such as seeds of improved rice varieties (Bruce et al., 2014; Wiredu et al., 2010; Uaiene et al., 2009; and Sserunkuuma, 2005). Kasirye (2010), observed that adoption of improved agricultural innovations relates to higher incomes and reduction in poverty levels; improvement in nutritional statuses; reduction in staple food prices; increment in job placements, and more wages for farm labourers.

Wani, Baba, Sundaram, Yousuf, and Yousuf (2013) also provided estimates for the levels of adoption of some improved rice seeds in the Kashmir valley and the effects of adoption on the socio-economic wellbeing of adopters of that innovation. They found that adopting those seeds led to astronomical increases in farmers' gross and net incomes with corresponding decreases in the costs of production. They established the fact that adoption of the innovation enhanced the socio-economic wellbeing of farmers in their study area. Wani et al. (2013) employed the economic surplus model and presented a strong case for more investments in academic research and developmental projects, extension delivery services and innovation dissemination in the Kashmir valley.

Muzari, Gatsi, and Muvhunzi (2012) reviewed studies on the effects of innovation adoption on the productivity of small-scale farmers in SSA and found that adoption did not result in higher income of farmers, due to land degradation, higher costs of fertilizers and production credit, among others. They concluded that, measures be put in place to enhance the adoption of agricultural innovations that increase agricultural productivity, decrease land degradation, and associated with reduced costs of fertilizers, farm credit and taxes.

A research conducted by Devi and Ponnarasi (2009) on the economics and the farmers' adoption behaviour of the Systems of Rice Intensification (SRI). They found a significant relationship between the adoption of SRI techniques with increases in rice production on the same pieces of land used for rice cultivation prior to the SRI regime. SRI led to higher incomes (Rs27009) than incomes from the traditional farming method (Rs 14499). The cost of production per metric tonne of paddy was lower in SRI (Rs 3937) than the conventional method (Rs 7404) of rice cultivation. The traditional method of farming is associated with low productivity and higher production costs. The amounts of income per costs of production are relatively higher in the SRI scheme than the traditional rice cultivation method. The incomes comprise farm business income, family labour income, net income, and farm investment income. The rise in production levels and net profit derived from the the SRI would make more farmers adopt SRI and perceive *saving water for future use* in rice cultivation as an important venture for effictive water management in rice farms.

Adisa, Ahmed, Ebenehi, and Oyibo (2019) assessed the benefits of adopting improved rice varieties among peasant farmers in Kogi State of Nigeria, and found that about 98.6% of the adopting farmers had increased output, 91.5% had acquired new skills in production, with another 85.5% and 72.2% of the respondents reporting increased incomes and farm sizes respectively. The innovations disseminated were rice production facilities, inputs for rice farming, and tillage techniques. Mohammed, Jaleta, and Berg (2015) studied adoption of several agricultural practices and its effects on farm household incomes, and found that adoption of several agricultural practices averagely provides higher incomes than adopting each of the practices separately or in any combinations. Their result likewise shows that total cost of production is significantly higher with adoption of several practices together than two, three or more combinations of the practices. The practice of adopting several technologies or a combination of technologies is known as adoption intensity. The higher the adoption intensity, the lower the cost of production, due to the economy of scale.

Adoption also improves yields, creates employment opportunities for women and youth, among others (Azumah, Tindjina, Obanyi, and Wood. (2017). Bruce et al. (2014) employed the treatment effect model comprising a probit regression model and a production function to investigate the determinants of adopting enhanced rice varieties and its effects on output of rice in Ghana. They discovered that the adoption of enhanced rice varieties had positive effects on farmers' rice output. Wiredu et al. (2014) also found that NERICA adoption significantly increased rice income, agricultural income, per-capita income and total annual income of farmers by $196.52, $446.37, $0.44 and $498.44, respectively. They recommended the need to intensify NERICA promotion through creation of access to the NERICA seeds along side their complementary technologies. It also means efforts should be made to improve market and road infrastructure to enhance access to farm input and output markets, due to the impact of NERICA adoption.

Row-planting technology adoption likewise exerted greater positive effects on rice productivity among small scale farmers in Northern Ghana (Donkor, Owusu-Sekyere, Owusu, and Jordaan, (2016). Martey, Dogbe, Etwire, and Wiredu (2015) likewise employed the propensity score matching approach to measure the effects of participating in farmer mentorship projects on a cross-section of 200 small scale farmers and found that participation had positive impact on farmers' technical efficiency by 28 percent. They observed that participation in farmer mentorship project had no positive significant association with farm income. Those findings suggest that farmer-participation in agricultural development projects may directly enhance farmers' technical efficiency within the shortest possible time without necessarily guaranteeing higher income perse.

From the above discussions, it is evident that numerous researches have been carried out on the effects of adopting modern rice varieties and their complementary technologies, globally, in Africa and Ghana, particularly the Northern Region. It is also important to note that these research findings cannot be generalized to draw conclusions on the effects of innovation adoption because of differences that exist in the various agro-ecological zones where the studies were undertaken. The technologies investigated and the socio-economic settings in which those productions took place were also different. In Ghana for instance, the conditions that pertain in the southern sector are quite different from those in the north. There are two cropping seasons per annum in the south while only one pertains in the north, among other considerations. The current study therefore contributes to the literature on adoption by examining the effects of adopting improved and traditional rice varieties on rice output of farmers in the Northern Region, Ghana.

3.3 Constraints and disadoption of improved rice varieties in Africa

This section presents the constraints of improved rice variety adoption, and disadoption of improved rice varieties in Africa.

3.3.1 Constraints to improved rice variety adoption

The constraints to improved rice variety adoption abound worldwide but they are location specific. One of the main constraints is the inability of people in the rice value chain, particularly in Africa, to buid research capacity for rice (Diagne, Soul-Kifouly, Wopereis and Akintayo, 2010). Another major constrain is the ability to produce edequate certified seeds to meet farmer demands particularly in West and Central Africa. National seed regulatory authorities do not exist or function well in a number of countries. Those authorities help to regulate demand and supply for certified rice seeds suitable for different ecological systems and consumption options (Diagne et al., 2010).

Besides, issues such as lack of access to certified seeds, recommended fertilizers, farm credit, and adequate production rates of rice, processing capacity, distribution channels as well as market and road infrastructure pose serious challenges to modern rice variety adoption (Diagne et al., 2010). This is in tandem with Mustapha, Undiandeye, Sanusi, and Bakari (2012) who observed that absence of fertilizer accounted for 96.25% of constraints affecting the use of new rice production ideas at Borno state in the federal republic of Nigeria. The adoption of improved varieties of rice promoted in Ethiopia since 1999 have equally been plagued with problems like high competition from imported rice, inappropriate infrastructure, inadequate mechanization services and grain processing technques. Others are lack of skilled labour and research ammenities, poor market and road infrastructure, and distribution channels (Tamirat and Jember, 2017). Similarly, socio-economic charateristics of farmers such as their ages, incomes, associations, family sizes, levels of education, farm sizes, and contacts with extension service providers affected adoption of new rice production practices at Imo state in Nigerian republic (Onyeneke, 2017).

Little adoption and unsustained adoption decisions of farming innovations are partly due to the fact that innovations are sometimes unavailable to farmers, and accessing such technologies from other places normally increase the cost and time of adoption (Kasirye, 2013). Mustapha et al. (2012) observed that the second most important (95.63%) challenge that the farmers of Borno State faced in adopting new rice production practices was credit unavailability. This has policy implied for farmers who not have cash to buy the necessary farm inputs, thereby reducing the levels of adoption of new rice production practices among farmers. Other significant limitations of rice farmers in adopting new rice production technologies includes; lack of awareness of innovations (50%), poor attitudes of farmers to change (46%), lack of availability of certified seeds (93.63%), poor extension service provision (47%), land tenure issues (91.75%), inadequate skilled labour (76.25%), inadeqaute processing facilities

(56.88%), poor roadnetwork (89.38%) and expensive agro chemicals (42.50%) (Mustapha et al., 2012). Use of new rice varieties is further hindered by low rate of diffusion and publicity on the innovation with its associated technologies. The major constraints to improved rice adoption in the Northern Region include perennial weed infestation, water stress, lack of suitable improved varieties, and poor soil conditions (Bruce, 2015).

3.3.2. Disadoption of Improved Rice Varieties in Africa

Oster and Thorton (2009) noted relatively higher disadoption rates in technology adoption in developing countries and suggested that understanding the process can help remedy the situation. Carletto et al. (2007) opined that pressure to disadopt agricultural innovations sets in after 20 years of adoption. However, for Kasirye (2013), disadoption of agricultural technology occurs regularly in developing countries. This means it does not take many years for farmers to disadopt an agricultural innovation, contrary to Carlotte et al. (2007) assertion. This is because rejection of an innovation can take place at any stage in the adoption decision process (Rogers, 2005). For Rogers (2005), adoption is said to have taken place when the innovation is accepted and used by adopters but *disadoption* occurs when the adopters are no longer interested in the innovation or its usage.

Disadoption is abandonment of an innovation (Mateos and Dadzie, 2014; Moser and Barrett, 2002). Normally, rejection of an innovation occurs when the intended beneficiaries are not interested in it, are no longer benefitting from it or after they have derived the maximum utility from it. For Rogers (2005), rejection can be passive or active. Passive rejection occurs when the intended beneficiaries hear about the innovation but do not express interest in its adoption. Active rejection occurs when the farmers express interest in the innovation, get to know all about it, consider adopting it but willingly refuse to adopt it. Active rejection is also known as discontinuous adoption (Rogers, 2005). Rejection of an innovation can therefore occur either before, during or after the innovation has been adopted but disadoption occurs only after the innovation has been accepted and used for some time. Disadoption means discontinuous adoption, abandonment of innovation after adoption.

Studies that examined the determinants of innovation abandonment are not many. Bravo-Ureta, Chocchi and Solis (2006) studied the causes of innovation abandonment among farm families in El Salvador. They found that farm sizes of the farmers prevented abandonment of the modern technologies. Moser and Barrett (2003) also analyzed the adoption of improved rice varieties in Madagascar and found that farmers easily accepted the high-yielding rice varieties when disseminated, but they significantly abandoned the varieties later. Though Moser and Barrett (2003) indicated that lack of certainty with the improved varieties and production risks contributed to disadoption, financial constraints accounted greatly to farmers' decision to disadopt the technologies. The research works above set the pace for this current study.

Adoption is the acceptance, use and continuous use of innovations while disadoption refers to the rejection, stoppage and discontinuous use of innovations after they have been adopted. The reasons for disadoption vary from effects of life cycle to changes in the returns of agricultural products. Lamptey (2018) discovered that rice farmers in the

Northern Region of Ghana stopped growing Nerica on a particular rice field after four successive years of cultivating same on that piece of land and cultivated other rice varieties for another period of four years before reverting back to Nerica. Their reasons were to break the life cycle of Nerica related pests and diseases, among others. However, most of them did not revert to Nerica cultivation as they claimed and rather adopted latest varieties like Agra and Jasmine. Hence, the proliferation and availability of several improved rice varities in the social system contributes immensely to disadoption.

Kasirye (2013) revealed that innovation disadoption occurs frequently among cattle farmers in the west of Uganda. The farmers abandon inorganic fertilizers and resort to farm yard manure (FYM). This is partly attributed to the huge presence of organic fertilizers or FYM among the livestock farmers. FYM may later become a cheaper source of fertilizer except that it is not as effective as chemical fertilizers. Moreover, the side effects of FYM on the soil are not as grievious as chemical fertilizers. Chemical fertilizers make soils acidic and their continuous use make arable lands infertile and counter preductive in their absence. Continuous and excessive use of organic fertilizers however causes lowland rice fields to become uplands or hills with time (Martey et al., 2013; Donkoh and Awuni, 2011). Similarly, four most common determinants of farmer disadoption of Conservative Agriculture (CA) in Zambia were lack of transport for manure (31%), high demands for skilled labour (25%), poor knowledge in CA practices (16%), and lack of motivation for farmers (16%) (Habanyati, Nyanga, and Umar, 2018). For Habanyati et al. (2018), promoters of CA should not induce farmers to adopt CA practices by providing them with juicy incentives. That is because most peasant farmers take undue advantage of the incentives associated with innovations and later abandon the innovations. Disadoption of Agricultural innovations in developing countries is therefore a gradual process, which happens in several ways depending on the countries and farmers involved.

Rice farmers in Uganda who also prefer their traditional methods of storing grains to modern methods normally revert to the indigenous methods of storing rice shortly after adopting the modern methods. Conservativism is therefore a potential cause of innovation disadoption. Meanwhile, disadoption of CA constrained development of some sustainable agricultural production systems for small scale farmers in the Zambia (Habanyati et al., 2018). Moreover, CA disadoption compromises how effective international development aids that promote CA could be (Habanyati et al., 2018). Besides, innovations like CA that bring about development would not sustain the environment, reduce household food insecurity and poverty in general if farmers continue to disadopt it (Habanyati et al., 2018). Disadoption of agricultural innovations therefore has enormous impacts on disadopters and their communities or nations.

Many improved rice varieties suffered disadoption in Africa, especially Ghana, Benin, Nigeria and Uganda. Kijima, Otsuka, and Sserunkuuma (2011) revealed that more than 50% of Nerica adopters in Uganda who adopted the Nerica in 2004 abandoned it in 2006, due to low profitability of Nerica relative to other crops. Kijima (2008) also observed that the early adopters of Nerica in Uganda stopped growing the crop within two years of adopting it while others started growing it, due to the opportunity costs and risks involved in the adoption. Studies on disadoption of improved rice varieties in Africa is not a common practice.

Odeniyi, Elizabeth, Robinson, and Srinivasan (2018) did not find any study that investigated reasons for which rural farmers in Nigerian disadopted modern rice varieties prior to theirs. They used a combination of quantitative and qualitative data and discovered three reasons for high rates of Nerica disadoption in Nigeria. One of the reasons was the fact that there was about 100% subsidy from the government for certified seeds, agro-chemicals and synthetic fertilizers, which reduced entry costs for the farmers during seed promotion campaigns. Withdrawal of the subsidy decreased continued Nerica profitability due to capital and labour-intensiveness as well as susceptibility to damages by birds resulting in greater opportunity costs. The second reason was that national promotion campaign for Nerica in places with low and unpredictable rainfall patterns resulted in high yield losses because of drought. So, even though Nerica is deemed to be drought resistant, unreliable rainfall resulted in its disadoption.

This means mass dissemination of improved rice varieties would not be successful at places where the rainfall pattern is erratic because most farmers depend on rainfall for their crop farming. They do so to cut down high costs associated with irrigation in order to maximize profit. The third reason was that the farmers updated their information about Nerica and discontinued with its adoption. This means rejection of agricultural innovations could take place at any point in time during the innovation-decision process (Rogers, 2003). The three reasons stated above limited the relative advantage Nerica had over other existing enhanced varieties of rice. As Rogers (2003) observed, innovations with higher relative advantage stand a better chance of adoption than those with lower relative advantage.

Odeniyi et al. (2018) further observed that agronomic traits like yield and tillering ability of enhanced rice varieties determine yield. Also, consumption characteristics like whiteness, taste and cooking ability help determine the marketability and relative profitability that influence farmers' decision to continue their adoption decisions in subsequent year(s). The farmers may have disadopted Nerica because of its relative higher cost of production and lower profitability. Odeniyi et al. (2018) concluded that to reduce disadoption rates of future improved varieties and enhance agricultural sustainability, rice breeders should prioritize varieties with desirable consumption traits. They also suggested that promotion of improved rice varieties should be based by ecological suitability rather than political sentiments for more impact (Odeniyi et al., 2018). Odeniyi et al. (2018) further opined that credit accessibility, effective delivery of extension services and stability of policy environment, which facilitate availability and affordability of other inputs should be improved in order to reduce disadoption of improved rice varieties.

Similarly, farmers in Mexico abandoned Jatropha cultivation due to their dwindling perception on profitability of the crop, lack of subsidy on jatropha seeds, financial position of the farmers, as well as pests and diseases infestation on the crop (Carol, Marc, Brenda, Bart, and Erik, 2017). It presupposes that governmental subsidies as well as profitability and risk factors associated with agricultural innovations serve as disincentives for their continuous adoption. Policy makers should therefore take cues from this phenomenon in disseminating agricultural innovations. The international community also needs to consider how appropriate it is to promote new crops at the farmers' level before examining the reality of their economic viability and diffusion.

Tsinigo (2014) observed that 49% of rice farmers, including some early adopters of the innovation, did not cultivate NERICA four years after the dissemination period mainly due to absence of improved seeds. The improved seeds were subsidized by the government. Lack of subsidy resulted in the non-availability of the certified seeds on the market for farmers. Tsinigo (2014) blamed the non-availability of improved seeds and the lack/inadequate information on the improved rice variety on poor extension service delivery. Adoption studies show that lack of seeds is a major factor that led to Nerica disadoption (Toborn, 2011; Science Council, 2007). Using a panel survey of 347 households, Kijima et al. (2011) pointed out the relative unprofitability of rice compared to other crops, proximity to rice processing centres, and eventually higher marketing costs as the main reasons for which disadoption rates keep soaring. Lamptey (2018) likewise conducted a survey of 378 Nerica farmers in Ghana and highlighted lack of ready market for the produce after harvest, seed contamination, poor soil fertility and capital intensiveness, among others, as farmers' reasons for disadopting Nerica. It presupposes that the reasons for disadoption of improved rice varieties in Ghana, Benin, Nigeria and Uganda were similar. An in-depth study on the reasons behind the disadoption of improved rice varieties in Ghana's Northern Region is therefore very timely.

3.4 Agricultural innovation communication channels and methods in Ghana

This section looks at the agricultural innovation communication channels and methods in Ghana. It is divided into two sun-sections. Sub-section 3.4.1 looks at the agricultural innovation communication channels in Ghana while sub-section 3.4.2 discusses the agricultural innovation dissemination methods in Ghana.

3.4.1 Agricultural innovation communication channels in Ghana

Until recently, agricultural innovation dissemination in Ghana has been the sole preserve of the state, since the colonial era (Buadi, Anaman, and Kwarteng, 2013). The AEAs of MoFA have been the main facilitators of this governmental role. This responsibility of the state (Lamontagne-Godwin, William, Bandara, and Appiah-Kubi, 2017) has been saddled with a number of challenges such as inadequate funding of extension service delivery, inadequate extension agents, poor logistics, lack of motivation of extension agents, farmers' overdependence on extension agents leading to extension agents engaging in other duties beside their core mandate.

McNamara et al. (2014) identified low farmer accessibility to extension agents such that there are about five million small scale farmers for 3500 AEAs in Ghana. This gives an approximate ratio of 1,429 farmers to 1 extension staff, which is inappropriate for any effective extension service delivery in Ghana. Therefore, AEAs may identify and discover the solutions to challenges confronting farmers but may be unable to send the solutions to the farmers, due to inappropriate innovation communication methods for promoting new technologies (Azumah, Donkoh, and Awuni, 2018). The reality is that there are about 3000 farmers to 1 extension agent in some deprived areas in Ghana

(MoFA-PFJ, 2017; GSS, 2014). Of late however, Not-for-Profit Organizations (NGOs), Farmer-Based Organizations (FBOs), development partners and other stake holders in agriculture have intervened to beef up governmental efforts of communicating agricultural innovations, training extension agents, recruiting and remunerating extension officers to carry out agricultural extension services (Lamontagne-Godwin et al., 2017).

Azumah, Donkoh, and Awuni (2018), identified as a matter of priority, and concluded that NGOs, fellow farmers, research centres, AEAs of MoFA, the mass media (video, TV, and mobile phones), and middlemen were the main channels of communicating innovations to rice farmers in the Northern Ghana. It presupposes that the AEAs of MoFA are not the sole communicators of innovations to farmers of rice in Northern Ghana in recent times. This could be because AEAs do not interact with the farmers on regular or daily basis.

There are also private extension service deliveries in Ghana, which is not very well patronized by smallholder farmers (Ackah-Nyamike, 2007). Government's attempts to privatize agricultural extension service delivery in Ghana has not been successful because of affordability (Buadi et al., 2013). Smallholder farmers prefer free extension service delivery and so are unwilling to pay for the services of private extension officers (Buadi et al., 2013). Public extension service delivery in Ghana has therefore been characterized by apathy with a corresponding ineffective extension service delivery (Azumah, Donkoh and Awuni, 2018). This makes dissemination of agricultural innovations a herculean task, due to higher farmer to extension agent ratio. Hence, agricultural innovations in Ghana are normally disseminated to sampled farmers in some selected communities and are expected to diffuse within the social system (Etwire, Martey and Goldsmith, 2019).

AEAs therefore educate farmers to gain adequate knowledge, have positive attitude towards innovations for the purposes of increasing their production levels and socio-economic wellbeing (Ackah-Nyamike, 2007). Thus, AEAs may use one or a combination of methods to disseminate innovations to farmers but farmers normally form their own opinions about agricultural innovations and make their own judgements and choices. The adoptions of such innovations may be successful or sometimes come to a halt when incentive packages associated with the dissemination processes are removed or exhausted or when there is a break in the diffusion process. The farmers therefore keep hopping from one innovation to another in order to benefit from the incentive packages, but not necessarily the inherent benefits of the innovations being promoted. AEAs also tend to be very active and mobile, visiting and educating farmers on new innovations during their dissemination periods more than during their adoption periods (Lamptey, 2018). This is primarily because logistics and motivational packages are made available to the AEAs during the dissemination periods than the adoption periods. Azumah, Donkoh and Awuni (2018) noted lack of funds for transport as one of the factors reducing AEAs access to farmers.

One would assume that it is normal for AEAs to limit their interactions with farmers who have been well educated on an innovation but this is far from the truth. The farmers need more contacts and visits by the AEAs both during the dissemination periods as well as the adoption periods (Etwire, Martey and Goldsmith, 2019). This is because some of these innovations come with associated technologies, which need to be regularly explained to farmers who might not be very conversant with their applications. Farmers who lack the technical-know-hows of the associated technologies are prone to disadopt such innovations and opt for less complex ones (Rogers, 2003). The reality is that farmers normally expect AEAs to pay them a visit rather than farmers contacting the AEAs for their services. Similarly, the AEAs limit their regular visitations to the farmers for lack of logistics and look out for new innovations with incentive packages to promote to the farmers (Lamptey, 2018). So, they keep promoting one innovation after the other such that the starting of the adoption period of one innovation begins the dissemination period of another innovation.

The irony of the matter is that researchers and NGOs who want to keep their jobs and appear relevant to the times and seasons keep generating and promoting one innovation after the other in the social system. This phenomenon seems to undermine the effectiveness of public extension service delivery, so there appears to be a collaboration between researchers, AEAs of MoFA and NGOs in the promotion of innovations in recent times (Lamptey, 2018). Sometimes the NGOs and other stakeholders in agriculture finance the generation and dissemination of certain agricultural innovations of interest to them (Azumah, 2019). Some of these innovations get governmental approval and support and get to the farmers without the direct involvement of the AEAs of MoFA.

So, what appears to be public-private sector participation in agricultural extension service delivery, which started from the period of structural adjustment period from 1983 to 2006 in this country, resulted in the decline of quality public extension services (Buadi et al., 2013). Private extension agents therefore promote some innovations with juicy incentive packages to the farmers who in turn disadopt existing innovations for the new ones. The practice seems to undermine the authority of MoFA as the main governmental agency responsible for public extension service delivery in this country.

This phenomenon is like what pertains in human relationship when individuals disengage with one person to be engaged to another with higher prospects (Donald and Parker, 2012). Rogers (2003) calls this practice replacement discontinuance.

3.4.2 Agricultural innovations dissemination methods in Ghana

Agricultural innovations are developed by researchers and communicated to farmers through AEAs, using various methods and materials (print and non-print). The various methods, materials, tools, strategies and styles used by extension practitioners to create situations in which communication can take place between rural people and extension agents are referred to as Extension Teaching Methods (ETMs) (FAO, 2019; Rathod, 2016). ETMs are also known as agricultural Innovation Communication Methods (ICMs) or Innovation Dissemination Methods (IDMs) (Rathod, 2016; MoFA, 2011).

Extension methods of disseminating Agricultural innovations include farm and home visits, result demonstrations, method demonstrations, frontline demonstrations, group discussions, exhibitions, general meetings, campaigns, conducted tours, printed matter (literature), radio, television, motion pictures (movies), agricultural clinic, flag method, peripatic team visits, agricultural games, snake and ladder games (FAO, 2019; MoFA, 2011; ICAR, 2006; Cole 1981). These methods are very good but some of them such as farm and home visits, conducted tours and television shows are rarely used because they are costly (Rathod, 2016). For example, farm and home visits alone take about 50% of the AEAs' activities (FAO, 2019).

According to the Ghana Statistical Service (GSS, 2014), 52% of women and 78% of males aged 15 to 49 years in Ghana listen to radio news once every week, and 51% of women and 66% of men watch television at least once a week. GSS, (2014) also reported that farmers' exposure to print media in Ghana is much less common; while 9% of women and 17% of men read a newspaper or magazine about once every week. Demonstration methods are effective ways of disseminating innovations to farmers. Method demonstrations are used to teach groups of farmers how a particular practice is performed while result demonstrations are employed to show individual farmers the outcomes of innovations that has been practiced for some time (FAO, 2019; Anandajayasekeram, Puskur, Sindu and Hoekstra (2008). Method demonstrations are effective in teaching because they enable farmers to see, hear, handle, discuss and practice the innovation before adoption whereas result demonstrations induce the farmers' interest in the innovation. Result demonstrations are as well employed to help farmers compare obstinate innovations with modern ones (FAO, 2019; Anandajayasekeram et al. (2008). Azumah, Donkoh, and Awuni (2018), discovered that field demonstrations, farmer-to-farmer visits, and house-to-house teaching of farmers were the most effective ETMs in Northern Ghana. That is because farmers who are trained by these methods grasp the concepts faster and better than the other methods, and they help to disseminate the innovations to other farmers at less cost. ETMs are categorized into two broad groups: (1) by the natures of contacts or usage and, (2) by the form it takes. By the nature of contact or usage, ETMs are grouped into individual contacts, group contacts and mass contacts/media as shown in Table 3.3:

Table 3. 3: Classification of extension teaching methods by nature of contacts

Individual Contacts/Usage	Group Contacts/Usage	Mass Contacts/Media/Usage
Farm and Home Visits	Method Demonstrations	News Stories/Newsletters
Result Demonstrations	Meetings/Discussions	Telephone Messages
Personal Correspondence	Leaders' Trainings	Publications/Journals
Telephone Calls	Community Fora	Television/Radio/Internet
Office Visits	Conducted Tours	Answering Systems
Counselling	Field Days/Symposia	Satellite Programmes
	Camps/Clinics/Contests	Exhibitions and Leaflets
	Workshops/Seminars	Interactive Conferences
	Short Courses/Interviews	Posters/Circulars/Bulletins
	Organized Clubs/Debates	Computer Aided Interactive Learning

Source: Cole, 1981; ICAR, 2006; Rathod, 2016; FAO, 2019

3.4.2.1 The Nature of Extension Teaching Methods

The three extension teaching methods are further classified as direct contacts (individual and groups contacts) and indirect contacts (mass media/contact). The indirect contacts do not work in isolation. Rather, they stimulate the need for direct contact in the target audience to seek further clarification from extension officers in the dissemination process.

The commonest methods of extension service delivery are individual, group, and mass media methods, none of which can be deemed the best since each of them has merits and demerits. Anandajayasekeram et al. (2008), opined that the choice of ETMs depends on several factors including the land tenure system in the locality, social organization, and availability of resources. For instance, group methods of extension service delivery could be more effective compared to individual methods at places that practice communal land tenure system. Group meetings, farmer field days/schools, and visitations schools (lecture methods) could be suitable under communal land tenure system and in homogenous societies than heterogenous societies that uphold individual tenure system of land management.

Person to person methods are more appropriate under the individual land holdings. Mass methods such as radio and television broadcasts are usually used to create farmers awareness of innovations followed by a group or an individual method or both, to disseminate the innovations (Rathod, 2016). These are done to harness the advantages of each method in the dissemination process. The essence of agricultural extension services is to consciously communicate information to help farmers become aware of innovations and opportunities available to them for enhancing their farming activities and welfare.

3.4.2.2 The Forms of Extension Teaching Methods

The form of extension teaching methods could be written (bulletins, leaflets, news articles, personal letters, circular letters, booklets and pamphlets) or spoken (general and special meetings, conferences, farm and home visits, official calls and radio). The form could also be visual/objective (demonstrations, exhibitions, charts, motion pictures, or movies, photographs, slides, film strips, models and specimens) or audio visual (television, meetings at the visual meetings site of demonstrations, involving motion pictures, charts and sound movies, radio vision, other visual material, drama, VCR, sound synchronized slides, internet, and CD-ROM) (FAO, 2019; Rathod, 2016; ICAR, 2006). The audio visuals can further be classified into audio, visual and audio-visual, as shown in Table 3.4:

Table 3. 4: Classification of audio-visual extension teaching aids

Audio	Visual	Audio-visual
Tape recorder	Flash cards	Cinema projector
Radio	Black board	Television
Recording	Pictures	Drama

Source: Rathod, 2016

The audio-visual can also be categorized into projected audio visuals (cinema, slide projector, opaque projector and overhead projector) and nonprojected audio visuals (flashcards, funnel graphs, charts, pictures, blackboards, bulletin boards, models, pictures, posters, specimens, exhibits, photographs) (Prakashkumar, 2016).

A combination of methods such as written and spoken or visual and audio-visual is an effective way of dissemination of agricultural innovations. For example, a film show can be followed by a discussion with farmers or farm families. Obeng (2013) classifies videos as projected visual aids used by extension officers in educating farmers. There are also new communication technologies that help in teaching or disseminating information to farmers. They include micro-computers, video texts, electronic mails, interactive videos, and teleconferencing (FAO, 2019; Rathod, 2016; ICAR, 2006). Such materials and means of education are more suitable for educated and sophisticated farmers. The choice of ETMs and materials to be used would therefore depend on the nature of the target audience, purpose of the education, time and other resources available for the training.

3.5 Factors affecting adoption and disadoption of agricultural innovations

Many studies that analyzed factors of innovation adoption by farmers in developing countries used simple ad-hoc models like ordinary least squares (OLS), probit or tobit regressions. The models are estimated for technology adoption using variables that represent socio-economic characteristics of farmers, and institutional and bio-physical factors. The socio-economic characteristics of farmers include farm size, tenurial status, farmers' education level, farming experience, family size, and gender. The institutional and bio-physical factors also comprise irrigation, credit, extension contact, and membership of farmer associations, proximity to input and out markets/bus terminals/extension offices (Asfaw and Admassie, 2004). A small number of these studies explain in unambigious terms the theories behind such ad-hoc modelling (Nkamleu and Adesina, 2000). This assumes the principle of utility maximization by rational farmers. Kijima (2008) found that the use of enhanced rice varieties in Uganda is affected by opportunity cost and risks faced by households as well as farmers exposure to the varieties.

The studies on agricultural innovation usage in developing nations find the underlisted factors as the most important in hinderances to adoption of agricultural innovations: risk and uncertainty, knowledge and education, profitability, input availability, credit constraints, tenure security, labor availability, biophysical factors, market incentives and social networks (Dercon and Christiaensen, 2011; Teklewold, Kassie and Shiferaw, 2013). Risk and uncertainty, knowledge and education, profitability and input availability are socioeconomic factors of farmers while credit constraints, tenure security, labor availability, market incentives and social networks are some of the institutional factors. The biophysical factors include pests and diseases, waters tresses and uptake of nutrients from the soil by plants roots. The factors that affect adoption also affect disadoption. Price of inputs and outputs also affect adoption and disadoption.

3.5.1 Socioeconomic factors/circumstances of farmers

One of the important issues in the study of agricultural innovations in helping to identify factors that facilitate long-term adoption of innovations is disadoption. Neill and Lee (2001) reported that farmers in Honduras disadopted the practice of crop rotation involving legume and maize at a rate of 10% per annum, due to the presence perennial weed species that increased labour costs. These increased labour requirements were also noted by Moser and Barrett (2006) as reasons for the disadoption of SRI in Madagascar. Marenya and Barrett (2009) likewise discovered that farm size, value of livestock owned, off-farm income, and supply of family labour, educational level, and female household headship, are significant factors that discourage farmers from continuously adopting integrated natural resource management approaches in the western parts

Kenya. Rahman, Wiboonpongse, Sriboonchitta and Chaovanapoonphol (2018) revealed that rise in Jasmine price, access to irrigation facilities and formal education were important fators that affected Jasmine adoption in Thailand. Similarly, Azumah (2019), identified age, sex, location, FBO membership, subsidy for farm input, training opportunities, access to farm credit, household size, and perception of farmers about changes in climate, as factors that significantly affected rice farmers' adoption of agricultural technology (irrigation) in Northern Ghana. The Agricultural Production Survey for the Northern Regions of Ghana (APS, 2015), reported that about 90% of respondents were male and 96% of them being household heads. Kehinde and Adeyemo (2017) revealed that household size and membership of organizations were determinants of disadoption of certified seeds. They also discovered that membership of farmer associations, access to farm credit, sex, and farm size were important determinants of farmers' disadoption decisions on pesticides. Kehinde and Adeyemo (2017) as well found out that farm size, contact with AEAs, and sex were specific factors which affected disadoption of fertilizers and other agronomic practices. It means all these facors should be considered in stepping up efforts to reduce disadoption of agricultural innovations.

On the other hand, access to relief food, ownership of CA tillage assets (cattle) and equipment (Chaka hoe), gender, location, education levels attained, and CA training sessions attended were not significantly associated with disadoption in Zambia (Habanyati et al., 2018). Farmer participation in training sessions on CA significantly limited the probability of CA disadoption in Zambia (Habanyati et al., 2018). This is because training increases farmers' ability to obtain, retain, process, and utilize information relevant to the innovations, which lead to greater adoption and sustainability of innovations (Wozniak, 1984). Similarly, when the educational levels of farmers are too low, it would take a lot of efforts to introduce modern technologies to them (Donkoh and Awuni, 2011). Educated farmers are more prone to adoption because they have tendency to co-operate favourably with other farmers (Martey et al., 2013). These findings are in tandem with those of Nyanga (2012) that training in CA significantly enhance the chances of its adoption. Lack of adequate knowledge about CA also contributed to technology disadoption in Zambia (Habanyati et al., 2018). These assertions attest to the fact that farmers inability to attend training sessions on innovation dissemination regularly are likely to be left behind as far as getting latest information on innovations is concerned. That might cause the farmers to disadopt the latest innovations available.

Besides, lack of adequate knowledge of agricultural technologies can be caused by lack of extension visits to farmers' farms. Younger farmers are also less likely to disadopt improved rice varieties than aged farmers. This is because young people have many years ahead of them to continue adopting innovations before they become aged or retire from farming. This gives avenues for extension to specifically concentrate on young farmers and use rice to curb food insecurity in the future. Martey et al. (2013) also posits household heads that are married also have a tendency of adopting modern rice varieties better than unmarried male household heads. The reason is that married male household heads are usully supported by their spouses to produce, process and market rice (FAO, 2016).

Similarly, household size positively influences farmers' adoption decisions of agricultural innovations because members of the households serve as sources of farm labour. Socio-economic characteristics of farmers including age, income, group membership, family size, educational level, farm plot size and number of contacts with AEAs affected adoption of modern technologies in rice production in Imo State of Nigeria (Onyeneke, 2017). These socioeconomic factors of farmers need to be taken into consideration in any adoption or disadoption studies.

The gender dimention to adoption and disadoption of agricultural innovations also need not be ignored. That is because males and females adopt agricultural innovations differently, due to several reasons (Donkoh and Awuni, 2011; Doss and Morris, 2001). Gender is a usuaslly a controversial factor in adoption research because unlike female farmers, male farmers are capable of participating in different meetings and training sessions. Therefore, male farmers have more access to information on improved technologies than females, who are ofted occupied with domestic chores (Kehinde and Adeyemo, 2017; Martey et al., 2013). The association of women's rights in development (AWID) (2004) and Jacoby (1991) opined that changes farming systems affect men and women in different ways. For Kokki and Bantilan (1997), this is partly due to variations in perception about innovation that exist between females and males in farm households. The females normally see technology in terms of how workable it is and aspects of fatique associated with its usage, while the males are mostly concerned about financial gains to be derived from using the technology. The impacts of innovation disadoption are likely to be higher for female farmers than for male farmers. Adoption of improved rice varieties is likely to be affected by gender because in many communities, there exist gender biases to the disadvantage of women. So, females are likely to have lower rates of innovation adoption than their male counterparts.

In Ghana, the female gender is normally associated with smaller farm plots than the male gender. Also, the majority of women own no lands, which goes a long way to affect adoption of agricultural innovations. Similarly, in some parts of SSA, women find it difficult to hire labour for their farm operations than men. So, it limits women's ability to adopt innovations than men.

3.5.2 Institutional and bio-physical factors

The most important determinants of technology adoption in countries comprise the country's human capital endowment, type of government, degree of openness to trade, and adoption of predecessor technologies (Asfaw and Admassie, 2004). Normally, old technologies tend to persist for a while and fade out after new technologies similar to the existing ones are introduced. This phenomenon can be explained by vintage human capital models of technology adoption, which states that the adoption of innovations result in technology specific experiences, called vintage human capital. These experiences reduce the incentive to adapt to new technologies, for fear of losing the value of those experiences. Hence, conservative adopters rather adhere to existing technologies than switch to new innovations. Conservatism is therefore an incentive to continuous adoption of technologies.

Though adoption decisions fade with time, the vintage human capital experience would rather enhance continuous technology adoption than disadoption. However, according to the vintage capital theory new technologies instantaneously dominate existing ones, which is the reason for the disadoption of older innovations. This seems to explain why older and existing innovations dissipate with time compared with new technologies, possibly due to depreciation. The vintage capital theory is useful for considering principles behind technology adoption and capital acquisition but does not give explanations to technological adoption disparities (Asfaw and Admassie, 2004).

Theories on innovation adoption and factor endowments elucidate potential factors underpinning differences in technology adoption (Asfaw and Admassie, 2004). These theories postulate that high educational statuses are important precursors to computer-technology adoption (Nkamleu and Adesina, 2000). This is not surprising because computers are mostly used in educational circles, especially among the elites, for academic and sophiscated operations. The less educated may also use computers for simple operations like marketing, watching movies and keeping simple records or playing games.

Theories and empirical evidences suggest that factor endowments partly drive technology adoption dynamics.

However, they are parts of the whole story. It is therefore essential to consider other equally relevant variables like trade. Trade might affect technology adoption rates in a countries through enertia or the forces of demand and supply. Market forces reveal that underdeveloped and developing countries that import goods and services from countries that are technologically advanced stand the chance of getting more exposure to new technological developments. Such underprivileged countries will eventually be more likely to adopt the technologies that are exposed to them (Nkamleu and Adesina, 2000). Hence, high-tech imports tend to 'push' the knowledge down the trade channel. This creates an unpleasant situation called 'dumping', whereby advanced countries offload their unwanted goods and services unto the less privileged countries, who also sometinmes imbibe them hook, line and sinker. Hence, without the possibility of re-ivention, it becomes more detrimental adopting some innovations than not adopting them. For instance, as discussed early on, continuous use of synthetic fertilizers have rendered some farm lands, especially in Northern Ghana, chemical fertilizer dependent without which those lands are unproductive. The best option in such situations is to adapt the innovations adopted to suit the prevailing conditions of a particular social system, instead of disadopting them.

Greene (2008) opined that analyzing technology disadoption without controlling the adoption and disadoption of other complementary and subplementary technologies could lead to bias, inconsistent and inefficient parameter estimates. Greene's (2008) admonition is worth heeding because other interrelated innovations, goods and services serve as complementary products of factors that can influence the disadoption of the innovations in question. Other specific institutional factors include credit, demand for complementary inputs, access to transport, access to certified seeds, and access to extension services. Specific institutional factors also include land tenure system, prices of inputs and outputs, and bio-physical stresses. A brief discussion on each specific factor would suffice here:

3.5.2.1 Credit: Access to and cost of credit are among the key institutional factors affecting adoption of agricultural innovations. Access to credit facilitates the use of risky innovations by reducing financial difficulties and by enhancing households' abilities to bear risks (Simtowe and Zeller, 2006). If the cost of credit goes up for smallholders, that extra burden will limit the possibility of adopting new technologies by smallholders (Sunding and Zilberman, 2000). Large scale farmers with higher affordability margins would access farm credits and thereby adopt new technologies easier and better than smallholder farmers. Hence, credit institutions in Ghana advance credit to smallholder farmers in solidarity groups so that the groups serve as guarantee to reduce the possibilities of loan default among farmers in the absence of collateral security (MoFA, 2012). The guarantee mechanism is designed in a way that makes credit advancement and repayment easy. The groups also serve as social security for individual farmers who would have become vulnerable or victims to exploitation by financial institutions. For Zakaria, Ansah, Abdulai, and Donkoh (2016), farmer groups give an avenue for social capital by getting chances to gain mutual support, knowledge and skills from fellow farmers and other stakeholders involved in agricultural.

Credit ccessibility prevents disadoption of the maize crop among farm households in Ethiopia (Mateos and Dadzie, 2014). Similarly, most rice farmers in Madagascar abandoned the SRI since it significantly requires extra labour inputs during the year when money is hard to come by and labour is in high demand (Moser and Barrett, 2001).

Hence, poverty and excessive dependence on rainfall to farm are some of the key factors of agricultural technology disadoption. Mateos and Dadzie (2014) also discovered that the systems of adoption and disadoption of improved technologies among poor farmers imply increaments in credit limits to help sustain adoption and prevent disadoption of cash crops.

3.5.2.2 Demand for Complementary Inputs: The dissemination of innovations may increase demand for complementary goods and when the supply of these goods is limited, adoption will be hindered (Donkoh, Eliasu, Sitsofe, and Ansah, 2016). For example, some high yielding crop varieties like maize need more use of water and fertilizer. Hence, private or public provision of wells or irrigation facilities, and the institution of fertilizer manufacturing and supply services would remove these constraints and contribute to the spread of improved wheat and rice varieties significantly. Adoption rates in high yielding crops would increase if complementary disease-control mechanisms are available.

3.5.2.3 Access to Transport: Inaccessibility to transport for manure, higher demand for labour, absence of incentives, and bad leadership of farmer associations were significantly associated with disadoption of CA in Zambia (Habanyati et al., 2018). Innovation disadoption is also positively related to lack of access to input and output markets (Simtowe and Mausch, 2018). This is because having access to markets make farmers get access to inputs such as seeds as well as find opportunities for marketing their products.

3.5.2.4 Access to Certified Seed: Inaccessibility to seeds was one of the main reason for disadopting improved sorghum varieties in Tanzania (Simtowe and Mausch, 2018). This can pose a huge challenge to farmers who are far from seed markets, since proximity to input markets enhance adoption of innovations.

3.5.2.5 Access to Extension Services: Adoption of new technologies is often affected by farmers' contact with extension service providers, since AEAs give improved inputs and technical advice to farmers. Donkor et al. (2016) revealed that accessing extension delivery services significantly enhances adoption of inorganic fertilizers, which in turn exerts positive influence on rice productivity in Ghana. Donkoh and Awuni (2011) blamed the problem of poor extension delivery system in Ghana and many other developing countries on improper motivation of the inadequate extension staff. However, by consorted efforts, researchers and AEAs team up to facilitate the flow of information and providing feedback in Agricultural Technology Systems (Lamptey, 2018; Donkor et al. 2016).

3.5.2.6 Land Tenure System: Land tenure insecurity in farming communities hinders farmers' accessibility to credit, farm investments, innovation adoption and the possibilities of sustaining agricultural development and productivity. If land tenure is secure, people's standard of living improves relatively based on the availability of household resources and conducive atmosphere for production. Doss and Morris (2001) argued that the presence of a well-functioning land tenure system may facilitate adoption of innovations which require adequate skills for their operation. Farmers in such systems might increase their farm sizes if they rent land from other farmers to enable them practice farm mechanization. Dube and Guveya (2013) also observed a powerful association between stable land tenure systems and investment in farms of small scale and commercial farmers in Zimbabwe. It means adoption of agricultural innovations in Ghana would be enhanced by a secure land tenure system coupled with complementary inputs and infrastructure.

3.5.2.7 Bio-Physical Stresses: Birds, insect pests, diseases and weeds reduce the possibilities of obtaining high yields in rice production (Savary et al., 2000). The presence of biotic stresses like diseases and pests, significantly influenced farmers to disadopt modern sorghum varieties in Tanzania (Simtowe and Mausch, 2018). Pest infestations mainly encouraged disadoption of a sorghum variety called Tegemeo but it evidently indicated the need to take future breeding efforts seriously.

Insects such as terrestrial arthropods and other pests and insects likewise visit rice ecological systems to attack rice stands and cause further concerns (Savary et al., 2000). There are about 20 insect-pests, including stem borers, gall midge, defoliators, and vectors (leafhoppers and plant hoppers) that cause collosal damage to the rice plant directly or indirectly serve as vectors to transfer diseases to the rice crop. The greatest variety of rice pests are domiciled in China and India. The Chinese have therefore invented enough genomic strategies to fight the infestation of rice pests by keeping the number at bay. However, developing countries that grow rice are still depending on the traditional methods of pest control in their rice farms (Savary et al., 2000).

Weeds in rice farms are grouped into three: grasses, herbs and broad-leaves (Savary et al., 2000). They all compete with rice palnts for space, air, water, sunlight and soil nutrients, but they can be controlled with herbicides or by rogueing. They can also be controlled biologically by allowing herbivours to feed on them but this method is not normally recommended because most herbivours like ruminants and poultry also feed on rice. Pigs for instance might end up wallowing in the mire in the rice fields while goats might not dare entre such fields since they are water fobia. Besides, this practice of using animals to feed in crop stands is only applicable in mixed farming and under plantation crops like pineapple, oil palm, coconut, citrus, guava, teak, rubber and raffia.

3.5.2.8 Input and Output Prices: Input prices tend to be higher than output prices, especially during the farming season. Inputs such as improved seeds, fertilizers, pesticides, weedicides, labour, farm tools and equipment normally come with custom made prices that leave famers who want to use them with no options but to try and obtain them as such. Farm output normally do not have any fixed prices, the prices are determined by forces of demand and supply. Also, due to the perishable nature of most agricultural products, their prices tend to be low during the peak season and high during the lean season. Their prices are also affected by location such that even within the same season, farmers at remote areas tend to sell their products at lower market prices than their counterparts that are closer to big markets or city centres with accessible roads. This phenomenon is such that most farmers do not have a say when it comes to determining the prices of their own outputs. They are also almost always at the mercy of middlemen and aggregators or processes who offer them peanuts for their hard work in the farm. The situation is such that the farmer either accepts the prevailing market price or he keeps his produce, which he cannot store for a very long time or he needs to sell to make ends meet. Many farmers therefore do not break even at the end of the farming period. The only motivation they have for farming year after year is the fact that their very existence and survival depends on it. So, they normally do cost their inputs against their outputs to avoid depression.

3.5.3 Locational factors

According to Awotide, Diagne, and Omonona (2012) the factors affecting the choice of improved rice variety to be planted in a given location include; the amount of rainfall, temperature, iron content in the soil, presence of diseases and pests such as rice blast (a fungus) and leaf-eater (an insect), as well as tastes and preferences of the local people. For example, in areas where annual rainfall is scanty, rice is grown as a rain fed upland crop (MoFA, 2011; ICAR, 2006). Agro Ecological conditions therefore play a key role in the adoption and diffusion of improved crop varieties among farmers. Usually, farmers prefer high yielding crop varieties that are hardy and acclimatized to the local climate and management practices (Aryal et al., 2018). Bruce (2015) found that uncontrolled floods affected field operations like pests control, fertilizer application, and harvesting, leading to poor rice outputs in Northern Ghana.

3.5.4 Socio-cultural, situational and technological forces

Modern technologies adoption could also be hindered by socio-cultural, situational and technological factors. That is because the innovation may not be in consonance with social norms, values and lifestyles of people. They may also not in compliance with the economic strata; or be technically complex, leading to use-fobia, obsolescence and risk (Rogers, 2003). In adoption research, it is common to examine the personal and soco-economic characteristics of farmers so as to understand their relative influence on the farmers' adoption behaviours (Umunna, 2010).

In the first place, adoption depends on people's ability to access information, and use it later. This ability depends on certain socio-cultural, economic, personal, political and locational variables. It is also based on how appropriate the information is, the credibility of the medium of communication, and the characteristics of the communication agent (Umunna, 2010; Rogers, 2005). For example, if an Extension Officer, is perceived by the farmers to be a dishonest, untrustworthy and an unreliable personality, any information s/he disseminates would not be regarded as useful or important.

Farmer groups and associations also spead up the adoption rates and diffusion of new agricultural practices within the social system. So, any innovation adopted by leaders of farmers associations or contact farmers easily diffuse within the social system. Even though adoption is an individual affair, disadoption of that innovation occurs and spreads faster among the famers in homogeneous societies. Farmers who are technologically inclined and patronize the mass media also adopt of agricultural via the mass media. This because the mass media positively affect the dissemination and adoption of agricultural innovations (Sezgin et al., 2011) and should be used to introduce the innovations to farmers for massive adoption.

3.5.5 Environmental factors

The Industrial Revolution, which started from the mid to late 1700s, led to a build up of green-house gases in the atmosphere. These gases keep trapping more heat from the skies to the earth's surface. Paramount among these gases are carbon dioxide and methane. The level of carbon dioxide in the atmosphere has increased for over 45% since the Industrial Revolution, leading to climate change (FAO, 2013).

The term climate change refers to any changes in the average weather conditions over a period of at least 10 or more years. It includes changes in the patterns of temperature, rainfall or wind, which pose serious threats to crops, humans and animal life on earth. Farmers observe the weather, that is, changes in atmospheric conditions of rain, snow, clouds, winds, floods or thunderstorms, which occur locally within short intervals ranging from minutes to hours and days, to help them adjust to the climate (FAO, 2013). Though developing countries contribute only 10% to climate change globally, the poor in farming communities in underdeveloped countries are the most vulnerable and most affected by climate change (Maskrey, Buescher, Peduzzi and Scaherpf, 2007). This is due to their unfavourable geographical location, few assets and heavy reliance on sources of income that are climate-sensitive (World Bank, 2013).

Lacombe, McCartney, and Forkuor (2012) analyzed climate patterns in Ghana for over four decades and discovered that humidity and rainfall are reducing but temperatures and evapotranspiration are on the rise. It is therefore important to increase farmers' awareness and access to more climate change adaption mechanisms, and reduce the cost of the coping mechanisms for poor and local households in underdeveloped countries.

Adaptation requires adjustments to the hazardous effects of climatic changes (Helling, Corner, Heiss and Berlin, 2015). Farmers have therefore developed various coping strategies to adapt to the phenomenon.

Some of these copying strategies include adjusting planting time, use of drought resistant varieties and practicing shifting cultivation or crop rotation (Ali and Erenstein, 2017). Others are; mixed farming, economical use of certain inputs, adopting new farming practices, alternating farming systems and undertaking off-farm ventures (Howden et al., 2007). The most practiced coping and adaptation mechanisms in the study area are herbicide and pesticide application (88.7 %), row planting (74.8 %), mixed farming (70.4 %), mixed cropping (65.7 %) and crop rotation (50.4 %) (Azumah et al., 2016). The most uncommon adopted coping mechanism by rice farmers in the Northern Ghana are irrigation (1.3 %), crop diversification (2.2 %), farm dugouts (3.9 %) and bunding of farms (5.2 %) (Azumah et al., 2016).

Lolig et al. (2014) outlined some adaptation mechanisms to drought as follows: appealing to idols; depending on uncultivated fruits and plants for food; depending on information from AEAs; late planting; depending on petty trade; practicing lean season farming; and supplementing local products with imported foods. Some coping mechanisms during flooding includes depending on wild fruits and plants for food, depending on extension information, cultivating crops on uplands and hills, early planting, petty trading and purchasing food from groceries to supplement farm produce (Lolig et al., 2014). Others include praying and offering sacrifices to God, engaging in off-farms jobs, migration and doing nothing about the situation (Amoako, Donkoh, and

Ansah, 2017). Poor Soils are other environmental factors that affect adoption and disadoption.

3.6 Determinants of rice output/yields

Improved rice varieties have the potential for higher yields (Angelucci et al., 2013). Favourable rainfall patterns, good soil fertility, farm size, absence of pests and diseases can also enhance rice output. Ragasa et al. (2013) noted that rise in rice output in the Northern Region was largely as a result of expansion in cropping area but not because of farm input use and improvement in farming methods, contrary to present population statistics in Ghana. Many (50%) of agricultural productivity and growth in the world is attributed to increased amount of fertilizer usage (Toenniessenn, Adesina, and DeVries, 2008). That has helped to improve incomes and welfare of farmers in many countries. A stochastic production frontier analysis of factors affcting Jasmine productivity in Thailand revealed that land availability, irrigation facilities and fertilizer usage were the most significant variables (Rahman et al., 2018). There is ample evidence that the adoption of improved rice seeds in Africa leads to increased output (Bruce et al., 2014; Wiredu et al., 2010; Uaiene, Arndt, and Masters, 2009). Bruce et al., (2014) observed that a 100% increase in farm size led to a 26% increase in rice output and 100% increase in labour led to 21% rise in output, but a 100% increament in certified seed usage led to a 5% rise in output, and 100% rise in fertilizer application led to 24% increament in rice output. It means the adoption of improved rice varieties alone cannot lead to maximum output unless other complementary inputs such as land, labour and fertilizer are in place.

Pests cause 33% production loss in India (Directorate of Weed Research, DWR, 2015), consisting of pest weed (12.5%) major insects (9.5%) and diseases (6.5%) as well as other pests (4.5%). It means weeds are the most important pests in rice farming. Therefore, minimizing the pest losses can be the most important approach to increased productivity (Dibyendu et al., 2017). Dercon (1993) opins that prices remain the most influential factors by which appropriate economic policies are formulated to affect agricultural variables like quantity of output, direction of supply, levels of farmers exports and incomes. It means rice farmers' output and income are largely influenced by market price. Production decision of rice farmers are therefore affected by both monitory and non-monitory factors.

The monitory factors include producers` price of rice, producers` price of substitute field crops like maize, world price of rice and maize and prices of fertilizer. The non-monitory factors are irrigation, investment in research and development, extension services, capital and credit access, favourable agroclimatic conditions, development of local infrastructure, abundant supply of farm labour, increase in farm sizes and income levels of rice farmers (Bingxin and Shenggen, 2009). Pricing and non-pricing motivation mechanisms such as increasing producer prices and provision of irrigation facilities to domestic rice farmers can go a long way to improve the domestic rice production in any country. The most critical determinants of rice output are environmental factors such as rainfall, humidity and temperature (Tanko, Iddrisu, and Alidu, 2016).

Optimum rice yield in Ghana is pegged at 2.5 tons/hectare but achievable yield based on on-farm trials is 6 to 8 tons/hectare (MoFA, 2011). In spite government interventions in the rice sector, lower adoption rates of inputs and modern technologies has become the main reason for this rice production gap (Ragasa et al., 2013). Rice productivity in the study area is mainly influenced by farmers' age, understanding of integrated soil and water conservation, seed and use of herbicides (Azumah and Zakaria, 2019).

Ragasa et al. (2013) compared the mean yield of improved rice varieties in Ghana and discovered that the use of fertilizer, certified seed, and herbicide led to higher yields compared to the use of enhanced rice varieties in the Northern Region. They also discovered that farmers who practiced irrigation bunding, leveling, and puddling had substantially higher yields than those who depended on rainfall and traditional farming practices. Planting in rows and priming of seeds are also lead higher yields in all rice farming but it is not certain whether higher yields are recorded in farms that follow recommended agronomic practices than farmers who do not observe these recommended practices (Ragasa et al., 2013). These recommended practices include timely fertilizer application, proper spacing, transplanting, broadcasting and dibbling methods of planting, plowing in crop residue, and manure usage. It would take an intensive modeling to find out the role different inputs and practices play on output to support the average yield analysis made by Ragasa et al. (2013).

Ayedun and Adeniyi (2019) employed multiple regression model with semi-log function to model rice output and identified factors influencing it. They discovered that farm size, quantity of seeds sowed, quantity of fertilizer applied, and number of labourers hired, number of man-days used and ploughing, were the positive significant factors that influenced rice output at 1% alpha level. Ayedun and Adeniyi (2019) also observed that family labour used and adoption of enhanced rice seeds were positive and significant at 10% level. They also found that farmers' age was negatively related output of rice and significant at 10% level of probability. Ayedun and Adeniyi (2019) likewise observed that holding other variables constant, planting of enhanced rice seeds increased output of rice by 18% and that enterprises with modern rice seed adoption had the highest profitability and Benefit: Cost ratio than other farming enterprises. They realized that farmers had low yields (<2000kg) despite the fact that they used primary inputs and practices like improved seeds (43%), herbicides (80%), insecticides (85%), fertilizers (70%), mono-cropping (95%), literacy (65%), irrigation (0.5%) tractor (8%). The study recommended the need to increase farmers' awareness levels, help farmers to obtain hectares of land that will encourage large scale farming, promote mechanization services and to continue to encourage mono-cropping and make available irrigation facilities in the communities to improve productivity. It means the use of improved seeds has the probability of increasing rice yields by 18% but farmers' age has no effect on increasing rice yields. Secondly, the fact that farmers use basic farming inputs does not guarantee high yields except they adhere to proper farming methodologies and agronomic practices.

Tanko et al. (2016) used a multivariate empirical regression model to determine the parameters of the internal and external factors that influence rice yield in the Northern Region of Ghana. They saw that yield increased with a corresponding increase in producer price of rice and labour availability, due to improvement in farm income and efficiency of labour in farming activities. Yield decreased with a corresponding increase in farm size and fertilizer price, due to inadequate fertilizer application. Yield also increased with an increase in producer price of maize due to a shift in resource allocation, which favoured maize production. Tanko et al. (2016) recommended that government improves farmers' ability to obtain fertilizer and credit to enable them increase fertilizer application rates on farms and strengthen the incomes of farmers to boost indeginuous rice production. Increase in fertilizer price decreases rice yields because farmers tend to apply less fertilizers than required for their rice fields due to the problem of affordability. That becomes a disincentive to adoption of improved rice varieties because farmers have the perception that improved rice varieties require more fertilizers and agrochemicals, which are sometimes either unavailable or unaffordable. However, a reduction in the prices of fertilizers and agro chemicals with a corresponding increase in the price of maize would still result in low yields of rice because the two commodities are competitive goods. Farmers would therefore divert resources and inputs to produce more maize than rice. Rice farmers are therefore expected to uphold recommended agronomic practices to ensure higher output.

3.7 Conclusions on the literature review

The review revealed that innovation adoption is associated with higher output, higher incomes, and lower levels of poverty, enhanced nutritional statuses, lower comsumer food prices, increased job opportunities and incomes for farm labourers. The economic benefits of adopting improved rice varieties by famers are therefore many and varied.

The review showed that several factors including socioeconomic and demographic characteristics of farmers; institutional, locational and environmental factors; biological and physical stresses; social, economic, cultural and technological factors; and characteristics of the innovation; among others, affect innovation adoption and disadoption.

Disadoption is the process of stoppage or noticeable reduction in the use of a previously valued behavior or possession, which can occur either abruptly or over the course of a long period of time. But disadoption can simply be termed as abandonment of innovations while adoption can be considered as the acceptance, use and continuous use of innovations. The nature of disadoption shows the disadoption process can be fairly complex and intricated, which can be catalyzed by a variety of external and internal factors, the effects of which may be cumulative. Disadoption can therefore not be simply analyzed with only univariate models such us probit and logit.

Although adoption studies abound globally and in Africa, including Ghana, disadoption studies are very few in the world and rare in Ghana. This is because many researchers ignore disadoption studies. Besides, there has not been a single study that combined adoption and disadoption of improved rice varieties in Ghana, prior to this study.

CHAPTER FOUR

THEORETICAL, CONCEPTUAL AND EMPIRICAL FRAMEWORKS

4.0 Introduction

This chapter discusses the theoretical, conceptual and empirical frameworks of the study. The first section of the chapter discusses the theories of innovation adoption and disadoption while the last section provides conclusions on the theoretical, conceptual and empirical frameworks.

4.1. Theories of Innovation Adoption and Disadoption

Technology usage occurs in three different stages: Pre-adoption, adoption, and post-adoption. At the pre-adoption stage, potential adopters may assess an innovation and think of its adoption. They form an opinion about the possibilities of adopting the innovation and they finally adopt or reject it, during the adoption stage. The adopters either continue to adopt the innovation or discontinue its adoption, during the post-adoption stage. If they abandon an innovation, they try to look out for another innovation to substitute it (Kim and Crowston, 2011). The practice of abandoning a technology after adopting it is known as disadoption. Disadoption of innovations is therefore a post-adoption phenomenon.

Theories and models in innovation adoption play a critical role in adoption research because they give impetus to guide research design and interpret results of research (Kim and Crowston, 2011). There are three distinct uses of theory (Eisenhardt, 1989). Theory can serve as a primary guide to research method and collection of data. Theory can also be used to guide the data collection and analysis processes. Theory can as well be used as a final outcome of the research. Since innovation adoption studies primarily take positivist methodology, theories and models are employed to guide the study and interpret its outcomes (Punch, 2005).

Theories provide a set of independent variables which can be used to forecast the occurrence of a particular condition while a model is a step by step description of a system, a theory or a phenomenon that explains its known or perceived characteristics, which may be used to further research into its characteristics. A model is also a construct used to understand, explain, predict or control a phenomenon under investigation, which may be an abstract representation of parts of the real world (Burch, 2003).

Several theories and models are formulated to study innovation usage and post-adoption behaviours. These theories and models focus on people's intentions to engage in certain behaviours as their main theoretical foundations. These theories include the Theory of Reasoned Action (TRA) and Theory of Planned Behavior (TPB) that are widely employed in innovation adoption research. TRA and TPB are fundamental theories that give the fundamental theoretical backgrounds for other innovation adoption theories comprising Technology Acceptance Model (TAM) and Enhanced TAM (Kim and Crowston, 2011).

4.1.1. Theories and Models of Technology Adoption

The primary assumption of TRA and TPB is that people intentionally determine whether to practice or not to practice certain behaviours. For this reason, the innovation adoption motives are normally considered as the main dependent variables that are affected by various explanatory variables. This study reviews major theories focused on innovation adoption, including TRA and TPB and their applied theories, Innovation Diffusion Theory, and Social Cognitive Theory.

4.1.1.1 Theory of Reasoned Action (TRA)

This is a notable social psychology theory formulated by Fishbein and Ajzen (1975) to explain people's behaviours based on their behavioural motives, which are caused by their attitudes towards the behaviours and perceptions of the subjective norms concerning those behaviours. TRA is used in innovation adoption study as a basic theoretical framework, and it can also be blended with other theories and models. (Brown, Massey, Montoya-Weiss, and Burkman, 2002).

TRA is the first theoretical concept to get genral acceptance in innovation adoption study (Fishbein and Ajzen, 1975). TRA is a universal behavioural theory that models the attitude-behaviour relationships of people. This theory postulates that individuals would adopt innovations if they could perceive positive benefits (outcomes) associated with their adoption.

4.1.1.2 Theory of Planned Behaviour

TPB is similar to TRA, and it is a well-known social psychology theory that also stipulates that specific salient beliefs affect behavioural motives and later behaviours (Ajzen, 1991). Compared to TRA, TPB has another construct known as Perceived Behavioural Control (PBC), which is defined as "one's perceptions of his/her ability to act out a given behaviour easily" (Ajzen, 1991). It is precipitated by the availability of skills, resources, and opportunities, as well as the perceived significance of those skills, resources, and opportunities to obtain results (Kriponant, 2007). Kriponant (2007) emphasized that by changing the attitude, subjective norm and perceived behaviour control, we can predict the likelihood that people's intentions to perform certain desired actions could be increased, which would in turn enhance the probability of the people actually doing them. PBC as an additional construct in TPB threw light on the significance of the perceived difficulty of the behaviours and the people's assumed ability to perform those behaviours. PBC directly affects the innovation usage intention (Wu and Chen, 2005) and continuance adoption intention (Liao, Chen, and Yen, 2007).

4.1.1.3 Decomposed Theory of Planned Behaviour (DTPB)

This theory was propounded by Taylor and Todd in 1995 to explore the dimensions of attitude, belief, subjective norm (social influence) and perceived behavioural control by decomposing them into specific belief dimensions (Taylor and Todd 1995a). Taylor and Todd (1995b) suggest disintegrating attitudinal belief into three forms: perceived usefulness (PU), perceived ease of use (PEOU), and compatibility. These three forms of attitudinal belief have been found to be constantly related specifically to Information Technology adoption (Kriponant 2007).

4.1.1.4 Technology Acceptance Model (TAM)

The TRA and TPB have affected TAM and its adjoining models, which mainly focus on technology acceptance and usage. The theories of Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) that influence the motive to adopt a system were formulated from TAM. Scholars have agreed that PU has a positive association with both adoption motive (Davis, 1989) and continuance motive (Venkatesh, 2000). TAM propounds that perceived usefulness and perceived ease of use determine people's motive to use a system whereby the motive to use serves as an intermediary of real system usage (Samaradiwakara and Gunawardena, 2014). Although TAM was propounded to form a solid theoretical basis for studying innovation adoption, several scholars have criticized it due to its numerous shortcomings including the original model's intended generality and parsimony, ignoring non-organizational location, and overlooking the regulating influences of innovation adoption in different settings (Kim and Crowston, 2011).

4.1.1.5 Enhanced Technology Acceptance Model (ETAM aka TAM2)

Venkatesh and Davis (2000) upgraded the original TAM to Extended Technology Acceptance Model (ETAM) and called it TAM2, to address the limitations of TAM1 and provide a comprehensive explanation of the main factors influencing judgments of assumed usefulness. They used TAM1 as a catalyst, and included additional theoretical constructs in TAM2 to involve social influence processes (subjective norm, voluntaries, image, and experience) and cognitive instrumental processes (job relevance, output quality, and result demonstrability), which original TAM lacked (Venkatesh and Davis, 2000).

TAM2 was formulated to enhance the power of explaining the original TAM just as the Unified Theory of Acceptance and Use of Technology model (UTAUT) was formulated to remove the same weakness in TAM2 (Venkatesh, Morris, Davis, and Davis, 2003). TAM2 is therefore a theoretical advancement of the TAM1 to comprise more key factors of TAM1 that explain assumed usefulness and adoption motives in terms of social effects and mental instrumental processes. Also, to know how the inluences of these factors later change with more adopter experience in the society (Kriponant, 2007).

4.1.1.6 Unified Theory of Acceptance and Use of Technology

This theory (UTAUT) gives a new look of how the factors of motive and behaviour emerge with time. The theory presumes three direct factors of motive to adopt, which are performance expectancy, effort expectancy, and social influence. It also assumes two direct factors of adoption behaviour, which are motive and intervening variables (Venkatesh et al., 2003). These associations are influenced by gender, age, experience, and volunteerism of adoption (Venkatesh et al., 2003). Empirical testing of UTAUT reveals that performance expectancy, effort expectancy, and social influence have significant associations with the adoption intention (Venkatesh et al., 2003).

4.1.1.7 Innovation Diffusion Theory

This theory (IDT) was formulated by Rogers (2003) to study individuals' innovation usage. The key objective of IDT is to understand the use of innovation in terms of four features of diffusion, which are the innovation, time, communication channels, and social systems. IDT also stipulates that an individual's technology use behaviour is affected by his or her imaginations concerning the relative advantage, compatibility, complexity, trialability, and observability of the innovation, as well as social norms (Rogers, 2003). Several studies employ IDT as their theoretical framework by combining IDT with other theories and models to explain innovation adoption (Kim and

Crowston, 2011). IDT seems to be the main theoretical perspective on innovation acceptance, which is applicable at both individual and organizational levels of analysis while its basic purpose is to give a reason for the ways in which technological innovations move from generation stage to the diffusion satge or disadoption stage (Dillon and Morris, 2001).

The IDT shows that in most countries, widespread spread of innovation was an S-shaped function of time, which was interpreted to mean that when an innovation is first released, only a few agents adopt it. More agents adopt it later to increase the rate of adoption. The number of potential adopters decreases with time, which reduces the rate of adoption until there is a stagnation in adoption (Rogers, 2005). Often, a climax is reached by the time all the adopters might have used the innovation (Donkoh and Awuni, 2011). Several reasons account for which some people do not adopt. They either do not find the innovation to be profitable or realistic. In some cases, they may find what they think it is more efficient than the prevailing innovation (Donkoh and Awuni, 2011). So, the rate of innovation adoption in a given context (rate of diffusion) initially increases and eventually decreases, to produce a curve that takes an S-shape (Rogers, 2005; 1962).

4.7.1.8 Social Cognitive Theory

This theory (SCT) explains how people get into and keep some behavioural forms based on what they learn from peers (Bandura, 1986). SCT postulates that parts of how people acquire knowledge can be affected by watching what other people do in the society, experiences, and also influenced by the social media. SCT postulates that behaviour is determined by both outcome expectations and self-efficacy, while outcome expectations and self-efficacy are also affected by prior behaviour. There are significant relationships between SCT and other constructs in innovation adoption research (Compeau and Higgins, 1995). SCT depends on the foundation that environmental factors such as societal pressures or perculiar situational factors, mental and other personal characteristics comprising people's personalities, and demographic factors are also important in determining behaviour (Bandura, 1986). Determinants such as gender, age, and experience, likewise play relevant roles in explaining adoption (Losh, 2004; Colley and Comber, 2003).

4.1.1.9 Cognitive Dissonance Theory

This theory (CDT) was propounded by Festinger in 1957 to explain how differences (dissonance) between one's cognition and reality change the person's subsequent cognition and/or behaviour (Bhattacherjee, 2001). This theory represents a process model of individual behaviour that shows that users form an initial pre-usage expectation (belief) about an innovation, experience its adoption overtime, and then form post-adoption perceptions of the innovation. The difference between adopters' original expectations and observed performances is captured in the disconfirmation theory (Bhattacherjee, 2001).

4.1.1.10 Expectation-Disconfirmation Theory

This theory (EDT) was derived from Cognitive Dissonance Theory definition and from marketing. It is now applicable to the adoption of innovations (Bhattacherjee, 2001). Its main focus is on the way and manner adoption decisions change with time. It has four main constructs, namely; expectations, performance, disconfirmation, and satisfaction.

4.1.1.11 Motivational Model (MM)

The Motivation theory was propounded in psychology by Davis, Bagozzi, and Warshaw in 1992. It serves as the fundamental concept behind this model (MM). A number of researchers have assessed motivational theory and re-invented it to suit specific situations and also used it to understand innovation adaption (Venkatesh and Speier, 1999). The main constructs of the theory are external motivation and internal motivation. The composite of these two factors informs an individual's behaviour and performance in a social system.

4.1.1.12 Combined TAM and TPB (C-TAM-TPB)

The main factors of TPB are influences of socio-cultural factors, which are not used to determine the behaviour in TAM but have been combined to form the C-TAM-TPB. Two other factors were added to TAM by Taylor and Todd in 1995 to give a more comrehensive test of the important factors of information technology adoption, because of their predictive usefulness in innovation adoption research and their general use in social psychology (Taylor and Todd 1995a). These determinants are subjective norm and perceived behavioural control. C-TAM-TPB is an accurate model of information technology usage for adopters who are both experienced and naïve with technological systems.

4.1.2 Post innovation adoption theories

Researchers mainly focus on the binary aspect of people's initial adoption or non-adoption decisions without capturing the dynamics of the post-adoption behaviour of innovation adoption. Post innovation adoption theories are extensions of adoption research theories, which are aimed at studying the post-adoption behaviour of innovations or adopters. Adoption research theories approach the aftermath of adoption behaviour as a mental process by which individuals intentionally assess their innovations during the adoption stage. Many post-adoption researchers employ the principles employed in the adoption studies comprising TAM (Hong, Thong, and Tam, 2006), TRA (Cenfetelli, Benbasat, and Al-Natour, 2008), and TPB (Hsieh, Rai and Keil, 2008) for their theoretical background.

Current post-adoption researchers employ new theoretical frameworks such as Expectation Confirmation Theory (ECT) (Hsu, Yen, Chiu and Chang, 2006), and IS Continuance model (Hsieh, Rai and Keil, 2008) to rectify the changes in people's assumptions on innovations after their adoption. These principles also take people's mental reasoning capacity into consideration, in relation to their post-adoption decision making processes. Habit has also been considered as a factor in automatic process of technology adoption, together with these mental process-based theories and models (Kim and Crowston, 2011). This study therefore reviewed major post-adoption-focused theories and models such as Expectation Confirmation Theory (ECT), Information System Continuance Model (ISCM), and habit. This section ends with a reflection on social exclusion and inclusion theories.

4.1.2.1 Expectation Confirmation Theory (ECT)

This theory was also derived from Cognitive Dissonance Theory definition and from marketing. It caters for the situation of increasing adopter experiences with innovations for a time period, as a vital construct in studying adoption and disadoption of innovations. ECT stipulates that adopters' post-adoption utility is jointly affected by their pre-adoption expectation, assumed performance of the innovation, and expectancy confirmation. ECT explains the determinants of utility by focusing on both the precursors of utility and the utility formation process (Susarla, Barua, Whingston, et al., 2003). Many researchers use the ECT as a key theoretical foundation in studying the post-adoption behaviour of innovations. Such studies show that *confirmation* has statistically significant relationships with several adoption and use constructs, including perceived usefulness (Hsieh, Rai and Keil, 2008), perceived ease of use (Hsieh, Rai and Keil, 2008; Thong et al., 2006), perceived enjoyment (Thong et al., 2006), perceived behavioural control (Hsu et al., 2006), and finally satisfaction (Bhattacherjee and Premkumar, 2004).

4.1.2.2 Information System Continuance Model (ISCM)

This model (ISCM) was proposed by Bhattacherjee (2001) as a theoretical model of innovation adoption continuance, which considers the differences between adoption and continuous adoption behaviours. The model depends on the similarity between individuals' continuous adoption decisions and consumers' incessant decisions to purchase by using the ECT. Satisfaction is a main principle in post-adoption behaviour, in both ECT and ISCM. Satisfaction is a factor that is both mental and emotional in nature (Smith and Bolton, 2002).

4.1.2.3 Habit

Like other constructs, habit is studied as a major construct, which affects the continued or discontinued adoption of innovations. Habit is simply understood as learnt sequences of acts that become automatic responses to specific circumstances that may be functional in achieving certain goals or end results (Verplanken, Aarts, and van Knippenberg, 1997). Habit is a repeated behavioural pattern that is formed as a result of consistent practice over a period of thirty days or more. As far as innovation acceptance and usage are concerned, habit can be defined as the degree to which individuals put up certain behaviours spontanuously as a result of constant practice (Limayem, Hirt and Cheung, 2007). Habit is therefore a reflex action. At the initial adoption stage of an innovation, people intentionally decide whether to adopt the technology or reject it. A habit is formed following the adoption of the technology, due to reflective mental processes that go on for a long period of time leading to a non-reflective, routinized behaviour, which repeats itself within the individual (Ouellette and Wood, 1998). What many former post-adoption researchers have ignored is the fact that regular behavioural patterns become habitual and automatic with time (Limayem et al., 2007). Therefore, any post innovation adoption research should consider both the continuance intention and the habit. This study is thus very keen on that.

4.1.2.4 Social Exclusion Theory (SET)

Social exclusion is a broader concept that encompasses low asset affordability and the inability to effectively participate in economic, socio-political and cultural life, and in certain characterization isolation and distance from the general society (Duffy, 1995). Social exclusion is normally related to lack of accessibility to relatively regular paid job, for at least a member of the family (Castells, 1998). Low accessibility to other services can also facilitate such marginalization. Due to such challenges, many recent reports have called for social action campagns to help create a "socially inclusive information society". Though such an action might contradict existing societal norms, it is however a useful umbrella term for advocating the aim of a just society in terms of "informational" sharing.

SET shows that poor or disadvantaged members of society lack adequate resources with which to achieve acceptable standards of living and with which to participate in the customary activities of society (Townsend, 1979). It is a multi-faceted concept which is operationalized as a combination of material deprivation; insufficient access to social rights; a low degree of social participation; and a lack of normative integration (Gerda and Cok, 2007). As a multidimensional phenomenon, social exclusion is not limited to material deprivation but includes poverty. The procedure is termed social ''disaffiliation'' or ''disqualification'', among other termnologies, and comprises humiliation as well as isolation in society (Hilary, 2007). The victim therefore is disadvantaged in many social endeavours. One of the ways in which groups are alienated from society is the creation of social classes or social boundaries such as gender. Accordingly, social inclusion processes, which seek to reverse this trend, include more than just economic empowerment of people.

4.1.2.5 Social Inclusion Theory (SIT)

Social inclusion is the process of improving the terms of participation in society, especially for deprived people, through enhancing opportunities, access to resources, voice and respect for rights. It is the way of improving the terms for people and organizations to take part in society and the procedure for improving the abilities, opportunities, and dignities of people, disadvantaged by their identities, to take part in society (World Bank, 2013). Social inclusion sees to it that people at risk of poverty and social exclusion get the needed opportunities and resources to participate effectively in economic, social, political and cultural life as well as to enjoy a normal standard of living in the society in which they live. SIT also ensures that people get greater opportunities to participation in decision making which affect their livelihoods and access to their fundamental human rights (Council of European Communities, 2003).

4.2 Conceptual framework

When farmers become aware of an innovation, they face a dichotomous decision in the adoption process: adopt or not. The farmers face yet another dichotomous decision when the innovation has been adopted: disadopt or continue to adopt (Soto and Achten, 2015). Several factors affect each of this adoption decisions of farmers (Rogers, 2005). Farmers' decision to continue to adopt or disadopt an innovation is determined by their need to maximize profit or derive the maximum utility from it. Farmers tend to continue the adoption if the expected utility or gains from persistence use is more than that of abandoning it. The expected satisfaction of a farmer is a matter of both household and farm specific factors (Soto et al., 2017). These characteristics can further be grouped into five categories. Namely, household factors, resource endowments, market incentives, risk and uncertainty relavant to the technology, and farm-level bio-physical factors. The concept is as shown in Figure 4.1.

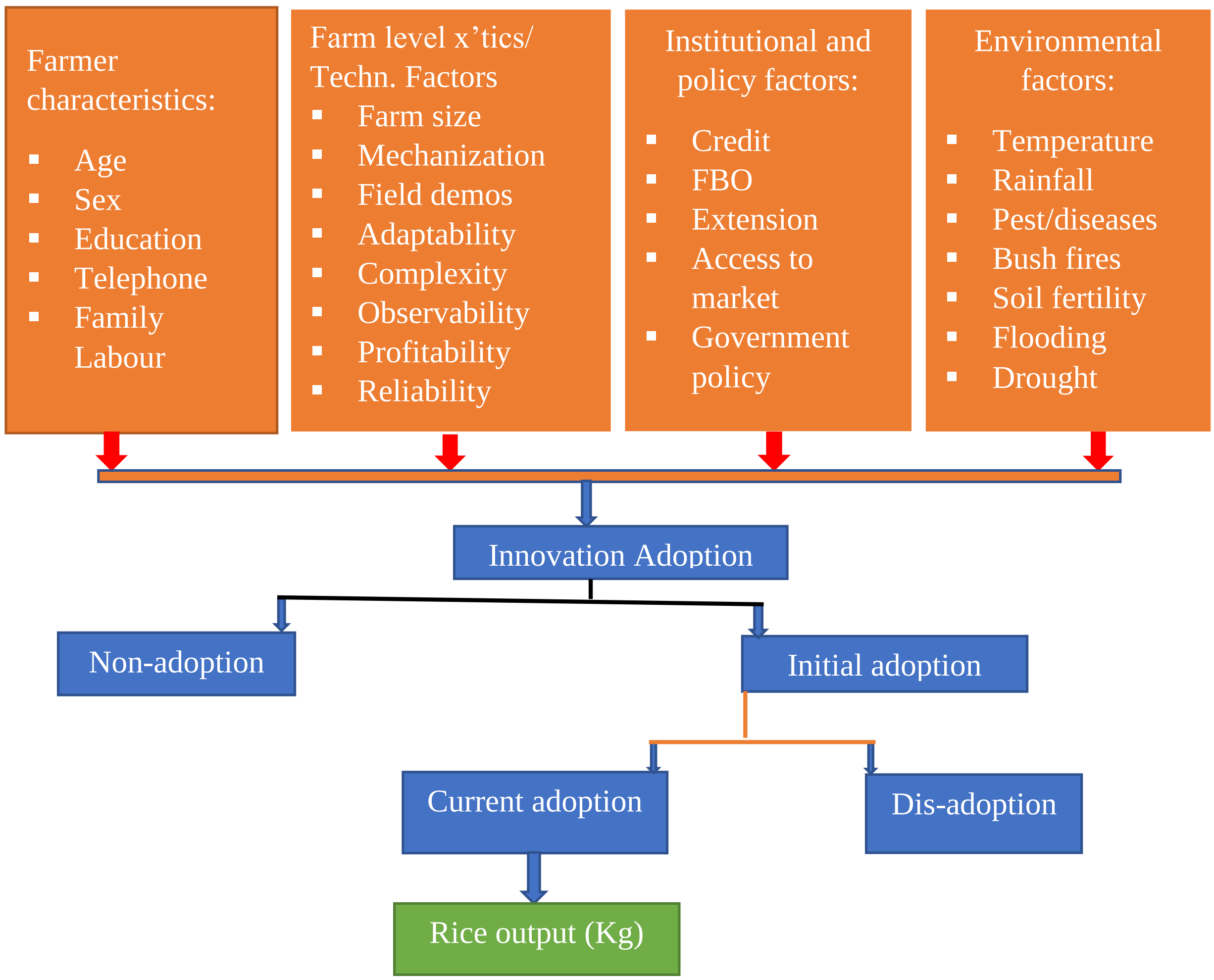

Figure 4. 1: Conceptual framework of adoption, disadoption and output

Source: Author's construct, 2020.

The disadoption is further influenced by intrinsic and extrinsic factors associated with the experiences of the farmers and inconveniences encountered during the adoption

(Neill and Lee, 2001). This study considers “initial adopters” as farmers who have cultivated any of the improved rice varieties after their dissemination, for a minimum of three years, from 2009 to 2019 and non-adopters as farmers who did not adopt for a maximum of three years, after their dissemination periods (Doss and Morris, 2001).

The disadopters are farmers who adopted any of the improved rice varieties but who have stopped the adoption and therefore did not cultivate any of those varieties in the 2019 farming season. The “actual adopters” (current adopters) are farmers who have continued the adoption of any of the rice varieties and therefore cultivated them as at the time of this survey. Farmers cannot adopt an innovation if they are not aware of it and they can also not disadopt it if they have not yet adopted it.

4.3 Theoretical frameworks and models

This section presents the theoretical frameworks and models for the study. It comprises a discussion on the generalized multivariate regression and propensity score models for the econometric analysis.

4.3.1 Generalized multivariate regression model

The fundamental purpose of regression analysis is to determine the best model in order to predict the dependent variable or variables (Gunasdi and Topal, 2016). Regression analysis is a statistical method of determining the functional relationship between dependent and independent variables (Dattalo, 2013; Rencher, 2002). As the name implies, multivariate regression is a technique that estimates a single regression model with more than one outcome variable (Afifi, Clark and May, 2004). The generalized multivariate regression model is generally represented as:

$$Y = \beta 0 + \beta 1X1 + \beta 2X2 + \cdots + \beta nXn + \mathcal{E} \quad (4.1)$$

Where n represents the number of independent variables, $\beta 0 \sim \beta n$ represents the coefficients $\beta 1 \sim$Xn are the independent variables while $\mathcal{E}$ is the error term (Dattalo, 2013; Rencher, 2002).

In a regression model, if there are one dependent (Y_1) and one independent (X_1) variables, the simple linear regression is used, if there are one dependent variable (Y_1) and more than one independent variables $(X_{1,} X_{2,} \ _{\ldots,} \ X_p)$, multiple linear regression model is used, and if there are more than one dependent $(Y_1, Y_2, \ldots, \ Y_q)$ and more than one independent variables $(X_{1,} X_{2,} \ _{\ldots,} \ X_p)$ multivariate multiple linear regression model is used (Dattalo, 2013).

Several forms of the multivariate regression exist. Commonly among them are the multivariate probit (MVP), multivariate logit, multinomial regression (multinomial logit), multivariate multiple regression (MMR) and multivariate multiple linear regression (MMLR) models. When there is more than one predictor variable in a multivariate regression model, the model is MMR.

MMLR is similar to multiple linear regression analysis (MLR). However, the numbers of dependent variables are more than one in MMLR. Computationally, MMLR gives the same coefficients, standard errors, t-and p-values and confidence intervals as one would estimate with individual MLR computations for each of the dependent variables separately (Mendes, 2011). The MLR and MMLR assume that the variable(s) to be predicted should be continuous and the data should meet other assumptions such as linearity, no outliers, similar spread across range (homoscedasticity), normality of residuals, and no multicollinearity (Dattalo, 2013).

Fundamenally, the MVP is estimated when the dichotomous outcome varibales are interdpedent on each other. The MVP model simultaneously models the influence of a set of explanatory variables on each outcome variable while allowing the observed and unmeasured factors (error terms) to be freely correlated (Greene, 2003). Complementary technologies are usually positively correlated while substitutionary innovations are normally negatively correlated (Greene, 2003). In multinomial regression analysis, the outcome varibales are technologies that are not interdependent on each other (Greene, 2003). Example, the use of improved rice seeds and *zai* farming technology are mutually exclusive. *Zai* technology refers to small planting pits in which organic matter such as farm yard manure, compost or dry biomas is buried prior to seed planting for the purpose of reclaiming degraded land and retaining soil moisture for about seven days after rainfall (Dagunda et al, 2020). It is suitable for crops like maize, okro and cowpea, but not rice (which requires much water for its cultivation). Multinomial logit is therefore employed when the dependent variables (technologies) are mutually exclusive.

Considering the complexity of the outcome variables in this study (i.e. intial adoption, current adoption and disadoption), and the fact that outcome variables could be mutually inclusive but are not technologies in themselves, the choice of MVP and multinomial regression would be inappropriate. Following Afifi, Clark, and May (2004), the genralized form of multivariate regression (mvreg) was estimated for this study.

In this process, the residuals from multivariate regression models are assumed to be multivariate normal, which is analogous to the assumption of normally distributed errors in univariate linear regression (i.e. OLS regression). The multivariate regression analysis is recommended for large samples as in the case of this present study that contained 404 observations. Smith (1983) asserts that a large sample will normally lie between 200 – 500 observations. In the generalized form of the multivariate regression model, the outcome variables should be at least moderately correlated for the multivariate regression analysis to make sense.

Multivariate regression is quite different from multiple regression. In multivariate regression, there are more than one dependent variable with different variances (or distributions), with one or multiple predictor variables while in multiple regression, there is just one dependent variable (y) with mulitple predictor variables or parameters.

The assumptions of the multivariate regression model include the fact that the population regression function (PRF) parameters have to be linear. Also, the population regression function independent variables should be additive in nature. Besides, realization from the process should be random (time series data does not normally satisfy this assumption) with a zero conditional mean of error. The model diagnosis for multivariate regression are RMSE, R-squared, F-ratio, and p-value (Gunasdi and Topal, 2016; Dattalo, 2013; Rencher, 2002).

4.3.2 Propensity score model

The Propensity Score Matching (PSM) approach was initially proposed by Rosenbaum and Rubin (1983) as an econometric model that is employed by researchers to examine the effects or impacts of a programme intervention on socio-economic outcomes. This model accounts for sample selectivity bias in programme interventions, since selection of participants into such programmes are often non-random and therefore is subject to sample selection bias. PSM is employed to analyze data from quasi-experiments to balance two non-equivalent groups on observed characteristics to get more accurate estimates of the effects of a treatment such as adoption of an intervention on which the two groups are different (Luellen et al., 2005). The motive behind the analysis is to eliminate or at least minimize sample selection bias since a treated group such as adopters and a control group like non-adopters in an intervention or a training programme often differ even in the absence of treatment. When the selection bias is removed, the differences in outcome(s) of the treated (adopters) and the control (non-adopters) group can be attributed to the intervention (Caliendo and Kopeinig, 2008). This study employed PSM to construct a group for comparisons based on probability model of adoption of improved rice varieties. Farmers who adopted the improved rice varieties are matched to non-adopters on the basis of the probability [or propensity scores, (PS)]. The real effect of improved rice varieties adoption can be calculated as the mean difference in rice output per acre (hectare) between the adopters and non-adopters after matching the individuals with similar characteristics in both the adopters (treatment) and non-adopters (control) groups. PSM helps to examine the probability of a farmer adopting an improved rice variety as well as to assess the effect of adoption on rice output. A binary choice model, usually logit or probit regression, is first employed to estimate the propensity score of each respondent as the probability of the respondent to adopt one or more improved rice varieties. Propensity scores are estimated using farmer, farm characteristics and the affinity to use improved rice varieties (Deschamps and Jean, 2013; Djido, Abdoulaye, and Sanders, 2013). The propensity score (PS) model of adoption can be represented mathematically with Y as the probability of a farmer to adopt improved rice varieties and X as the set of covariates that influence this decision:

$$PS = P_r\left(\frac{1}{X}\right) \quad (4.4)$$

$$= (b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + \cdots b_{11}X_{11} + \mu) > 0. \quad (4.5)$$

Where;

X_0 denotes all variables that determine treatment selection. Specifically, X_1 is a farmer's membership to a farmer group (FBO) (dummy 1, if farmer belonged to an FBO and 0, otherwise); X_2 = Access to market (dummy, 1 if farmer had access, and 0, otherwise); X_3= Access to agricultural extension services (dummy; 1 if farmer had access, and 0 otherwise); $_4$ X_4= Farm plot area in acres. X_5= Government Policy (dummy; 1 if farmer knew of any government policy for the rice sector, and 0 otherwise); X_6= household size; X_7= access to production credit (dummy; 1 if farmer has access to production credit, and 0 otherwise); X_8 = age of respondent; X_9= education (dummy; 1 if farmer had at least attended primary school, and 0 otherwise); X_{10}= rainfall (dummy; 1 if farmer depended on rainfall, and 0 otherwise); and X_{11} = harvesting method (dummy, 1 if farmer used combined harvesters, and 0 otherwise).

The basis of the PSM is that it helps in comparing the observed output of improved rice variety adopters to the output of counterfactual non-adopters based on the predicted propensity of adopting at least one variety (Wooldridge, 2005; Heckman, Ichimura, Smith and Todd, 1998). The next task after estimating the propensity scores using the logit or probit model is to estimate an average treatment effect (ATE) for adoption on rice output. The propensity scores are used to match treated observations (adopters) with untreated observations (non-adopters). The ATE is estimated as the mean difference in rice output between adopters, which is represented by $[Y(1)]$ non-adopters, represented by $[Y(0)]$. The model for estimation of the ATE is symbolically represented by equation (4.6) below:

$$ATE = E[Y(1)\ Y(0)] = E[Y(1)]\ E[Y(0)] \quad (4.6)$$

The ATE model compares the rice output of farmers who adopted one or more improved rice varieties with that of non-adopters or control for farmers that are similar in terms of observable characteristics and also partially control for non-random selection of participants in the improved rice variety adoption. The ATE as calculated in equation (4.7) could be interpreted as the effect of the improved rice variety adoption on rice output. Apart from the ATE, an average treatment effect on the treated (ATT) is also estimated. The ATT model measures the effect of adoption on output for only farmers who actually adopted the improved rice varieties rather than across all rice farmers who could potentially adopt these varieties or who have initially adopted them. ATT is calculated using the expression in equation (4.7) as follows:

$$ATT = E\left[Y(1)\frac{Y(0)}{D} = 1\right] E\frac{[Y(1)]}{D} = E\left[\frac{Y(0)}{D} = 1\right] \quad (4.7)$$

Where;

X_0 is a dummy variable or indicator for treatment (D = 1 for adopters, 0 for non-adopters). One could as well estimate the average treatment effect on the untreated or control groups (ATC) to measure the effect of adoption on output for farmers who did not adopt the improved rice varieties. The model for measuring such a parameter is expressed by equation (4.8) below:

$$ATE = E\left[Y(1)\frac{Y(0)}{D} = 0\right] E\left[\frac{Y(1)}{D} = 0\right]\ E\left[\frac{Y(0)}{D} = 0\right] \qquad (4.8)$$

Earlier empirical works that used the PSM approach have revealed and stressed that the results depend crucially on the strict specification and the matching methodologies employed (Caliendo and Kopeinig 2008; Imbens, 2004). Therefore, sensitivity analysis is often required to check the robustness of the model employed for the estimation. In empirical work, many researchers employ different specifications and matching designs as a robustness check, and the same method is used in this study. The matching techniques commonly employed in propensity score matching models are the nearest neighbour matching (NNM), kernel-based matching (KBM), radius caliper matching (RCM), and Mahalanobis matching (Caliendo and Kopeinig, 2008). This study employed the NNM and KBM methods, and also included the results from regression adjustment method (RAM) to compare three different estimation techniques, in serving as a sensitivity check.

The NNM paired adopters and non-adopters of improved rice varieties, and those closest in their propensity scores as matching partners, to construct a counterfactual outcome (Baffour-Kyei et al., 2021). Observations that provided better matches were given more weights. The weighted average was compared with the outcome for the adopters, and the difference provided an estimate of the treatment effect for each adopter. A sample mean over the total sample therefore served as an estimate for the ATT.

4.4 Empirical studies on adoption of agriculture innovations

This section looks at various adoption studies and the methodologies employed to analyze the data in those studies. This study reviewed adoption studies that employed Multi-Variate Probit (MVP), MMR and PSM models for estimation.

Studies that employed MVP analysis include Danso-Abbeam and Baiyegunhi (2017) and Ahmed (2015). Danso-Abbeam and Baiyegunhi (2017) used the MVP model to explore small scale cocoa farmers' adoption decisions of agrochemicals in the Ghanaian cocoa industry, using farm-level data collected from a sample of 838 farmers in four cocoa growing regions. Danso-Abbeam and Baiyegunhi (2017) revealed that the use of agrochemicals positively and other complementary inputs positively affect farmers' adoption decision. They also revealed that the extent of agrochemical adoption depends on socio-economic and institutional factors like extension service delivery and farmers' participation in demonstration farms.

Onweremadu and Matthews-Njoku (2007), on the other hand, used structured interviews to collect data and used percentages, mean and MMR analysis to determine the effects of socio-economic characteristics on levels of adoption and sources of soil management information in Owerri Agricultural Zone, South-eastern Nigeria. They discovered that crop farming was dominated by relatively younger and educated farmers who can increase adoption and soil management technological dissemination. The results in their study as well revealed that the farmers were exposed to several impersonal sources of soil information and had capabilities of promoting such soil information among other farmers. Similarly, Mwangi and Kariuku (2015) reviewed the factors that influence the use of modern agricultural technologies by small scale farmers in underdeveloped countries and discovered that the perception of farmers about aninnovation was a key determinant for adoption. They grouped the factors that influence adoption into farmer specific characteristics, economic factors, technological and institutional characteristics. Their review also suggested that, the effect of each of those factors on technology adoption might differ based on the type of innovation. For Mwangi and Kariuku (2015), technology adoption by farmers can be facilitated by policy makers and developers' understanding of farmers' need and ability to adopt new technologies. That would help to generate and disseminate appropriate and suitable innovations to farmers.

Various methods can be used to address observed and unobserved biases in a sample when measuring the effect or impact of innovation adoption. These methods include PSM for observed biases, Heckman's selectivity bias correction measure and treatment effect for unobserved biases. Studies that employed PSM include Anang et al. (2016) and Villano, Bravo-Ureta, Solís, and Fleming (2015).

Anang et al. (2016) addressed self-selection into credit participation using PSM, and found that the mean TE did not differ between credit users and credit constrained farmers. Villano et al. (2015) used cross-sectional farm-level data from 3,164 rice farmers in the Philippines, to determine the effect of new rice farming technologies on farm productivity. They got enough control groups using PSM to minimize the effect of biases from observable variables. Their analysis showed that the use of enhanced seeds has a significant and positive impact on productivity, efficiency and net income of rice farmers.

Similarly, Azumah, Donkoh, and Ehiakpor (2016) determined the factors that influence farmers' participation in contract farming and the effect of participation on farm income in the savannah zone of Ghana, using a sample of 230 farmers and estimated a treatment effect model. They found that, access to extension services, credit, farm size, and off-farm income had significant influence on the participation in contract farming. Their study established generally that farmers who participated in contract farming had higher incomes compared to their non-participating counterparts. Other explanatory variables that significantly influenced farmers' rice incomes were land, labour, weedicides and inorganic fertilizers.

The review of previous empirical studies provided direction to the selection of variables and the choice of appropriate methodology for this present study. It also enabled the researcher to improve on the shortfalls in previous adoption studies. Specifically, this study examined the socio-economic, institutional, location and technical constraints to the use of enhanced agricultural practices by rice farmers in Northern Ghana, which have not been sufficiently captured by literature as stated above. Several of the reviewed studies have often concentrated on smallholder farmers generally. Information on crop specific studies (for example rice) are either scanty or non-existent. Again, these studies failed to explicitly analyze the constraints to adoption and the adoption decision of rice farmers. This provide a literature gap on adoption in northern Ghana, hence the need for this study.

4.5 Conclusions on the theoretical, conceptual and empirical frameworks

This chapter provides a review of the theoretical, conceptual, and empirical literature relevant to the study. The study revolves mainly around Rogers (2003) innovation-diffusion theory (IDT). The conceptual framework constructed by the author is based on excerpts from litetrature. The chapter further discusses empirical studies that employed mutivaraiate regression and PSM models for estimation, similar to those estimated for this study.

The review shows that several forms of the multivariate regression exist. Commonly among them are the multivariate probit (MVP), multivariate logit, multinomial regression (multinomial logit), multivariate multiple regression (MMR) and multivariate multiple linear regression (MMLR) models. Theoretically, the MVP can accommodate interdependencies among technologies (innovations), while multinomial regression model is unable to explain adoption and disadoption because it cannot contain the interdependencies among the variables. However, the MVP does not give MMR or OLS results. The MMR model therefore seemed appropriate for analyzing factors affecting initial adoption, current adoption and disadoption of improved rice varieties in the Northern Region, because the technologies being studied are not mutually exclusive.

However, considering the complexity of the outcome variables in this study (i.e. intial adoption, current adoption and disadoption), and the fact that outcome variables could be mutually inclusive but are not technologies in themselves, the choice of MMR, MVP and multinomial regression would be inappropriate. The genralized form of multivariate regression (mvreg) was thus estimated for this study, following Afifi, Clark, and May

(2004). The generalized multivariate regression (MRM) model was also chosen over the MLR and MMLR because the dependent variables in this study are not continuous. Though various methods can be used to address observed and unobserved biases in a sample when measuring the effect or impact of innovation adoption, the PSM model was found more suitable for objective five of this work.

CHAPTER FIVE

METHODOLOGY OF THE STUDY

5.0 Introduction

This chapter presents the profile of the study areas and the methodology used for the study. The study area is the Northern Region of Ghana, where improved rice varieties are disseminated, adopted and disadopted. Methodology is a framework for the research study, which includes the research methods, procedures and tools for data collection and analysis, so as to find answers or solutions to research questions (Kumekpor, 2002). It is therefore necessary that a research methodology is well designed and followed to get accurate and valid data for analysis and interpretation for the purpose of answering the research questions and objectives.

5.1 Profile of the study area

This section looks at the location and size, vegetation, soil and climate, as well as the demographics and the economy of the study area.

5.1.1 Location and size

The Northern Region is the 8th among the sixteen created regions of Ghana. It can be found in the north of the country, with Tamale as its regional capital. It used to be the largest of the ten regions of Ghana, covering an area of 70,384 square kilometres or 31% of Ghana's land mass before December 2018, when the Savannah and North East Regions were carved from it. The Northern Region shares borders with the North East Region to the north, and Togo to the east, Oti Region to the south, and Savannah Region to the west.

Four out of the sixteen districts in the Northern Region were purposively selected for this research, namely; Tolon, Kumbungu, Savelugu, and Nanton. They were so chosen because they serve as home for the promotion and use of enhanced rice varieties in the north of Ghana. Each of the four districts however, has some peculiar characteristics described based on information obtained from the Ghana Statistical Service (GSS, 2014).

The Tolon District is bordered to the North Gonja (Daboya District) in the west, Kumbungu District in the north, Central Gonja in the south and Tamale Metropolitan in the east (GSS, 2014). The Kumbungu District is also respectively bordered to Savelugu Municipal in the east, Tolon District in the south, North Gonja District in the west, and Mamprugo/Moaduri District in the north (MoFA-SRID, 2018). Savelugu Municipal can be found at the northern part of the region and has a total land mass of about 2022.6 square kilometers with a population density of 68.9 persons per square kilometer. It is bordered to West Mamprusi Municipal in the north, Karaga District in the east, Kumbungu District in the west and Tamale Metropolitan Assembly in the south. The Municipality is 400 to 800 feets above sea level. The population of the Municipality, according to the 2010 population and housing, census stands at 139,283 with 67,531 males and 71,752 females (GSS, 2014). Nanton District is one of the 260 Metropolitan, Municipal and District Assemblies (MMDAs) in Ghana, and forms part of the 16 MMDAs in the Northern Region. The Nanton District Assembly was carved out of the Savelugu-Nanton District Assembly as one of the 38 new created and upgraded districts assemblies in 2018. It is an agrarian district interspersed with commerce and industry.

5.1.2 Vegetation, soil and climate

The Northern Region is drier than southern areas of Ghana, due to its closeness to the Sahel and the Sahara. The vegetation consists mainly of grassland, particularly savannah with pockets of drought-tolerant trees like dawadawa, mahogany, neem, baobabs and acacia, among others. The only economic tree that has gained international recognition in the cosmetic industry is the Shea tree, which produces shea nuts for the extraction of shea butter. The biodiversity in tree vegetation used to be high, but now it is reducing due to excesssive exploitation (Azumah, Donkoh, and Awuni, 2018).

The main types of soil in the region are from sandstone, gravel, mudstone and shale that have weathered into different grades of soil. Soil types resulting from the weathering of these rocks are sand, clay and laterite ochrosols. The area is therefore characterized by poor soil conditions and two climatic seasons (MoFA-SRID, 2016). Onset of the rainy season is in April and peaks up in August or September but gradually deminishes by October or November with an average annual precipitation of 750 mm to 1050 mm (30 to 40 inches high). The dry season occurs from November to April annually and is characterized by dry harmattan winds which engulf the whole region. The highest temperatures are recorded at the end of the dry season, the least being from December to January. However, the hot harmattan wind from the Sahara blows regualarly from December to February. The temperatures vary from 14 °C (59 °F) at night to 40 °C (104 °F) in the day time. This is usually associated with shorter wet season and less precipitation with a corresponding longer dry season and hot weather, which may be inimical to rainfed agriculture.

5.1.3 Demographics and economy

The Northern Region is characterized by a low population density with English as the official language. It is dominated by the Dagomba, Mamprusi and Konkomba. Over 75% of the economically active population are engaged in one form of agricultural activity or the other (MoFA-SRID, 2016). This value is beyond the national average of 41.2% (GSS, 2012).

The region is considered as one of the deprived in Ghana, with about 50% of the people below the poverty line (GSS, 2014). The main economic activity of the people is farming of crops and animals with most parts of the region being rural (GSS, 2014). Arable crops grown in the region include cereals (maize, millet, rice and sorghum), tubers (yam) and legumes (groundnut, cowpea, and bambara groundnuts). Majority of the farmers till the land using hoes, bullocks and tractors. Many of the crop farmers also keep livestock (MoFA-SRID, 2016). Ruminants like cattle, sheep, goat, and poultry (guinea fowls and chicken) are very common. The animals serve as alternative sources of income (Azumah, Donkoh, and Awuni, 2018), and improve farmers' financial security.

The region houses the Savannah Agricultural Research Institute (SARI), which is one of the 13 research institutes of the Council for Scientific and Industrial Research (CSIR). SARI is located 16 kilometers west of Tamale in the Tolon District. It has a mandate "to provide smallholder farmers in the Northern, Savannah, North West, Upper East, and Upper West Regions of Ghana with appropriate innovations to boost their food production based on a sustainable production system, which maintains and/or increases soil fertility." SARI's research mandate also comprises the designing of appropriate cropping systems, developing varieties of crops such as maize, rice, sorghum, millet soybean, cowpea, groundnuts, bambara groundnuts, cotton, and vegetable crops, among others, which suit the needs of farmers in the different ecologies of northern Ghana. Most of the improved rice varieties developed by SARI and its research partners were keenly promoted in the Tolon, Kumbungu, Savelugu and Nanton Districts in the Northern Region.

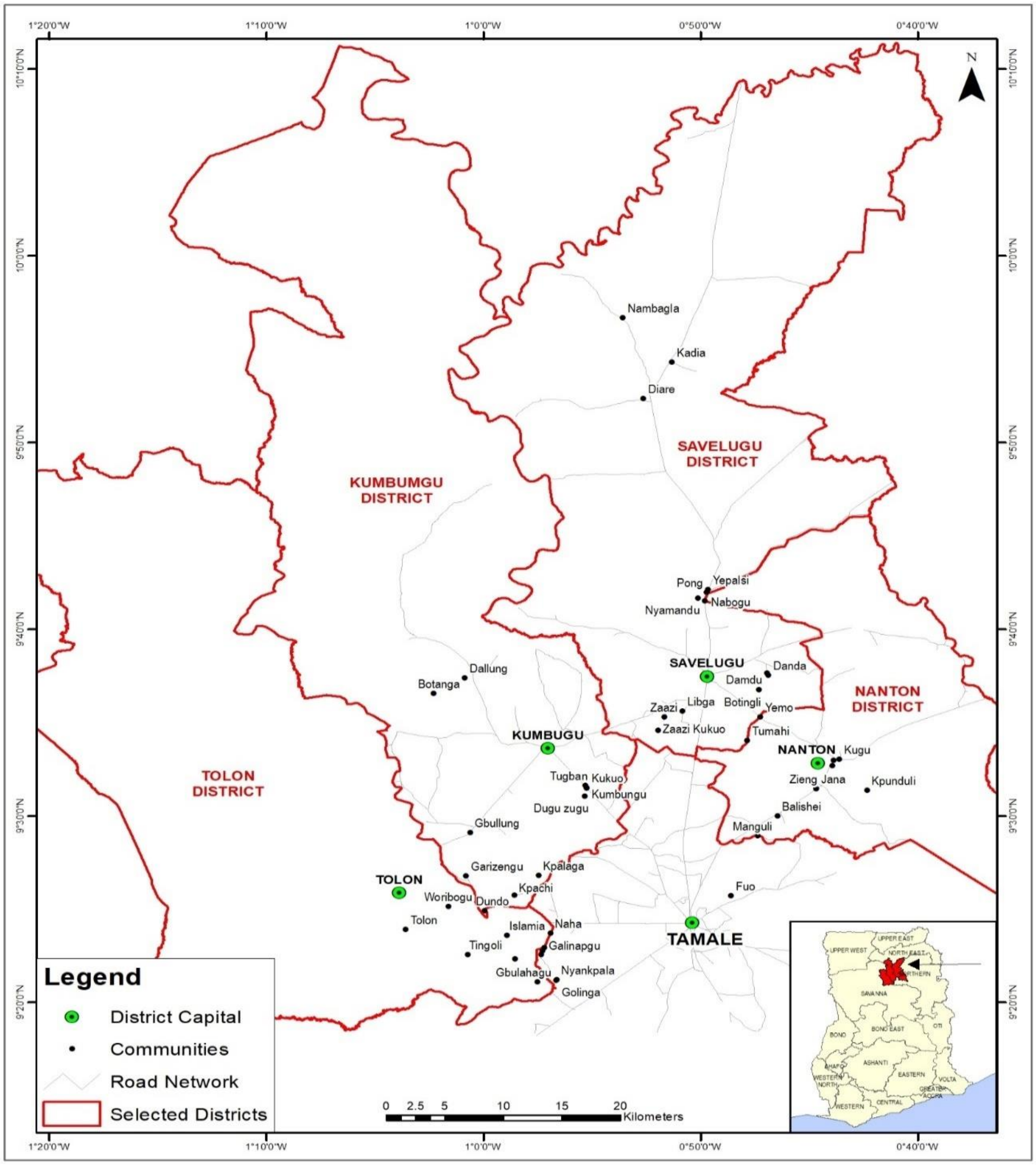

Figure 5. 1: Map of the study area showing the selected districts and communities

Source: Author's construct, 2020

5.2 Research design

Nchor (2011) describes a research design as the logic that links the data to be collected and the conclusions to be drawn to the research questions. It deals with a logical problem to avoid a situation in which the evidence does not address the initial research questions, and hence maximizes the validity and reliability of the research findings. This study employed quasi experimental research design by using both qualitative and quantitative data. That made it possible to analyze and discuss the quantitative data with econometric models such as PSM, based on experimental and control groups, particularly in objective five of the study. The outcomes of the econometric models were complemented with descriptions, narrations and explanations from the qualitative data. The quasi experimental research design employed for this study therefore helped to blend the strengths of the qualitative data with those of the quantitative data by using descriptive statistics and econometric models to produce objective results (Gravetter and Forzano, 2009).

The quantitative data for this study was collected through a cross-sectional survey of rice farmers and the qualitative data was obtained through observation, focus group discussions and key informant intervivews. This study opted for cross-sectional data based on the objectives of the study and the availability of information for the purpose of analysis during the research. Besides, the researcher could not collect information on the same respondents over time, to consider panel or time series modelling. The study therefore blended the qualitative data with the quantitative data to produce objective scientific results for making sound decisions on the subject matter.

5.3 Sampling and sampling procedure

The concept of sampling is very fundamental in conducting quantitative research and surveys, except when a complete census is required. Generalization can then be made about the population, based on the sample (Osuala, 2001). Beside financial and time constraints, there is normally no need to cover the entire population. It is therefore necessary to select a representative sample or units from which results of the analysis are extended or generalized for the population. Yet, in so doing care needs be taken to ensure that the sample is practically representative of its target population, so as to provide valid results (Kumekpor, 2002). This study therefore purposively selected the Norther Region of Ghana, where most of the improved rice varieties in this country were disseminated, adopted and disadopted. Stratified random sampling technique was used for this study, to select the specific individuals to be included in the sample.

5.3.1 Sample size determination

The sample was obtained from a population of rice farmers in the Northern Region. The Ghana Living Standard Survey round six (GLSS6, 2014) puts the number of households in the Guinea Savannah zone who produce rice as 296,489. However, the population of rice producing households in the newly created Northern Region is large and unknown, more homogenous than heterogeneous. The more heterogeneous a population, the larger the sample size needed to get a given level of precision and the more homogeneous a population, the smaller the sample size (Israel, 1992). Although tables can provide a useful guide for determining the sample size, one may need to calculate the necessary sample size for a different combination of levels of precision, confidence, and variability

(Israel, 1992). Israel (1992) is of the view that whatever the study seeks to achieve, the sample size should be appropriate for the analysis planned. For a more rigorous state impact evaluations, a good size sample of 200-500, is required for multiple regression, analysis of covariance, or loglinear analysis (Smith, 1983). Hence, a 95% confidence level, 0.5 standard deviation, and a margin of error (confidence interval) of +/- 5% was chosen to determine the sample size for this study. The confidence level of 95% corresponded to a Z-score of 1.96, which is a constant value needed for the equation (Smith, 2019):

$$Sample\ size\ (n) = (Z - score)^2 * Std\ Dev. * \frac{(1 - Std.Dev.)}{(margin\ of\ error)^2} \quad (5.1)$$

$$n = 1.96^2 * 0.5 * \frac{(1-0.5)}{0.05^2} = 1.9208 * 200 = 384.16 \approx 385$$

Therefore, the necessary sample size for this study was 385 rice farmers. This figure (385) corresponded to a population of 10,000 farmers at 5% Level of Precision, a Confidence Level of 95% and a P Value of 5, according to Yamane (1967) table/formula. The P Value is the estimated proportion of an attribute that is present in the population. The sample size of 385 farmers was appropriate enough to prevent any erroneous conclusions in this study. The study however adjusted this sample size to 410 to cater for some design effects that might have arisen. After data cleaning, 404 questionnaires were found to be consistent and reliable for the analysis.

5.3.2 Sampling procedure

A multistage sampling method was employed to select the respondents from rice-growing communities in the Northern Region. The Northern Region was also purposively chosen for this study since it is considered the main "rice basket" of this country (MoFA, 2013), accounting for 68,407.25 metric tonnes of paddy rice per annum (MoFA-SRID, 2016), and it is where most of the improved rice varieties under study were disseminated to farmers for adoption (MoFA-SRID, 2016). Besides, the region is dominated by vast natural lowlands suitable for rice production, which may have accounted for why is noted as the rice basket of Ghana. Tolon, Kumbungu, Savelugu and Nanton Districts were also purposively selected because they are the main districts in the Northern Region where improved rice varieties are disseminated, adopted and disadopted among smallholder rice farmers. Each district was divided into zones (strata) and each stratum (zone) had a number of rice-growing communities from which a total sample of 410 farmers were randomly selected for this study.

Thus, a combination of sampling methods including purposive sampling, stratified sampling, and simple random sampling (lottery method) were used to select 410 rice farmers from 48 selected communities, 14 zones and 4 districts based on Smith's (2019) formula (see equation 5.1 under 5.3.1), which is used to calculate sample size when little information is available for the population (Ryan, 2013). The breakdown of the sample size is as shown in Table 5.1.

Table 5.1: Sample size per district

District	Sample Size	Percentage	Operational Areas
Tolon	116	28.92	Four Zones
Kumbungu	112	27.32	Four Zones
Savelugu	120	29.27	Four Zones
Nanton	62	15.12	Two Zones
Total	**410**	**100**	**Fourteen Zones**

Source: Author's construct, 2020

An average of thirty farmers were drawn from each zone for the survey, based on the population of farmers in the zones as show in Table 5.2.

Table 5. 2: Number of farmers per zone

District	Zone	Farmers	Percentage
Tolon	Nyankpala	29	7.07
	Tingoli	29	7.07
	Tolon	29	7.07
	Woribogu	29	7.07
Kumbungu	Botanga	28	6.83
	Kpachi	28	6.83
	Gbullung	28	6.83
	Kumbungu	28	6.83
Savelugu	Diare	30	7.32
	Libga	30	7.32
	Nabogu	30	7.32
	Savelugu	30	7.32
Nanton	Nyamandu	31	7.56
	Nanton	31	7.56
Total	**14**	**410**	**100**

Source: Author's construct, 2020

5.4 Data collection methods and instruments

This study employed a mixed-methods approach to collect both quantitative and qualitative primary data. A structured questionnaire was used to collect the quantitative data while observation, focus group discussions and key informant interviews were used to collect the qualitative data. The qualitative data collection aimed at soliciting detailed information on the lived experiences of the farmers, researchers and AEAs to help verify and substantiate claims in the quantitative data.

The researcher also studied other research related to the research topic and was oriented about the field situation and methods of research investigation. According to Laws, Harper, and Marcus (2003), studying and reviewing relevant documents for secondary information to support other sources of data is essential in social and scientific research. The researcher therefore consulted and read extensively on existing literature. For Twumasi (2001), the researcher needs to review relevant literature of past and present works, official reports, statistical data, and many related writings in the course of the research to help ideas of the work. This study therefore reviewed rice production reports and relevant literature on adoption and disadoption of agricultural innovations to help understand and interpret the primary data. This study therefore maintained a good balance of quantitative and qualitative data collection methods.

Formal and informal procedures were employed in the qualitative and quantitative data collection processes. The qualitative data collection process involved participatory rapid appraisal methods like observation, focus group discussions and key informant interviews to collect information about the communities as well as general information about the communities with regard to rice production. That provided good information for enhancing the quantitative data collection.

The quantitative data was gathered in a formal survey using semi-structured questionnaire with the aid of Computer Assisted Personal Interviewing (CAPI) of individual farmers. The information gathered included data on farmers' demographic and socioeconomic charatersitics, and innovation communication channels and methods used to educate farmers on improved rice varieties. The information also comprised institutional, locational and environmental determinants of adoption and disadoption of enhanced rice varieties, the levels of adoption and disadoption of the main rice varieties in the study area, and the effects of improved rice adoption on farmers' output in the Northern Region. The survey also took into consideration the reasons, processes and types of innovation adoption and disadoption in the study area.

5.4.1 Focus group discussions

A Focus Group Discussion (FGD) was conducted in each of the forty-eight (48) selected communities with a maximum of ten (10) leaders from the rice farmers' association per community. The discussions were held at convenient locations to each group in each community. The researcher was assisted by five post graduate students from the University for Development Studies (UDS) to do the focus group discussions. The participants were asked to answer the questions that they were comfortable with and allow others to express their views. They were also made to bear in mind that their participation in the discussions was voluntary and that their views represented the general concerns of farmers in their respective communities/associations. They were assured that the outcome of the discussions would serve as a feedback to researchers, through MoFA, to enhance proper breeding, dissemination and use of enhanced rice varieties in Ghana. The moderators recorded the discussions for easy transmission to the researcher. Their maximum cooperation was sought to make the discussions successful.

5.4.1.1 Focus group discussion guide

A guide for Focus Group Discussions comprising four (4) sections was developed for the study. The first section consisted of three main questions on the socioeconomic, institutional, locational and environmental determinants of adoption and disadoption of modern rice varieties in the Northern Region. The second section also consisted of three questions on the main rice varieties adopted and disadopted by farmers in the region. The third section likewise had two questions aimed at analyzing reasons for the adoption and disadoption of the main rice varieties among farmers in the Northern Region. The final section had two questions that sought to measure the effect of improved rice variety adoption on outputs of adopter in the Northern Region. In all, 48 FGDs were conducted in the study area, one in each community.

5.4.2 Key informant interviews

In all, 34 key informants, comprising 2 researchers from SARI, 1 Agronomy and 1 Agricultural Extension Lecturers from the UDS, 12 AEAs of MoFA, 8 rice aggregators, 4 rice processors, 2 certified seed dealers and 4 opinion leaders in the study area were interviewed to verify and authenticate findings from the farmers. Their views were treated with utmost confidentiality and incorporated into the findings from the questionnaire.

5.4.2.1 Key informant interview guide

A guide for Key Informant Interviews (KII) comprising four (4) sections was developed for the study. The first section consisted of questions on the socio-economic, institutional, locational and environmental determinants of adoption and disadoption of enhanced rice varieties in the Northern Region. The second section consisted of four questions on the improved rice varieties adopted and disadopted among farmers in the study area. The third section likewise had two questions aimed at analyzing reasons for the adoption and disadoption of the main rice varieties among farmers in the Northern Region. The final section had five questions that sought to measure the effect of improved rice variety adoption on output of adopters in the Northern Region.

5.4.3 Questionnaire

An eight paged semi-structured questionnaire comprising five sections in accordance with the specific objectives of the study was developed for individual interview with the farmers. Each section had not less than ten (10) questions, some of which were open ended and others were closed ended. The questionnaire contained main and follow up questions for the purpose of triangulation to help cross-check responses from the farmers.

5.5 Methods and instruments of data analysis

The qualitative data were transcribed, coded, and put into various themes with respect to the study objectives. The transcripts were exported into NVivo 9 qualitative data analysis software and analyzed on the basis of the major themes and content analysis. The outcome of the qualitative data analysis were mainly in the form of narrations, explanations, descriptive and inferential statistics. Generalized multivariate regression and PSM models were used to analyze the quantitative data.

Adoption researchers mostly use a probit or logit model to determine the factors that affect adoption, where only one innovation is involved. However, where there is adoption of more than one innovation, the Poisson model is most appropriate. OLS estimation is not suitable because, the basic assumptions of normality and homoscedasticity of the error term would be violated and more so, the calculated probabilities may lie outside the 0–1 range (Greene, 2003). In binary models, the regressand, (adoption) is unobservable, a dummy variable which shows whether a farmer adopts or does not adopt a given innovation is what is seen. Many adoption studies consider people who are aware but do not use agricultural innovations and those who try the innovations but discard or reject them as non-adopters (Rogers, 2005; Doss et al., 2003). This study went a step further to look at farmers who actually adopted improved rice varieties for a minimum of three years within a decade, and later discontinued the adoption as disadopters. The ordered probit model and count data models such as Poisson regression, zero inflated Poisson regression and the negative binomial regression models were found to be inappropriate to analyze the data on adoption of multiple innovations such as the enhanced rice varieties in this present study. Multinomial, Endogenous Switching Regression and Heckman Two-Staged models were likewise found unsuitable. Hence, descriptive and inferential statistics, narratives, generalized multivariate regression and PSM models were employed for this study.

5.5.1 Empirical model for the generalized multivariate regression

The generalized multivariate regression model was estimated to analyze the factors that influenced the initial adoption, current adoption and disadoption of five main rice varieties in the Northern Region. The empirical model for the three types of adoption ($Y_i = Y_{1=}$ initial adoption, $Y_{2=}$ current adoption, and $Y_{3=}$ disadoption) was represented by one equation, since the same variables were used for the estimation, as follows:

$$Y_i = \beta_{01} + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_{13} X_{13} + \varepsilon_i \quad (5.2)$$

Where

X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_9, X_{10}, X_{11}, X_{12} and X_{13} respectively represented age, sex, education, input market, farm size, family labour, telephone ownership, FBO membership, production credit, extension service, field demonstrations, perception of temperature and awareness of government policy. ε_i was the error term and β was the logistic coefficient for the independent variables.

5.5.2 Descriptive statistics and narratives

The first objective of this study (the main innovation communication channels and methods used to teach farmers on improved rice varieties in the Northern Region) was analyzed using descriptive statistics (frequencies, percentages). Before, then, the demographic and socioeconomic characteristics of the farmers were examined using frequencies, percentages, means, and standard deviations, and results presented in tables. Descriptive statistics and narratives were also used to analyze the second and third objectives of this study (i.e. the levels of adoption and disadoption of the main rice varieties; and reasons, processes and types of adoption and disadoption of improved rice varieties from 2009 to 2019). Frequencies and percentages were first used to determine the levels of initial adoption, current adoption and disadoption of the main rice varieties in the Northern Region. The reasons, processes and types of adoption and disadoption of improved rice varieties in the study area from 2009 to 2019 were also investigated descriptively using frequencies, percentages, narrations and explanations from expert interviews with researchers and extension agents as well as focus group discussions with the farmers. Lastly, the challenges to the adoption of improved rice varieties were analyzed descriptively using frequencies and percentages, and corroborated with information from FGDs and KIIs.

5.5.3 Estimation of the impact of adoption on rice output

The determinanats and effects of adoption of improved rice varieties on output among farmers in the Northern Region, were estimated using treatment effect model. The model estimated was the PSM approach. The PSM approach was employed to control for noticeable features in the model because it does not account for hidden factors (Baffour-Kyei et al, 2021). It was also used to account for any possible biasness in the data collection process.

As part of the PSM approach, Logistic Regression (logit) was first employed to analyze the factors affecting adoption and non-adoption of improved and traditional rice varieties used in the study area. The binary dependent variable (adoption) was measured as a dummy variable equals 1 if the farmer adopted improved rice varieties and 0 otherwise. The covariates used to estimate the propensity scores depended on similar covariates in adoption literature (Baffour-Kyei et al., 2021; Owusu et al., 2011; Caliendo and Kopeinig, 2008). The empirical model for the logit estimation is as follows:

$$Log \left\{\frac{P_I}{1-P_I}\right\} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \cdots . \beta_{15} X_{15} + \varepsilon_i \quad (5.3)$$

Where,

Pi denoted the probability of farmers adopting improved rice varieties and $\left\{\frac{P_i}{1-P_i}\right\}$ was the odd ratio in favour of adoption and $X_1 \ldots . X_{15}$ represented the socio-economic characteristics of farmers such as; age, gender, electricity, education, family labour, FBOs, telephone, input markets, production credit, extension service, farm size, temperature, field demonstrations, mechanization service and government policy, respectively. ε_i was the error term and β was the logistic coefficient for the independent variables. Since the determinants of adoption and non-adoption were catered for by the generalized MRM, the PSM concentrated on the second, third, fourth and fifth steps in the treatment effect model.

The second step employed a histogram to check for overlaps and common supports in the propensity score distribution. The third step was a propensity score test of variables in the model. The fourth step was an overall quality test of factors before and after matching while the final step estimated the impact of improved rice variety adoption among the farm households in the region, using average treatment effect model.

CHAPTER SIX

RESULTS AND DISCUSSIONS

6.0 Introduction

This chapter presents and discusses the results of the study. The first section comprises a summary of the demographic and socio-economic characteristics of the farmers while the other sections consist of the various models used to address the objectives of the study.

6.1 Summary of the socioeconomic characteristics of farmers

Data on 404 rice farmers from the study were analyzed. Summary of the demographic and socio-economic characteristics of the farmers or the descriptive statistics of the variables used in the study are first discussed in this section.

6.1.1 Age and Educational Level of Farmers

This section presents the age and educational status of respondents. The results in Table 6.1 show that the mean age of the farmers was approximately 40 years, corroborating with what was reported by Azumah et al. (2017) and Ragasa et al. (2013) but significantly less than the regional average age (44.8 years) of farmers (GLSS7, 2019; MoFA, 2013). It is also lower than, what was estimated by Bruce, Donkoh, and Ayamga (2014) (48 years) for the same area. It implies that rice farmers are in their economically active life and can therefore farm rice for many more years until they become aged and weak enough to farm. It also implies that rice farming is attractive to the youth, possibly due to the incentive packages associated with rice dissemination projects in the region (Martey et al, 2013).

Table 6. 1: Age distribution and educational levels of farmers

Age range	**Frequency**	**Percent**
19-25	33	8.2
26-30	57	14.1
31-37	101	25.0
38-44	72	17.8
45-51	82	20.3
52-58	37	9.2
59+	22	5.4
Total	**404**	**100.0**
Mean	39.69	
Std. deviation	10.65	
Educational Level of Farmers	**Frequency**	**Percent**
No formal school	285	70.54
Formal school	119	29.46
Total	**404**	**100.00**
Mean	2.67	
Standard deviation	4.69	

Source: Survey data, 2020

Majority (70.54%) of the farmers had no formal education. The Agricultural Production Survey for the Northern Regions of Ghana [APS] (2015) also found that 64% of farmers in the Northern Region were illiterate in English. The mean level of education of the farmers was 2.67 years, which means that the educated farmers had an average of about three years of formal education. This figure is lower than that of Donkoh, Azumah and Awuni (2019) who found that a farmer in Northern Ghana had an average of 4.05 years of formal education. The difference may be due to the fact that Donkoh, Azumah and Awuni (2019) conducted their study in the Northern and Upper East Regions whereas this study was carried out only in the Northern Region where majority of the inhabitants have no formal education (APS, 2015; GSS, 2014). The Ghana Living Standards Survey [GLSS7] (2019), also found that the Northern Region has the lowest levels of education among the population 15 years and older in Ghana, with 56.8% males and 35.9%

females being educated respectively. It shows low level of education among rice farmers in the study area, compared to the national averages of 87.9 male % and 76.1.7% female respectively for people 15 years and above (GLSS7, 2019). This can negatively affect adoption and enhance disadoption of agricultural innovations, corroborating Marenya and Barrett (2009).

6.1.2 Sex and household status of farmers

This section presents sex and household status of rice farmers in the Northern Region. The data was analyzed in frequencies and percentages. The results on Table 6.2 show that most of the farmers (90.1%) were male and the majority (80.2%) of them were household heads. This is consistent with Gomda, Zakaria, and Sulemana (2018), and APS (2015), which reported that about 90% of respondents were males and 96% of them were household heads. It means the proportion of rice farmers who were household heads (80.2%) in the study area was lower than what was reported for farmers in the Northern Regions (96%). The percentage of female farmers (9.9%) in the sample was less than 20% and (24.6%), which were recorded by Ragasa et al. (2013) and Bruce, Donkoh, and Ayamga (2014) respectively. The low percentage of females involved in improved rice farming shows that rice farming is male dominated enterprise.

Table 6. 2: Sex and household status of farmers

Sex	Frequency	Percent
Male Farmers	364	90.1
Female Farmers	40	9.9
Total	**404**	**100.0**
Respondents Being Household heads	324	80.2
Respondents Not Household heads	80	19.8
Total	**404**	**100.0**

Source: Survey data, 2020

This study found that many female household members mainly provided family labour and helped their male counterparts with transplanting, weeding, harvesting, parboiling, processing and marketing of rice, corroborating Donkoh, Azumah, and Awuni (2019). This confirms FAO (2011) report that women contribute about 60-80 percentage of the labour for agriculture in Africa.

6.1.3 Farmers' access to researchers and extension agents/services

Majority of the farmers had access to researchers at SARI (75.74%) and AEAs of MoFA (79.70%) mainly because the improved rice varieties were jointly disseminated by staffs of SARI and MoFA. The farmers could contact the researchers on phone, visit them in their offices or meet them at the demonstration farms in the study area. That contradicts McNamara et al. (2014) assertion of poor farmer access to extension staff in Ghana. The mean extension visit per year was 3.10, meaning each farmer had a minimum of three extension visits in a year. That is plausible, considering the high ratio of farmer to extension services in this country, coupled with logistic constraints of the AEAs (MoFA-PFJ, 2017; GSS, 2014; McNamara et al., 2014). However, the mean of three extension visits per farmer in a year is woefully inadequate for any meaningful extension impact on rice farmers, compared to the expected number of 192 extension visits per farmer annually (MoFA, 2020). That is due to high costs involved in reaching out to farmers individually (FAO, 2019; Rathod, 2016; Boadi et al., 2013). As a result, the AEAs usually meet the farmers in groups at the community level to address their common concerns (MoFA, 2020; FAO, 2019). After reaching out to the farmers through groups and mass media methods, the minimum of three extension visits per farmer per year is deemed *inadequate* but *acceptable*, where there are no pests and diseases outbreaks and adverse weather conditions affecting the farming enterprise, coupled with prevalent logistic constrains (MoFA, 2020).

Table 6. 3: Farmers' access to researchers and extension agents/services

Response	**Frequency**	**Percent**
Access to researchers	306	75.74
No access to researchers	98	24.26
Access to extension agents of MoFA	322	79.70
No access to extension agents of MoFA	82	20.30
Access to NGO extension services	107	26.50
No access to NGO extension services	297	73.50
Mean extension visit/year	3.10	
Standard deviation	3.24	

Source: Survey data, 2020

About 26.50% of the farmers had access to NGO extension services, which implies that promotion of improved rice varieties in Ghana is not a preserve of MoFA (Lamontagne-Godwin et al., 2017). Some of the NGOs are farmer friendly or farmer-based-organizations that help to train and employ private extension officers to assist farmers to ensure food security and reduce poverty among famers, corroborating Lamontagne-Godwin et al., (2017).

6.1.4 Farmers' access to social amenities and perception of climate

Results from Table 6.4 reveal that majority of the farm households, constituting 77.70%, had access to electricity while 22.30% had no access to light. The few farmers who had no access to electricity may be deprived of sources of information on improved rice varieties such as television, radio, internet and even mobile phones. Households with no access to pipe borne water were 80%. This situation could hinder irrigation farming where there are no dams. About 46.8% of the farmers belonged to farmers associations in their communities whereas 53.2% did not.

That means that about half of the farmers had a social network of sharing information on improved rice varieties and supporting one another to farm or market rice while the others were own their own. Individualism among the farmers implies that the rice growing communities are becoming heterogenous, possibly due the fact that most farmers' associations disintegrate after successful promotion and adoption of improved rice varieties. This is in tandem with Rogers (2005) position that adoption is an individual affair. This phenomenon can lead to disadoption more than continuous use of modern rice varieties. Many of the farmers (55.20%) had no access to credit/funds to farm because they did not belong to farmers' associations in the communities. Group membership serves as collateral for obtaining loans, corroborating Yussif, Obeng, Sulemana, and Zakaria (2017).

Table 6. 4: Farmers' access to social amenities and perception of climate

Access to Water and Electricity	Frequency	Percent
Households with no light	90	22.30
Households with light	314	77.70
Total	**404**	**100.00**
Households with no access to pipe born water	323	80.00
Households access to pipe born water	81	20.00
Total	**404**	**100.00**
No Membership of Farmers' Association	215	53.2
Membership of Farmers' Association	189	46.8
Total	**404**	**100.00**
No Access to credit/funds to farm	223	55.20
Access to credit/funds to farm	181	44.80
Total	**404**	**100.00**
Access to input on credit	143	35.40
No Access to input on credit	261	64.60
Total	**404**	**100.00**
Access to Good road network	301	74.50
No Access to Good road network	103	25.50
Total	**404**	**100.00**
Perception of Climate		
Perceived increased in temperature	380	94.06
Perceived decreased in temperature	24	5.94
Total	**404**	**100.00**
Perceived increased in rainfall	34	8.42
Perceived decreased in rainfall	370	91.58
Total	**404**	**100.00**

Source: Survey data, 2020

However, most of the farmers explained during FGDs that they do not prefer obtaining loans to farm rice due to the difficulties involved in obtaining loans and the uncertain nature of the weather. It means obtaining loans to farm rice is not a priority to most farmers in the study area, since they depend on household income or resources to farm. Majority of the farmers, constituting 74.50%, had access to good road network, which means they had less difficulties in going to their farms or market centres to obtain inputs or sell their produce. Most of the farmers perceived increase in temperature (94.06%) and decrease in rainfall (91.58%) patterns in the past ten years respectively. This shows that the farmers are aware of climate change and its repercussions on their farming activities since majority of them depend on rainfall for their farming activities, corroborating Azumah, Donkoh, and Awuni (2019). FGDs with the farmers showed that they have adopted mechanisms to overcome the effects of climate change on their farming activities.

6.1.5 Agricultural companies purchasing farmers' rice in Northern Region

Results on Table 6.5 show that each farmer cultivates more than one rice variety at a time and also sells rice to different buyers each year. A careful study of the results revealed that 86.40% of the farmers sold their produce to market women and 39.60% also sold to Processors/Aggregators. The results also show that NGOs/FBOs do not normally buy rice from the famers, because buying of rice is not one of their objectives of engaging with farmers. Rather, they help farmers to produce and the market their rice (MoFA, 2020). A small percentage (4.20%) of the farmers said they sold their rice to SARI/MOFA as seeds to be resold to other farmers while 2.0% sold their produce directly to other farmers for cultivation. It means about 6.2% of the farmers sell their rice as seeds while 93.8% sell theirs as grains. FGDs with the farmers revealed that some market women also buy and sell rice seeds. Also, 4.70% of the farmers sell their rice directly to AVNASH Company Limited while 39.60% sell theirs to aggregators and other processors. The low percentage of farmers who sell their products directly to processors is a reflection of the low presence of processors in the region, which is in tandem with APS, (2015). Most of the farmers explained during FGDs that they do not sell their rice to processing companies because the companies are not reliable. According to the farmers, those companies buy the rice at a moisture content higher than what the market women normally prefer.

Table 6. 5: Agricultural companies purchasing farmers' rice

Company/agent [K]	Frequency	Percent
Market Women	349	86.40
Processors/Aggregators	160	39.60
Family/Friends	52	12.90
AVNASH Co Ltd	19	4.70
MoFA/SARI	17	4.20
Others (fellow farmers)	8	2.0
NGOs/FBOs	2	0.50

[K] means a farmer can sell many rice varieties to different agents/companies
Source: Survey data, 2020

However, they tend to lose the market for their produce if the companies do not turn up on time to buy them or when they fail to buy them. It means farmers in the region are not using the services of the National Food Buffer Stock Company (NFBSC) established by the government of Ghana as an alternative channel of market for farmers. This confirms the findings of APS (2015). Ordinarily, farmers in the region have about five principal marketing channels to sell their rice output as follows: at the farm gate; in the village market; at a market in another community; at a market in a district other than the farmer's own district; and at market in another region. The choice of a marketing channel for a farmer is a function of several factors such as market availability, accessibility and infrastructure as well as transactional costs, among others.

The farmers explained during FGDs that their wives play major roles when it comes to marketing their farm produce irrespective of the channel they use. They either sell the paddy rice raw or process them (add value to them) before selling at the various markets (Azumah, Donkoh, and Awuni, 2019; Abdul-Hanan, Ayamga, and Donkoh, 2014). Such women also buy paddy rice (at the farm gate) from other farmers and process them for sale. All the women involved in buying, processing and selling rice, including traders from other regions, are commonly called market women. That may have accounted for why market women dominated the groups of people or companies that buy farmers' output in the study area.

6.2 The main innovation communication channels and methods used in the region

This section of the thesis looks at the main innovation communication channels and methods used to educate farmers on improved rice varieties in the study area. The data was analyzed descriptively and the results are presented in frequencies and percentages.

6.2.1 Innovation communication channels for improved rice varieties

The various channels of communicating information on improved rice varieties among farmers in the Northern Region of Ghana were analyzed and the results presented in frequencies and percentages as shown on Table 6.6. Different channels were used to communicate the various varieties to each farmer at different times in different communities. That was because AEAs were not the sole agents of innovation dissemination in the study area. Individual farmers therefore gave multiple responses by choosing as many channels (from a list of eight alternatives) as applied to them. The highest channel of communication was “farmer-to-farmer” (89.11%), followed by agricultural extension officers and researchers from SARI (57.43%), and certified seeds and input dealers (43.33%). The rest were less than 40% with NGOs and FBOs being the least on the list (13.86%). Information from KIIs and FGDs with the farmers shows that AEAs of MoFA collaborated with researchers from SARI to promote improved rice varieties in the study area. They usually worked with contact farmers in the various communities who linked them to the farmers. Most of the farmers however did not get information on the improved rice varieties directly from the researchers and extension officers as shown on Table 6.6.

Table 6. 6: Communication channels on improved rice varieties

Innovation communication Channels/Agents*	Frequency	Percentage
Farmer-to-Farmer (Fellow Farmers and Contact Farmers)	360	89.11
Agricultural Extension Officers and SARI Researchers	273	57.43
Certifies Seeds and Input Dealers	171	42.33
Mass Media (Radio/Television/Internet)	158	39.11
Others (Political and Religious Leaders)	142	35.15
Market Women and Produce Aggregators	135	33.40
Rice Processing Companies	73	18.07
NGO and FBO Service Providers	56	13.86

Source: Survey data, 2020; **Note:** * means multiple choice, farmers were allowed to choose as many channels as applied to them since the rice varieties were not promoted at the same time by the same agents in their respective communities. N=404 (for each channel).

The AEAs also trained leaders of farmer groups in the various communities to help promote the improved rice varieties. The researchers and extension officers therefore served as facilitators while the contact farmers and leaders of farmer groups served as front-liners in promoting the rice varieties. That helped to overcome the logistic constrains of the AEAs and other challenges confronting extension service delivery in the region (DAES, 2018; MoFA-PFJ, 2017; Lamontagne-Godwin et al., 2017; McNamara et al., 2014). This finding is in tandem with Etwire, Martey, and Goldsmith (2019) who found that farmers in the study area were encouraged by researchers and AEAs to engage in peer extension by sharing their knowledge gained from innovation dissemination projects with other farmers.

The presence of other innovation communication channels in the study area also helped to promote the improved rice varieties among the farmers, except that some of them worked independent of the AEAs of MoFA, which somehow undermined the primary role of MoFA as extension service providers to farmers.

6.2.2 Innovation dissemination methods used to promote improved rice varieties

The various agricultural innovation communication methods, otherwise known as Extension Teaching Methods (ETMs), were categorized into individual, group and mass media methods in tandem with FAO (2019). There were eighteen methods identified, five of which were individual methods, seven were group methods, and six being mass media methods. Different ETMs were used to promote the various varieties to each farmer at different times in different communities. That was because AEAs were not the sole agents of innovation dissemination in the study area. The results in Table 6.7

show that all the ETMs were well used to promote improved rice varieties in the region, due to the fact that the Northern Region is the largest producer of rice in Ghana (AGRA-SSTP, 2016; Ragasa et al., 2013). The results show that the three main individual ETMs used to promote the improved rice varieties were farm and home visits (99.01%), result demonstrations (98.27%) and telephone calls (76.24%).

Similarly, the three main group ETMs used were method demonstrations (98.76), meetings/discussions (94.31%) and community fora/durbars (88.61%). In the same way, the three main mass media methods employed were radio (Radio/Television/Internet) broadcasts (98.51%), telephone messages (62.13%) and publiccations/journals (59.41%). Top on all the lists of the individual, group and mass media methods were farm and home visit, method demonstrations and radio broadcasts, which means a combination of these three methods of promoting improved rice varieties in the study area would be the best.

There were higher percentages of individual methods than all the other ETMs among the farmers, indicating that the individual methods were more common than the group and mass methods of teaching farmers. This is in tandem with Azumah et al. (2018) and DAES, (2018) but opposed to Rathod (2016), who stated that individual ETMs, especially farm and home visits, are not commonly employed by agricultural extension officers due to high costs involved. Since the individual methods were most commonly used, it means the farmers received individual attention at the household level.

Table 6. 7: Extension teaching methods used to promote improved rice varieties

Extension Teaching Methods*	Frequency	Percentage
Individual Contacts		
Farm and Home Visits	400	99.01
Result Demonstrations	397	98.27
Telephone Calls	308	76.24
Personal Correspondence	263	65.10
Office Visits	243	60.15
Group Contacts		
Method Demonstrations	399	98.76
Meetings/Discussions	381	94.31
Community Fora/Durbars	358	88.61
Conducted Tours/Field Trips	350	86.63
Field Days/Symposia	312	77.23
Conferences/Seminars/Workshops	260	64.36
Short Courses/Interviews	205	50.74
Mass Media Methods		
Radio/Television/Internet Broadcasts	398	98.51
Telephone Messages (Text messages)	251	62.13
Publications/Journals (Academic Publications and Research Journals)	240	59.41
Newsletters (Graphics, Magazines)	222	54.85
Exhibitions/Leaflets/Handbills	218	53.26
Posters/Billboards/Seculars/Bulletins	207	51.24

Source: Survey data, 2020; **Note:** * means multiple response, no totals; N=404

That, coupled with the method demonstrations and radio broadcasts gave the farmers better understanding of the knowledge imparted to them by AEAs and other promoters of the rice varieties, since they got to hear, see and feel the innovations disseminated to them.

Since many farmers also got education on improved rice varieties through other mass media methods beside radio broadcasts, it means those avenues were available, accessible and affordable to the farmers. It confirms the fact that mass media methods are usually used to create farmers awareness of innovations followed by a group or an individual method or both, to disseminate the innovations (FAO, 2019; Rathod, 2016). The access to electricity in all the communities, presence of Simli Radio at Dalung and Might FM at Savelugu and SARI as well as UDS at Nyankpala may have accounted for farmers getting education on improved rice varieties via radio and print media. This is consistent with GLSS7 (2019), and GSS (2014), that 52% of women and 78% of men age 15-49 years listen to the radio at least once a week, and 51% of women and 66% of men watch television at least once a week. It further confirms GSS (2014), report that farmers' exposure to print media in Ghana is much less common; with 9% of women and 17% of men reading a newspaper or magazine at least once a week.

6.3 Levels of adoption and disadoption of rice varieties in the Northern Region

This section presents and discusses the levels of adoption and disadoption of the main rice varieties in the Northern Region for the past ten years. The researcher's experience in rice farming, coupled with existing literature on rice and information obtained from SARI and MoFA showed that there are twelve main rice varieties in the study area. Ten of these varieties are improved while two are traditional. The improved ones are Digang, Mandee, Faro 15, GR 18, Nerica, Jasmine 85, Agra, Afife, Tox and Sakai. The traditional ones are Salma-Saa and Kpokpula.

The other improved rice varieties are *Moses* and *Iddi* while the traditional ones include *Adonga Adongo (Pole), Basolugu, Shinkafa Kpana, Abugna, Alhaji Addae, Jakukuo and Anyofula* in the region. These sum up to twelve improved and nine traditional rice varieties in the region. However, for the purpose of econometric analysis, this study concentrated on only the major varieties, especially in the subsequent sections. Ragasa et al. (2013) also found a number of other varieties of rice cultivate by farmers in Ghana besides the accredited ones. The levels of initial adoption, current adoption and disadoption of rice varieties in the study area are as shown in Table 6.8.

Table 6. 8: Initial adoption, current adoption and disadoption levels of rice varieties

Main Rice varieties*	Initial Adoption		Current Adoption**		Disadoption**	
	Freq.	Percent	Freq.	Percent	Freq.	Percent
Agra[I]	150	37.13	116	**77.33**	34	22.67
SAKAI[I]	2	0.50	1	**50.00**	1	50.00
Jasmine[I]	166	41.09	67	**40.64**	99	59.64
Afife[I]	82	20.30	19	**23.17**	63	76.83
Nerica[I]	68	16.83	2	**5.88**	64	94.12
Digang[I]	57	14.11	7	**12.28**	50	87.72
Mandee[I]	55	13.61	10	**18.18**	45	81.82
GR-18[I]	52	12.87	3	**5.77**	49	94.23
Tox[I]	50	12.38	6	**12.82**	44	87.18
Faro 15-20[I]	27	6.68	3	**11.10**	24	80.90
Salma-Saa[T]	95	23.51	64	**67.37**	31	32.63
Kpokpula[T]	50	12.38	3	**6.00**	47	94.00
Others varieties *						
Iddi[I]	52	12.87	3	**5.77**	49	94.23
Moses[I]	27	6.68	3	**11.10**	24	80.90
Anyofula[T]	50	12.38	6	**12.82**	44	87.18
Basolugu[T]	27	6.68	3	**11.10**	24	80.90
Adonga Adongo[T]	50	12.38	4	**8.00**	46	92.00
Abugna[T]	50	12.38	3	**6.00**	47	94.00
Alhaji Addae[T]	50	12.38	3	**6.00**	47	94.00
Shinkafa Kpana[T]	17	4.21	1	**5.88**	16	94.22
Jakukuo[T]	20	4.95	1	**5.00**	19	95.00

*Multiple responses ** Current Adoption + Disadoption = Initial Adoption
Source: Survey data, 2020 *I* = Improved variety *T* = Traditional variety

Among the improved varieties, the initial adoption rates were higher for Jasmine (41.09%), Agra (37.13%) and Afife (20.30%) while Agra had the highest current adoption rate of 77.33% followed by Sakai (50%) and Jasmine (40.64%). GR18 had the lowest current adoption rate of 5.77% followed by Nerica (5.88%) and Faro (11.10%). It means the four most adopted improved rice varieties in the study area over the past decade were Agra, Sakai, Jasmine and Afife. Agra and Jasmine had high initial and current adoption rates because they were the main varieties promoted in the study area during the period under review, corroborating the findings by MoFA-PFJ (2017), APS (2015) and Ragasa et al. (2013).

Regarding the traditional varieties, Salma-Saa had initial and current adoption rates of 23.63% and 67.37% respectively while those of Kpokpula were 12.68% and 6.00% respectively. It means Salma-Saa was the most adopted (cultivated) traditional rice variety in the study area, with a current adoption rate of 67.37%.

The results from Table 6.8 further show that the most disadopted improved rice varieties were GR 18 (94.23%), Nerica (94.18), Digang (87.72%), Tox (87.18%), Mandee (81.82%) and Faro (80.90%). The disadoption rate of Kpokpula, a traditional variety, was 96.00%, which was higher than the disadoption rates of any of the improved rice varieties. The other improved (Iddi and Moses) and traditional rice varieties (Adonga Adongo (Pole), Basolugu, Shinkafa Kpana, Abugna, Alhaji Addae, Jakukuo and Anyofula) were dotted within the region. The study found that each farmer adopted more than one rice variety and no farmer adopted only improved or traditional varieties over the ten-year period. It means the farmer have adopted both improved and traditional rice varieties in the study area.

FGDs revealed that *Moses* and *Iddi* were introduced to the farmers by Honourable Moses Yahaya, a Member of Parliament (MP) for Kumbungu District in 2012 and one Mr. Iddrisu respectively. Those rice varieties were named after the people who brought them (possibly form Southern Ghana) to the Northern Region because their brand names were unknown to the farmers. Tsinigo (2014) also found that farmers in the Brong Ahafo and Ashanti Regions of Ghana grew a traditional rice variety called *Mr. Moorl.* It would be helpful to subject such rice varieties to laboratory analysis to determine their true constituents and brand names. This is because most of the names were coined for the varieties in their respective communities, corroborating Ragasa et al. (2013) and AGRA-SSTP (2016). For example, *Adonga Adongo* (Pole) derived its name from the fact it grows tall and it is very suitable for inland valleys and swampy areas. *Shinkafa Kpana* is “bad rice”, which grows on its own in existing rice fields year after year. It is sometimes allowed to grow on uncultivated fields as “hybridized” rice for domestic consumption. Other times, they are allowed to grow together with cultivated rice but harvested separately from the cultivated ones, and used for domestic purposes. However, farmers who want “pure” seeds or grains (true-to-type cultivated) normally get rid of it through roguing.

Moses had a higher current adoption rate (11.00%**)** than *Iddi* **(**5.77%**)** with their corresponding disadoption rates of 80.90% and 94.23% respectively**,** possibly due to pollical influences. Among the other traditional varieties, *Anyofula* had the highest current adoption rate of 12.82% followed by *Basolugu* (11.10%) and *Adonga Adongo* (8.00%) with their corresponding disadoption rates of 87.18%, 89.90% and 92.00% respectively. The current adoption rates for the rest of the other traditional rice varieties were below 8.00%, similar to the rest of the main varieties. It means the farmers have adopted and disadopted both improved and traditional rice varieties in the region, and were more inclined towards the adoption of the improved ones, with much focus on the latest varieties such as Jasmine and Agra.

6.4 Reasons for the adoption and disadoption of the main rice varieties

This section presents reasons for the adoption and disadoption of the main rice varieties. Reasons for the adoption are discussed first, followed by the reasons for disadoption, the types of improved rice variety disadoption, and the processes of improved rice variety adoption and disadoption in the study area.

6.4.1 Reasons for adoption

Farmers' reasons for adopting the improved rice varieties are as shown in Table 6.9. The specific reasons farmers gave for adopting improved rice varieties, in order of importance are, ready market for the produce (81.68%), resistance to pests and diseases (76.73%), higher demand for produce (56.93%), advised by extension staff to cultivate (51.98%) and advised by researchers to cultivate (50.00%). Only 4.95% of them said they adopted the varieties because they got free seeds from promoters.

Table 6. 9: Farmers' reasons for adopting improved rice varieties

Reasons for Adoption*	Frequency	Percentage
Ready market for the produce	330	81.68
Crops resistant to diseases/pests	310	76.73
Higher demand for product	230	56.93
Was advised by extension staff to cultivate	210	51.98
Was advised by researchers to cultivate	202	50.00
Seed more suitable for the soils	120	29.70
Crops very resistant to droughts	145	35.89
Others (nice taste/aroma, easy to cook, easy to mill)	67	16.58
Low input requirements	27	6.68
Got free seeds from promoters	20	4.95

Source: Survey data, 2020 * Multiple responses N=404

It means the farmers were mostly motivated by the marketability of the produce after harvest, because rice has now become a commercial crop in Ghana (APS, 2015; Ragasa et al. 2013). The farmers said during FGDs that most of them farmed rice to sell for money and not only for food. Hence, many of them adopted Agra, Jasmine and Salma-Saa, which had ready market and other good qualities such as nice taste and aroma. It means the farmers adopted rice varieties that had relative advantage over other varieties (Rogers, 2005).

The farmers also emphasized during the FGDs that they normally do not reject any improved rice varieties introduced to them. Rather, they try them for some time before adoption and they may continue to do so until other newly improved varieties with better qualities are introduced to them for adoption. This also explains why Agra and Jasmine had higher adoption rates than other improved rice varieties, which were promoted earlier in the study area. It means Agra and Jasmine are likely to also give way to the adoption of other better improved rice varieties to be promoted in the region, corroborating Oster and Thorton (2009), who posited that understanding the procedure of innovation adoption can help to predict adoption patterns.

Similarly, the adoption rate of Salma-Saa was higher than that of Kpokpula because Kpokpula is much older in the study area than Salma-Saa. FGDs with the farmers and KIIs with researchers and extension officers revealed that Kpokpula is an indigenous variety that has been in the region for over half a century now but Salma-Saa is a strain (an incomplete breed) of Jasmine 85 that has been under cultivation in the region prior to the release of Jasmine 85 about a decade ago. This is in line with Ragasa et al. (2013) who reported that Jasmine 85 (Saa Rice) got accreditation a decade ago, but it was already being cultivated by many farmers in different parts of the country. Salma-saa has some of the unique characteristics of Jasmine 85, in addition to the fact that it has adapted to growth and climatic condition of the area. The farmers explained that the indigenous rice varieties such as Salma-Saa, Kpokpula, and the others, have low input requirements and minimal agronomic practices than the improved varieties. They therefore continued to cultivate those traditional varieties even when they did not have good markets, milling and cooking abilities. The farmers added; "we do not buy those seeds", "those seeds are easy to obtain" and "they can still give us some yields even when the rains fail". These assertions of the farmers are in tandem with Taxler and Byerlee (1993) who observed that crop attributes such as grain quality, straw yield, grain yield, and input requirements are all factors farmers consider in adopting a new technology.

The farmers emphasized that there was no way they would entirely abandon their native varieties to "foreign" ones. According to the farmers; "We met our fathers and fore-fathers growing those varieties and we are used to them." They further explained that those varieties have medicinal, cultural and religious values than the improved ones: "Some herbalists and traditional authorities prefer the indigenous varieties to the improved ones, as custom demands." They went on to state that the traditional varieties were economical (affordable, easily accessible, easy to cook) for occasions such as marriage, outdooring, passing out and funeral ceremonies as well as festivals when masses of people are fed. They re-iterated that "Kpokpula" owed its name to the fact that it was more suitable for making "rice balls" than any other rice variety in the region. Their responses show that some of them were conservatives who exhibited the characteristics of peasant farmers or laggards (Rogers, 2005). This is in tandem with Azumah (2019), who found that 35% of the rice farmers in Northern Ghana produced solely for subsistent purpose. Non-participant observations made in the communities confirmed these facts.

Finally, some of the farmers said they were known as Seed Growers in their communities. Therefore, researchers and other farmers from different localities normally contacted them for seeds of various improved rice varieties. So, they produced seeds of various improved rice varieties even when their fellow farmers were no more adopting them. That might be the reason for 50% current adoption rate of Sakai even though its initial adoption rate was 0.50%. The reason for Seed Growers' adoption decision is what Donald and Parker (2012) referred to as Future Viability, whereby farmers continue to adopt certain innovations with the aim of preserving them for future engagements.

6.4.2 Reasons for disadoption

This section also discusses farmers' reasons for disadopting the main rice varieties, with particular emphasis on the improved ones. The farmers' main reasons for disadopting improved rice varieties were high input requirements (95.80%); absence of ready market for the produce (69.31%), output was no longer demanded by consumers (51.98%) and inability of the crops to withstand droughts (42.08%). The least reason they gave for their disadoption of improved rice varieties was that they were advised by extension staff to stop (26.49%). Other reasons are as shown in Table 6.10, which are consistent with Moser and Barrett (2003), who found that farmers willingly adopt high yielding rice varieties when promoted, but they significantly abandon the varieties in subsequent years, partly due to liquidity constraints. These findings on disadoption of the rice varieties are also consistent with Taxler and Byerlee (1993) who observed that crop attributes such as grain quality, straw yield, grain yield, and input requirements are all factors farmers consider in assessing a new technology. Other attributes of innovations that determine their rates of disadotion include adaptability, reliability, observability, profitability, complexity, and relative advantatage (Rogers, 2005).

Demand and supply are market forces that determine market price for products and which also influence their adoption. It implies that the farmers disadopted improved rice varieties that had high input requirements and were no longer driven by market forces as well as those that were not compatible with the environment.

Table 6. 10: Farmers' reasons for disadopting improved rice varieties

Reasons for Disadoption*	Frequency	Percentage
High input requirements	387	95.80
No ready market for the produce	280	69.31
Output of seed no longer demanded by consumers	210	51.98
Seeds make crops too susceptible to droughts	170	42.08
Seed no longer suitable for the soils	150	37.13
Seed too costly	130	32.18
Was advised by researchers to stop	119	29.46
Other Reasons (seed contamination, variety seeking)	113	27.97
Seeds make crops too susceptible to diseases/pests	110	27.23
Was advised by extension staff to stop	107	26.49

Source: Survey data, 2020 *Multiple responses N =404

It means the farmers were no longer deriving maximum utility from adopting those innovations and decided on their own to disadopt them, without being coerced or intimidated by external forces. Hence, they cited extension officers as having contributed the least (26.49%) to their disadoption of improved rice varieties. This is in line with Rogers (2005) who penned that adoption is an individual affair.

KIIs revealed that the advice by extension agents or researchers was not meant for farmers to disadopt the varieties but to revert to purchasing certified seeds for their fields after every three or four years and also to desist from cultivating the same improved rice varieties on the same piece of land after four successive years of cultivating those varieties. They were likewise advised to avoid "recycling" the same seeds or using hybridized seeds year after year, since they do not have the same vigor as the certified seeds. These findings are consistent with AGRA-SSTP (2016), APS (2015), Ragasa el at. (2013) and Doss, (2006). The idea is to avoid the build-up of pests and diseases associated with those varieties and also to prevent the recessive traits of those varieties from showing up. Martey et al. (2013) as well as Donkoh and Awuni (2011) also found that rice farmers in the study area discontinued the use of organic manure to fertilize their rice fields due to their poor perception about it.

According to the key informants, the farmers sometimes complain of seed contamination due to flooding and cross pollination with wild varieties (bad rice) in their fields. So, they advise them to replace the impure seeds with pure improved seeds or practice roguing. However, the farmers perception of high cost of pure or certified seeds and labour intensiveness of roguing (high input requirements), make them resort to either cultivating local varieties on their fields or not reverting to cultivate the improved varieties they once cultivated. The farmers confirmed during FGDs that they normally do not re-adopt improved rice varieties they disadopt because there are several other improved rice varieties to choose from. This shifts the reason for disadoption to the door steps of institutions and agents that promote several improved rice varieties incessantly in the study area. Even though institutions rarely advice farmers to disadopt innovations, they do so when the innovations become undesirable or obsolate (Donald and Parker, 2012; Lastovicka and Karen, 2005; Price et al. 2000).

The farmers said during FGDs that there were no need re-adopting improved rice varieties they once disadopted: "We stopped growing them because they were no longer good for us. If they were good for us, we would not have disadopted them in the first place. So, why should we go back for them when there are better ones around?" The reason for the farmers response or behaviour above is termed 'Variety Seeking', which happens when the farmers have several alternatives to choose from (Donald and Parker, 2012; Rogers, 2005). It means the farmers disadopt some improved rice varieties in order to adopt other ones. Rogers (2005) described this practice as replacement discontinuance, whereby a farmer discontinues an innovation to adopt a better innovation. The farmers' responses also show that they disadopted those varieties due to the negative aspects of the innovations, corroborating Donald and Parker (2012), and Jones (2005) who posited that technologies disadopted are as ineffective as technologies not adopted.

The fact that farmers disadopt some particular improved rice varieties does not necessarily mean they have adopted other improved rice varieties (Lastovicka and Karen, 2005). That is why the disadoption rates of some improved rice varieties in the study area were high, yet the adoption rates of other improved rice varieties were very low. Rogers (2005) referred to that practice as disenchantment discontinuance, where a farmer discontinues an innovation with or without replacement as a result of dissatisfaction with the innovation's performance. Also, the fact that farmers disadopt some particular improved rice varieties does not necessarily mean they dislike all improved rice varieties. Hence, the levels of disadoption of some improved rice varieties in this study were high and the adoption levels of similar varieties in the same region were not much lower.

Moreover, the fact that farmers disadopt some particular improved rice varieties does not necessarily mean those improved rice varieties are no longer in existence and therefore cannot be re-adopted. This is in tandem with Johnson et al. (2011) who argued that disadoption does not terminate relationships but it can create brand enemies and former friends. Most of the farmers in this study appeared to have abandoned GR 18, Faro 15, Digang and Nerica but it does not mean all farmers have disadopted those improved rice varieties.

Even though Nerica was also keenly promoted in the study area about a decade ago, the farmers have disadopted it alongside the older varieties, due to lack of ready market for its output (Lamptey, 2018; APS, 2015; Asuming-Brempong et al. 2011). Kijima et al. (2011) also found that more than 50% of Nerica adopters in Uganda who adopted the Nerica in 2004 abandoned it in 2006, due to low profitability of Nerica relative to other crops. This finding is contrary to Carletto et al. (2007) who opined that pressure to disadopt agricultural technologies sets in after 20 years of use.

6.4.3 Types of disadoption

This study revealed three types of improved rice variety disadoption in the study area, with the farmers at the centre stage. They were; farmer-initiated type of disadoption, institutional initiated farmer disadoption and nature induced disadoption as in the termination of human relationships. The type of innovation disadoption caused by "high input requirements" is known as farmer initiated disadoption of unsustainable innovations. This is because farmers are rational being who advise themselves when they realize they can no longer afford an innovation, sustain it with its associated practices or derive maximum utility from its continuous adoption. This is in tandem with Doss et al. (2003), who found that farmers do not adopt innovations "wholesale". Rather, they pick and choose aspects of the innovations that are convenient, applicable and relevant to them. Rogers (2005) refers to that phenomenon as "adaptability" and "possibility of re-invention". The type of disadoption caused by environmental factors such as "when seeds make the crops too susceptible to droughts", or pests and diseases infestations are known as nature induced disadoption as in termination of human relationships (Donald and Parker, 2012; Lastovicka and Karen, 2005; Perrin-Martinenq, 2004). The same applies to when an adopter dies, migrates, relocates or stops farming for other occupations that have no need for the innovation in question. Innovation disadoption caused by researchers, extension agents and market forces are referred to as institutionally induced disadoption of undesirable innovations (Donald and Parker, 2012; Lastovicka and Karen, 2005). Hence, all three types of innovation disadoption prevailed in the study area. According to the farmers:

> *SARI and MoFA staff normally bring us new improved rice varieties to cultivate, which they claim are better than the existing ones in terms of yield, resistance to pests, diseases and water stress. So, we normally have many varieties at our disposal to choose from. When we produce the newly improved rice varieties, we get high yields but poor markets for them because most consumers and traders are not familiar with them. When we produce them for sale and we do not get good markets for them, we stop and go in for those that the market women like buying. We do that because we need money to pay for our input and tractor services, children's school fees, hospital bills, light bills, and to meet other social and family*

responsibilities. Besides, we farm to make profist, not losses. (FGD, Tingoli, January 22, 2020; 11:30am).

The above extract shows that researchers, extension agents and market forces served as institutional factors leading to farmer disadoption of improved rice varieties. This type of disadoption did not occur because the rice varieties had outlived their usefulness in the communities but due to the fact that they did not meet the tastes and preferences of their target audience. This does not mean that the rice varieties did not have good tastes and nice aroma. Rather, farmers, consumers and traders were not used to them. They were therefore readily available for adoption but incompatible with the ideals, norms and values of the social system, corroborating Rogers (2005). Hence, they were disadopted. The best thing should have been to promote their adoption and consumption at the same time. It means rice dissemination projects should factor in promotional campaigns to enhance their demand and consumption by the public.

The type of improved rice disadoption that was caused by pests, birds, floods, drought, bushfires, and poor soil fertility, as recorded during FGDs and KIIs exemplify nature induced disadoption of improved rice varieties. The farmers also said:

We sometimes do not farm certain improved rice varieties because they demand ploughing and harrowing, more fertilizers, herbicides, weedicides, and other agro-chemicals. They are also labour intensive time consuming to plant, transplant and to harvest. They do not give good yields when we do not have time for them. The old improved rice and traditional varieties are not like that. They can still give some yields even if we do not have *much time and resources for their cultivation (FGD, Naha, January 12, 2020; 11:33am).*

The above narrative gives rise to what is termed farmer-initiated type of disadoption of unsustainable innovations, corroborating Donald and Parker (2012). The farmers said all of them do not stop cultivating a particular improved rice variety at the same time ecause every farmer has the reasons for which he or she cultivates rice. However, they said they all cultivate rice for food and income. So, when they realize cultivating a particular improved rice variety does not meet their expectations for food and income, they stop its adoption, one after the other farmer, until the whole community disadopts it. They also said they do not re-adopt rice varieties they have once disadopted since they keep getting better varieties for adoption.

The fact that most of the farmers do not revert to the improved rice varieties they disadopt makes this type of disadoption what we call disadoption as in termination of human relationships (Donald and Parker, 2012; Lastovicka and Karen, 2005)**.** The fact that all the farmers do not disadopt improved rice varieties at the same time confirms Donald and Parker (2012), view that disadoption involves a gradual alienation or a more liminal state of dissociation and separation over time.

Since all the three types of innovation disadoption occurred in the study area, it means the disadoption of improved rice varieties in the region cannot be blamed solely on the farmers, institutions or nature because they all served as actors to the types of disadoption discussed. This is in tandem with Donald and Parker (2012) that disadoption is a process in society that involves many people, besides the disadopters. It means many people were implicated in a disadoption processes in the study area.

6.4.4 Processes of improved rice variety adoption and disadoption

This section looks at the processes of improved rice variety adoption and disadoption in the study area. Adoption of improved rice varieties in the study area followed the normal process of awareness, trial, acceptance and usage (Rogers, 2005) but the disadoption followed an irregular and protracted pattern. The disadoption happened either gradually or abruptly, intentionally or unintentionally, corroborating Donald and Parker, (2012). According to the farmers, when they became aware of the improved rice varieties through the various agents and channels of innovation communication, they learnt how to cultivate them from either their fellow farmers or agricultural extension officers and researchers. They attended farmer field schools, demonstration farms, group discussions and community fora to acquaint themselves with the appropriate ways of cultivating them.

Some of the farmers also said during FGDs that they only saw the performances and output of the improved rice varieties in their fellow farmers' farms and demonstration plots of the extension officers in their communities, and also looked for the seeds the subsequent cropping seasons to cultivate. Other farmers also said they did not see the performances and output of those varieties but they got the seeds from either traders or their relatives who had brought them from other regions and communities and encouraged them to cultivate. The farmers explained that those of them who did not belong to farmer groups did not have the opportunity to attend the farmer field schools and demonstration farms of the researchers and extension officers, but they either saw the farms or heard about them. They explained how they adopted the improved rice varieties as follows:

When we get any new rice varieties, we normally allocate small portions of our farms (about 0.25 acres) to try growing the seeds for the first time. That helps us to test their viability and productivity for the very first time. We then multiply the seeds the following year on about 0.5 acres of our rice fields to determine whether they are suitable for our soils, weather conditions, consumption, and market demands. When all those conditions are favourably met, we then cultivate them on large scales of about 2 acres or more. If not, we ignore them and either adhere to the cultivation of our traditional varieties or look for other improved varieties with better qualities to adopt.

However, when we cultivate any new varieties continuously for about four years, we change them and grow different varieties on the same fields. If not, they mix up with wild rice varieties from the soil and neighbouring fields. They also become susceptible to pests and diseases infestations as well as decline in yields, among other reasons. We are normally advised by the extension officers and researchers to buy new certified seeds after every four years but those seeds are more expensive. So, we continue to recycle our own seeds for subsequent cultivation. Besides, we normally use the same rice fields for all our rice varieties so the only thing we do is to change from one variety to another. However, we normally do not revert to the old varieties because there are other new varieties available for cocultivation (adoption). The best thing would have been for us to use different fields for different rice varieties but the land is limited; we have few rice fields. Our lands are also

> *not fertile. So, we spend huge sums of money buying fertilizers and other agro-chemicals. It therefore becomes difficult for us to keep buying new certified seeds every now and then.*
>
> *Sometimes, we get free improved seeds and fertilizers from MoFA, middlemen, processing companies and NGOs, so we leave the existing varieties and cultivate those ones since most of them come with ready markets and other incentive packages. But when they fail us, we stop growing their rice and stick our own varieties. For example, in the case of NERICA, SARI and MoFA used to buy the seeds and grains from us but when they stopped, we had nobody to buy them from us, and we loss woefully. The market women and consumers prefer AGRA and JASMINE 85 to NERICA and other improved rice varieties. We are therefore cultivating AGRA and JASMINE 85 now because they sell (FGD, Botanga, January 19, 2020; 3:15pm).*

Some individual farmers also recounted how they adopted and disadopted some improved rice varieties. A contact farmer at Kpachi in the Tolon District said he invested so much money into the cultivation of Jasmine 85 in 2016 because AVNASH processing company at Nyankpala was buying huge quantities of rice grains from farmers in the district. But he lost his farm to drought that year and had since not recovered from the shock. So, he stopped cultivating Jasmine 85 in 2016 and started Agra cultivation in 2017. Another farmer at Nabogu in the Savelugu Municipality also said he lost about twenty acres of his Mandee rice farm at Diare to a swam of birds in 2016 at the time of harvest. So, had also stopped growing

Mandee since those birds were prevalent in that community, and relocated to Nabogu to cultivate Tox, also known as Nabogu rice.

Similarly, a farmer at Jana in the Nanton District recounted:

> *In 2017, I harvested over fifty bags of Afife rice in my farm and managed to carry them with the help of labourers to a nearby roadside. I went to town to look for a vehicle to convey them home but upon my return to the roadside, I realized that bush fire had devoured my entire harvest. I lost both my grains, and rice seeds, which I would have used for sale and subsequent cultivations respectively. I was devastated. So, I had to look for different rice seeds (Salma-Saa) to grow the following year. The Afife was good for my soil and I used to cultivate five acres but now I only cultivate two acres of Salma-Saa (FGD, January 26, 2020; 11:30am).*

In the same way, many farmers in the Kumbungu District said they predicted the weather to sow their rice seeds in 2017 and 2018 cropping seasons but most of the seeds failed to germinate because the rains did not come down as expected. Those that germinated also got scorched by the sun and weathered. They then looked for different varieties of seeds to sow and those seeds also got rotten and some were washed away, due to flooding.

They said they could not get the same varieties they usually cultivated on their farms (Faro 15, GR 18, Agra and Jasmine 85) after those horrible incidents, for re-cultivation. So, they resorted to the cultivation of Mandee and Kpokpula, which matured in about four months. However, due to the reduced rainfall pattern in recent years, those two varieties also dried up in the fields before maturity. Hence, they could not break even in 2017 and 2018. They therefore resorted to the cultivation of an improved rice variety called Moses and a traditional variety known as Alhaji Iddi, which were common in the study area. Many farmers at Botanga and Dallon did not experience those devastating effects of droughts and flooding due to the presence of irrigation facilities in their communities. It means adoption of the improved rice varieties occurred after farmers became aware of them, had tried them and were convinced to accept and grow them for commercial purposes, corroborating Rogers, (2005). The disadoption of the improved rice varieties occurred after adoption, when farmers faced adverse conditions for their continuous adoption and had lost the needed utility from their adoption decisions, corroborating (Lastovicka and Karen, 2005).

This shows that adoption and disadoption are indeed two sides of the same coin. There was relatively little uncertainty in the disadoption processes about what farmers were missing, compared with the adoption processes in which uncertainty was inherent. The farmers also adopted the rice varieties by receiving them but disadopted them without getting rid of them in their communities. The farmers as well went through several psychological processes such as loss phobia and possession utility in the disadoption processes than in the adoption processes, which were more fulfilling and satisfying. The farmers therefore showed excitement narrating their adoption experiences but sadness when recounting the processes that led to their disadoption decisions. That confirmed the fact that the psychology of choice is markedly different from the psychology of rejection (Lastovicka and Karen, 2005).

The processes of improved rice variety disadoption in the study area therefore comprised withdrawal, disengagement, discontinuity, abandonment, desertion and rejection. Each of these process terminologies can be investigated as an entity, over a long period of time (Duck, 1982). This makes disadoption studies a protracted phenomenon compared to adoption studies that are quite dichotomous. The protracted nature of disadoption studies discourages many researchers from venturing into that terrain, especially in Ghana.

6.5 Factors influencing initial adoption, current adoption and disadoption of improved rice varieties in the Northern Region

This section analyzes the factors influencing initial adoption, current adoption and disadoption of improved rice varieties in the Northern Region. It begins with the descriptive statistics of factors affecting the adoption and disadoption of the five selected rice varieties (6.51). That is followed by definitions of variables used for the adoption/disadoption model and their a-priori expectations (6.5.2). The section (6.5.3) continues with a discussion on the factors influencing initial adoption, current adoption and disadoption of improved rice varieties in the study area. Finally, the section (6.5.4) ends with summary of factors affecting adoption and disadoption of improved rice varieties in the study area.

6.5.1 Descriptive statistics of selected variables for the adoption/disadoption model

The results of demographic and socio-economic features of the rice farmers are discussed in section 6.1. However, this sub-section presents a brief discussion on the descriptive statistics of factors affecting adoption and disadoption of the five selected rice varieties used for the adoption/disadoption model. The results presented in Table 6.11 shows that the descriptive statistics of variables used in the adoption/disadoption model are not very different from the socio-economic and demographic charateristics of the farm households in the region.

Besides, the study found that about 46% of the rice farm households continued to adopt the improved rice varieties in the study area. This implies that the majority of rice farmers (54%) disadopted the improved rice varieties. That could lead to low rice production and productivity, which could worsen food insecurity and poverty among rice farm households. Key informant interviews with researchers and extension agents revealed that the reasons for disadotion of improved rice varieties include (1) poor access to farm inputs and output market; (2) pests and diseases infestations; (3) lack of access to production credit; (4) poor taste and aroma of some rice varieties; and (4) labour intensiveness for adopting the varieties as well tasking agronomic practices associated with their adoption. A contact farmer at Nabogu lamented on January 9, 2020:

> *I used to cultivate Jasmine rice variety when it first came to our community. However, I realized that it is less resistant to pests and diseases. So I stopped planting that variety and adhered to Kpokpula, a local rice variety, which is hardy and resistant to pests, diseases and water stress.*

On February 7, 2020, another rice farmer at Kpachi in the Kumbungu District argued:

> *When NGOs and MoFA are coming to implement improved rice variety adoption projects, they give us easy access to farm inputs and ready markets for outputs. They leave us tot our fates when the projects end, which makes it difficult for us to access farm inputs and markets for our produce. Would*

this situation encourage us to continue adopting such rice varieties when the projects end?

This anectode confirms the fact that innovation adopters are rational beings responsible for their adoption/disadoption decisions (Doss, 2006; Rogers, 2003). It also buttresses the fact that much of the success stories of improved rice variety adoptions in Africa revolve around the dissemination periods (Lamptey, 2018; FAO, 2013; World Bank, 2013).

Table 6. 11: Descriptive statistics of selected variables

Variable	Mean	Std. Dev.
Adoption/disadoption	0.46	0.50
Age	39.69	10.65
Gender	0.90	0.30
Education	0.29	0.46
Electricity	0.80	0.40
Family labour	5.63	8.80
FBOs	0.47	0.50
Mobile phone	0.25	0.43
Field demo	0.62	0.49
Input market	0.85	0.36
Production credit	0.35	0.48
Extension service	0.80	0.40
Farm plot area	3.87	3.81
Government policy	0.87	0.34
Mechanization	0.78	0.41
Rainfall perception	0.92	0.28

Source: Survey data, 2020

Otherwise, the results in Table 6.11 further shows that the mean age of rice farm households in the region was approximately 40 years with an average of 3 years of schooling. This means the rice farmers were predominantly in their youthful years with little education, which could translate into real adoption/usage of improved rice varieties. Meanwhile, formal education among rice farmers was still low, which resulted in the disadoption of rice production technologies. Martey et al. (2013) revealed that farmers with formal educational backgrounds are more prone to adoption because they tend to co-operate favourably with other farmers' development organizations. The family labour and mean farm size of the rice farmers were approximately 6 people and 0.65 ha respectively. The little higher use of family labour means that rice farmers can rely on family labour to reduce the cost of production when adopting new rice varieties. The little rice farm sizes of the farmers confirmed MoFA-SRID (2016) findings that about 90% of smallholders cultivate less than 2 Ha in Ghana. The study further revealed that about 90% of the respondents were males, meaning that rice is predominantly produced by men in the region. The low percentage of female farmers in this study corroborates Martey et al. (2013) who asserted that females were normally occupied with domestic activities such that they did not have enough time to participate in Rice Development Projects (RDP) compared to their male counterparts. Rice farmers' awareness of government policy about rice production plays a critical role in technology adoption to enhance rice production and productivity. The study demonstrated that about 87% of rice farmers were aware of government policy for the rice sector. This will influence farmers positively, especially the youth, to make rice production a business instead of conventional farming. Also, about 62%, 85%, 80%, and 35% of rice farmers had access to field demonstration, input market, extension services and production credit respectively. These imply that rice farmers' ability to access agricultural extension services, farm inputs, and participation in rice field demonstrations was high to enhance adoption. However, they had less access to production capital, which could induce disadoption. About 92% of rice farmers perceived a decrease in the rainfall pattern for the past ten years, 75% had access to good road network, 47% belonged to FBOs, 25% owned mobile phones, and 78% practiced mechanization (used tractor for land ploughing). These all have the potentials of influencing adoption/disadoption either negatively or postitively, as shown in Tables 6.12.

6.5.2 Definaitions of variables and their a-priori expectations

The Table 6.12 illustrates the definitions of variables and their a-priori expectations relative to adoption/disadoption. Here, adoption is considered as a dummy variable and denoted by 1, if a farmer ever adopted any of the selected rice varieaties before 2019 and 0, if otherwise. Similarly, adoption takes on a dichotomous nature and is denoted by 1, if a farmer continued to adopt any of the selected rice varieties as at the 2019 cropping season and 0, if otherwise. Any farmer who did not cultivate a particular rice variety for a minimum of three years, from 2009 to 2019 cropping seasons, was therefore considered a *non-adopter* (Doss, 2006; Rogers, 2005; Doss et al., 2003; Doss and Morris, 2001). By extension, farmers who adopted any of the rice varieties for a minimum of three years within the reference period were categorized as *initial adopters*. Adopters who maintained their adotption decisions and cultivated any of the improved rice varieties during the 2019 cropping season were categorized as *current adopters.* Hence, adopters who had discontinued their adoption decisions and who no longer cultivated any of the selected rice varieties as at the 2019 farming year were considered *disadopters*.

Table 6. 12: Definitions of variables and their a-priori expectations

Variable	Description	Measurement	A-priori expectation
Adoption	If a farmer ever adopted improved rice variety, and continued to adopt.	Dummy: (1) Yes (0) No	N/A
Age	Age of a rice farmer.	Years	+/-
Gender	Sex of a rice farmer.	Dummy: (1) Male (0) Female	+/-
Education	Number of years a rice attended formal school.	Years	+
Family labour	Total number of family labour used in rice production	Number	+/-
Electricity	A rice farmer household have access electricity	Dummy: (1) Yes (0) No	+/-
FBOs	A rice farmer belong to rice farmers association	Dummy: (1) Yes (0) No	+
Mobile phone	A rice farmers have his/her own phone for communication	Dummy: (1) Yes (0) No	+
Output market	A rice farmers had access to output market in the community/nearby community	Dummy: (1) Yes (0) No	+
Input market	A rice farmer have access to inputs market in the community.	Dummy: (1) Yes (0) No	+
Credit	A rice farmer have access production credit.	Dummy: (1) Yes (0)No	+
Extension service	A rice farmer had access to extension service in 2019/2020 cropping calendar	Dummy: (1) Yes (0)No	+
Farm area	Rice farm plot area of a farmer.	Acres	+/-
Rice policy	A rice farmer is aware of any government rice policy in Ghana	Dummy: (1) Yes (0)No	+
Field Demo	A rice farmer ever participated in rice production field demonstration	Dummy: (1) Yes (0) No	+
Road network	A community have good road network to marketing centers/towns	Dummy: (1) Yes (0) No	+
Mechanization	A farmer have access to tractor service and used it for ploughing rice field.	Dummy: (1) Yes (0)No	+
Rainfall perception	A rice farmer perception of rainfall pattern.	Dummy: (1) decreased (0) increased	+
Combine harvester	A rice farmer have access and used combined harvester	Dummy: (1) Yes (0)No	+

Source: Author's construct, 2020

6.5.3 *Factors influencing initial adoption, current adoption and disadoption*

This sub-section looks at the factors that affect initial adoption, current adoption and disadoption of improved rice varieties in the study area, using the generalized form of the Multivariate Regression Model (MRM). Three dependent variables and thirteen explanatory variables, of which eleven were dummy and two continuous, were included in the model for each of the five rice varieties under study. The independent variables considered were age, sex, education, input market, farm size, family labour, telephone ownership, FBO membership, production credit, extension service, field demonstrations, perception of temperature and awareness of government policy for the rice sub-sector of MoFA, as shown on Tables 6.13 and 6.14. The tables give several observations, number of parameters, RMSE, R-squared, F-ratio, and p-value for each of the initial adoption, current adoption and disadoption decisions for each of the five main rice varieties. The tables also give the coefficients and their standard errors, for each of the initial adoption, current adoption and disadoption decisions for each of the five main rice varieties, grouped by outcome.

The results indicate that the model was suitable for the analysis made, since nine out of the thirteen p-values were less than 0.0001. In the row labelled R^2, we see that the thirteen predictor variables explained 9.90%, 5.35% and 5.30% of the variance in the outcome variables; initial adoption, current adoption and disadoption decisions of Mandee, respectively. The R^2 values in this case were standard R-squared values, not adjusted R-squared values. Similarly, the values for Jasmine were 29.70%, 13.80%, and 13.80% respectively. In the same way, the values for Agra were 41.80%, 38.40% and 38.30%; those of Afife were 13.90%, 6.70% and 6.70% while

9.80%, 11.57% and 11.60% were for Salma-Saa, respectively. Looking at F row, we see that each of the initial adoption, current adoption and disadoption decisions were statistically significant for all the five rice varieties modelled.

Table 6. 13: Factors influencing initial adoption, current adoption and disadoption of improved rice varieties (MRM)

Variable	Mandee			Jasmine			Agra		
	Initial adoption	**Dis-adoption**	**Current adoption**	**Initial adoption**	**Dis-adoption**	**Current adoption**	**Initial adoption**	**Dis-adoption**	**Current adoption**
	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)
Age	**0.003**** **(0.002)**	**-0.004**** **(0.002)**	**0.004**** **(0.002)**	0.001 (0.002)	**0.004**** **(0.002)**	**-0.004**** **(0.002)**	0.001 (0.002)	0.002 (0.002)	-0.002 (0.002)
Sex	**-00.132**** **(0.056)**	0.014 (0.055)	-0.014 (0.055)	-0.004 (0.071)	-0.007 (0.059)	0.007 (0.059)	**-0.180***** **(0.071)**	0.104 (0.065)	-0.104 (0.065)
Education	0.002 (0.00o4)	-0.0002 (0.004)	0.000 (0.004)	-0.004 (0.005)	**0.009***** **(0.004)**	**-0.009**** **(0.004)**	-0.002 (.005)	0.002 (0.004)	-0.002 (0.004)
Family Labor	0.010 (0.006)	**-0.011*** **(0.006)**	**0.011*** **(0.006)**	**0.024***** **0.008)**	**-0.017**** **(0.007)**	**0.017***** **(0.007)**	**0.018**** **(0.008)**	**-0.016**** **(0.007)**	**0.016**** **(0.007)**
FBOs	**-0.107***** **(0.038)**	**0.100***** **(0.037)**	**-0.100***** **(0.037)**	**0.123***** **(0.048)**	-0.044 (0.040)	0.044 (0.040)	**0.119**** **(0.048)**	**-0.204***** **(0.044)**	**0.204***** **(0.044)**
Credit	**-0.068**** **(0.034)**	-0.041 (0.033)	0.041 (0.033)	-0.024 (0.043)	**0.065*** **(0.036)**	**-0.065*** **(0.036)**	**-0.091**** **(0.042)**	0.068* 9(0.039)	**-0.068*** **(0.039)**
Extension	**90.081*** **(0.043)**	-0.069 (0.043)	0.069 (0.043)	-0.083 (0.055)	0.022 (0.046)	-0.022 (0.046)	0.044 (0.055)	-0.024 (0.050)	0.024 (0.050)
Inputs market	-0.073 (0.051)	-09.034 (0.050)	0.034 (0.050)	**0.302***** **(0.065)**	**-0.146***** **(0.054)**	**0.146***** **(0.054)**	**0.331***** **(0.064)**	**-0.210***** **(0.059)**	**0.210***** **(0.059)**
Farm size	-0.009 (90.006)	**0.011*** **(0.006)**	**-0.011*** **(0.006)**	**-0.017**** **(0.008)**	**0.023***** **(0.007)**	**-0.023***** **(09.007)**	**0.038***** **(0.008)**	**-0.039***** **(0.007)**	**0.039***** **(0.007)**
Telephone	0.053 (0.042)	-0.9021 (0.042)	0.021 (0.042)	**0.201***** **(0.054)**	0.027 (0.045)	-0.027 (0.045)	**0.366***** **(0.053)**	**-0.314***** **(0.049)**	**0.314***** **(0.049)**
Field Demo	-0.019 (0.037)	-0.022 (0.036)	0.022 (0.036)	0.321*** **(0.047)**	**-0.119***** **(0.039)**	**0.119***** **(0.039)**	-0.026 (0.046)	**0.083**** **(0.042)**	**-0.083**** **(0.042)**
Temperature	0.090 (0.072)	-0.083 (0.071)	0.083 (0.071)	**0.203**** **(0.091)**	-0.085 (0.076)	0.085 (0.076)	0.114 (0.091)	-0.044 (0.083)	0.044 (0.083)
Government	**-0.111****	0.047	-0.047	0.083	**-0.127****	**0.127****	0.056	-0.079	0.079

Policy	**(0.050)**	(0.049)	(0.049)	(0.064)	**(0.053)**	**(0.053)**	(0.063)	(0.058)	(0.058)
_cons	0.202	1.114	-0.114	-0.247	0.987	0.013	-0.112	**1.035*** **	-0.035
	(0.130)	(0.127)	(0.127)	(0.165	(0.137)	(0.137)	(0.163)	**(0.150)**	(0.150)
Model summary									
RMSE	0.331	0.326	0.326	0.422	0.351	0.351	0.418	0.384	0.383
R^2	0.099	0.0535	0.053	0.297	0.138	0.138	0.301	0.3063	0.306
F	3.293***	1.695**	1.695**	12.665***	4.811***	4.811***	12.888***	13.247***	13.247***
P	0.0001	0.0596	0.0596	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

*, **, and *** represent 10%, 5%, and 1% level of significance respectively.
Source: Survey data, 2020

Table 6. 14: Factors influencing initial adoption, current adoption and disadoption of improved rice varieties (MRM) --- continued

Variable	Afife			Salma-Saa		
	Initial adoption	**Dis-adoption**	**Current adoption**	**Initial adoption**	**Dis-adoption**	**Current adoption**
	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)	Coefficient (Std. Err.)
Age	0.001	0.001	-0.001	0.003	**-0.003** **	**0.003** **
	(0.002)	(0.002)	(0.002)	(0.002)	**(0.002)**	**(0.002)**
Sex	-0.062	0.051	-0.051	0.093	-0.104*	**0.104***
	(0.065)	(0.055)	(0.055)	(0.069)	(0.057)	**(0.057)**
Education	0.0002	0.003	-0.003	0.004	-0.002	09.002
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)
Family Labor	**0.021*** **	-0.002	0.002	**0.015***	-0.001	0.9001
	(0.007)	(0.006)	(0.006)	**(0.008)**	(0.006)	(0.006)
FBOs	**-0.162*** **	**0.095*** **	**-0.095*** **	-0.075	**0.073** **	**-0.073** **
	(0.044)	**(0.037)**	**(0.037)**	(0.047)	**(0.038)**	**(0.038)**
Credit	0.016	-0.008	0.008	0.004	-0.042	0.042
	(0.039)	(0.033)	(0.033)	(0.042)	(0.034)	(0.034)
Extension	-0.043	**-0.080***	**0.080***	**0.203*** **	**-0.131*** **	**0.131*** **
	(0.050)	**(0.043)**	**(0.043)**	**(0.053)**	**(0.044)**	**(0.044)**
Inputs market	**0.266*** **	0.028	-0.028	-0.085	0.011	-0.011
	(0.059)	(0.050)	(0.050)	(0.063)	(0.052)	(0.052)

Farm size	0.004	0.004	-0.004	**-0.014***	**0.017*****	**-0.017*****
	(0.007)	(0.006)	(0.006)	**(0.008)**	**(0.006)**	**(0.006)**
Telephone	**0.128*****	**-0.118*****	**0.118*****	**-0.103****	0.066	-0.066
	(0.049)	**(0.042)**	**(0.042)**	**(0.052)**	(0.043)	(0.043)
Field Demo	**0.152*****	-0.047	0.047	**-0.106****	**0.143*****	**-0.143*****
	(0.043)	(0.036)	(0.036)	**(0.045)**	**(0.037)**	**(0.037)**
Temperature	0.158*	-0.030	0.030	**0.193****	**-0.134***	**0.134***
	(0.083)	(0.071)	(0.071)	**(0.089)**	**(0.073)**	**(0.073)**
Government Policy	-0.014	-0.008	0.008	0.032	**-0.093***	**0.093***
	(0.058)	(0.049)	(0.049)	(0.062)	**(0.051)**	**(0.051)**
_cons	-0.177	**0.871*****	0.129	-0.180	**1.265*****	**-0.265****
	(0.151)	**(0.128)**	(0.128)	(0.160)	**(0.131)**	**(0.131)**
Model summary						
RMSE	0.385	0.327	0.327	0.410	0.336	**0.336**
R^2	0.139	0.067	0.067	0.098	0.1157	**0.116**
F	4.841***	2..148**	2.148***	3.268***	3.925***	**3.925*****
P	0.0000	0.0112	0.0112	0.0001	0.0000	**0.0000**

*, **, and *** represent 10%, 5%, and 1% level of significance respectively.

Source: Survey data, 2020

Age significantly and positively influenced initial adoption and current adoption of Mande, the disadoption of Jasmine and the current adoption of Salma-Saa at 5% but negatively influenced the disadoption of Mandee, the current adoption of Jasmine, and the disadoption of Salma-Saa, also at 5% level. The contrasting influences of age on the adoption decisions of farmers show that older farmers were prone to adopting Mandee and Salma-Saa while younger farmers were more inclined towards disadopting Mandee and Salma-Saa but adopting Jasmine. The finding on age is consistent with that of Donkoh, Azumah and Awuni (2019). Unlike Denkyirah et al. (2016), who found a negative effect of age on adoption of pesticides, Simtowe, Asfaw and Abate (2016) as well as and Danso-Abbeam and Baiyegunhi (2017) also found a positive and significant relationship between the age of a farmer and the adoption of agricultural technology.

Sex was only significant but negative in explaining the initial adoption decisions of Mandee and Agra at 5%. It means female rice farmers were more inclined towards the initial adoption of Mandee and Agra than their male counterparts. Donkoh, Azumah and Awuni (2019), also found that the sex of a farmer positively and significantly influenced only nursery, spacing and line planting, but redundant in explaining the adoption of the other technologies in the study area. Mulwa et al. (2017) and Ragasa et al. (2013) likewise found the sex variable to be positive and significant in influencing the adoption of improved agricultural technologies. Education was only able to significantly and positively explain the disadoption decision of Jasmine at 10% but negatively influenced the current adoption decision of the farmers at 5%. This implies that educated farmers disadopted Jasmine while their uneducated counterparts currently adopted Jasmine.

This is opposed to Donkoh, Azumah and Awuni (2019), who found the education variable to be redundant in explaining farmers' adoption decisions of agricultural technologies in the study area.

Family labour significantly and positively influenced farmers' initial adoption decisions of Jasmine and Afife at 1% each, Agra at 5%, and Salma-Saa at 10% respectively. Family labour however negatively influenced farmers' disadoption decisions of Mandee at 10%, Jasmine and Agra at 5% each, but redundant in explaining those of Afife and Salma-Saa. Family labour was likewise positively significant in influencing farmers' current adoption decisions of Mandee at 10%, Jasmine at 1%, and Agra at 5% but insignificant for those of Afife and Salma-Saa. It means farmers who largely depended on family labour initially adopted Jasmine, Afife, Agra and Salma-Saa, and were currently inclined to the adoption of Mandee, Jasmine and Agra than their counterpart farmers who depended less on family labour. It also means that farmers who depended less on family labour were prone to the disadoption of Mandee, Jasmine and Agra. The findings met the a priori expectation of this study since family labour was less expensive compared to hired labour (Lamptey, 2018). The farmers also confirmed during FGDs that the adoption of improved rice varieties in the study area had high input requirements such as labour, certified seeds, fertilizers and other agro-chemicals, among others.

FBOs had positive and negative significant associations with the adoption and disadoption decisions of the various rice varieties except the initial adoption of Salma-Saa, the disadoption and current adoption of Jasmine. There were positive and significant relationships between FBOs and farmers' disadoption decision of Mandee, initial and current adoption decisions of Jasmine, the current adoption of Agra, and the disadoption of Afife at 1% respectively. FBOs also influenced the initial adoption decision of Agra and the disadoption of Salma-Saa positively at 5%. FBOs likewise negatively influenced the initial and current adoption decisions of Mandee as well as the disadoption of Agra at 1%, and the current adoption of Salma-Saa at 5%, respectively. The positive associations between FBOs and the various rice varieties imply that farmers who belonged to FBOs adopted or disadopted those rice varieties more than their counterpart farmers who did not belong to any farmer groups, and vice versa. Donkoh et al. (2019), and Mulwa et al. (2017), also observed a negative association between membership of FBO and the use of improved technologies. Aryal et al. (2018) also found that FBO membership increased farmers' level of using stress tolerant rice varieties positively and significantly. FBO membership serves as a social capital for farmers to utilize opportunities for mutual support and to share knowledge and skills in the agricultural value chain (Zakaria et al., 2016).

Farm credit negatively and significantly influenced the initial adoption of Mandee and Agra at 5%, the current adoptions of Jasmine and Agra at 10%, but related positively to the disadoption decisions of Jasmine and Agra at 10%, respectively. The positive associations between farm credit and farmers' disadoption decisions of Jasmine and Agra indicate that farmers who had access to farm credit disadopted Jasmine and Agra more than the other rice varieties. The negative associations between farm credit and the initial adoptions of Mandee and Agra as well as the current adoption decisions of Jasmine and Agra imply that farmers who did not have access to farm credit initially adopted Mandee and Agra and have stacked to their current adoption decisions of Jasmine and Agra. That should be expected, because the farmers explained during FGDs that they did not depend on credit for their farming activities, due to uncertainties, such as unpredictable climate and market price, associated with rice cultivation in the region. Zakaria et al. (2016) and Martey et al. (2013) also found positive associations between production credit and farmers' adoption of agricultural innovations. Economic theory shows that farmers will access credit only if it is economical to do so; where profitability depends on the price of credit and the potential returns of investment (Doss, 2006). It may also be that the use of those varieties may increase production risks, such that if the crops fail, the financial losses will be higher (Doss et al., 2003). Similarly, Mateos and Dadzie (2014) found that access to credit prevents disadoption of the maize crop among farm households.

Extension was positively significant in relating to farmers' initial adoption and current adoption decisions of Mandee and Afife at 10% each, the initial and current adoption decisions of Salma-Saa at 1% each, but negatively related to the disadoption decisions of Afife at 10% and Salma-Saa at 1%, respectively. It means farmers who had more extension contacts and access to extension services adopted Mandee, Afife and Salma-Saa more than farmers who has less extension contacts. That should be expected, because extension contacts ranked third on the list of innovation communication channels analysed in this study. It also means inadequate extension contacts or services led to the disadoption of Afife and Salma-Saa, but extension contacts were insignificant in explaining farmers' initial adoption, current adoption and disadoption decisions of

Jasmine and Agra (the prevailing improved rice varieties in the region). This finding is consistent with those of Akpan et al. (2013) and Amao (2013). Donkoh et al. (2019) also found that access to research and extension services positively and significantly influenced the adoption of only one out of seven agricultural technologies promoted in the study area.

Input markets significantly influenced farmers' adoption and disadoptions decisions at 1%. Input markets had positive and significant associations with farmers' initial and current adoption decisions of Jasmine and Agra as well as the current adoption of Afife, but related negatively with the disadoption decisions of Jasmine and Agra, all at 1% each. It means farmers who were closer to input markets adopted Jasmine, Agra and Afife while those who were far off disadopted Jasmine and Agra. That should be expected, because market accessibility was one of the incentives for improved rice variety adoption in the study area, as indicated by the farmers during FGDs and confirmed by KIIs. Farm size had significant but contracting associations with the farmers' adoption and disadoption decisions of all the rice varieties, except Afife. Farm size positively related to the disadoption of Mandee at 10%, the disadoption decisions of Jasmine and Salma-Saa at 1% each, the initial and current adoptions of Agra at 1% respectively. It however related negatively with the initial adoption of Salma-Saa and current adoption of Mandee, both at 10%, the initial and current adoption decisions of Jasmine and disadoption of Agra, and the current adoption of Salma-Saa, respectively at 1% each.

It means farmers with smaller farm sizes adopted Salma-Saa, Agra, but disadopted

Mandee, Jasmine and Salma-Saa as opposed to their counterpart farmers with large farm sizes. The conflicting effects of farm size on farmers adoption and disadoption decisions imply that the decision to adopt or disadopt the main rice varieties was not primarily dependent on the size of a farmer's farm. This finding is consistent with the study of Kassie et al. (2015), who suggested that the scarcity of land can induce agricultural intensification through the adoption of improved technologies.

There were positive significant effects of telephone ownership on farmers' initial adoption decisions of Jasmine, Agra and Afife, as well as the current adoptions of Agra and Afife, all at 1% each. Telephone ownership however, negatively affected the disadoption of Agra and Afife at 1%, and the initial adoption of Salma-Saa at 5% respectively. The results show that farmers who had access to telephones adopted Jasmine, Agra and Afife whereas those who did not have telephones disadopted Agra and Afife but adopted Salma-Saa in the past. This is plausible, since telephone is one of the main channels of promoting rice varieties in the region. Zakaria, Azumah, Akudugu and Donkoh (2019) also found that ownership of mobile phone had positive and statistically significant relationship with livelihood diversification.

Field demonstrations significantly and positively related with farmers' initial and current adoption decisions of Jasmine, the current adoption of Afife and the disadoption of Salam-Saa, all at 1% each; but negatively affected the disadoption of Jasmine at 1%, the current adoption of Agra at 5%, the initial adoption of Salma-Saa at 1% as well as the current adoption of Salma-Saa at 5% respectively. These show that farmers who participated in demonstration farms or had the opportunity to see the demonstration farms of improved rice dissemination projects had higher tendencies of adopting Jasmine and Afife, and disadopting Salma-Saa than farmers who did not see or participate in the demonstration farms of the AEAs and contact farmers.

Temperature was only able to positively explain farmers' initial adoption decisions of Jasmine and Salma-Saa at 5% each, Afife at 10%, the current adoption of Salma-Saa at 10%` but negatively related to the disadoption of Salma-Saa at 10%, respectively. These imply that farmers who perceived increase in temperature over the past decade adopted Jasmine, Salma-Saa and Afife than farmers who thought otherwise. This is in tandem with Zakaria et al. (2019), who also found the perception indicators of climate change (rainfall and temperature) to be significant and negatively influenced livelihood diversification among rice farmers.

Similarly, government policy positively influenced farmers' disadoption decisions of Afife and Agra at 1% each, the current adoption decisions of Jasmine at 5% and Salma-Saa at 10% but negatively affected farmers' disadoption decisions of Salma-Saa and Jasmine at 10% and 5% respectively, as well as the initial adoption of Mandee at 5%. The implications of these findings are that farmers who were aware of government policies for the rice sub-sectors of the economy disadopted Afife, Agra, and adopted Jasmine and Salma-Saa more than those who were not aware of such policies. Though the government policies served as incentives for rice farmers, their disadoption of the rice varieties were primarily influenced by climatic factors, market forces and inherent characteristics of the rice varieties themselves.

6.5.4 Summary of factors affecting adoption and disadoption

Generalized MRM was used to examine the factors influencing initial adoption, current adoption and disadoption of improved rice varieties. The initial adoption and current adoption decisions for almost all the rice varieties had common signs (positive) while disadoption decisions had opposite signs (negative). These indicate that the same factors influenced adoption and disadoption but in opposite directions.

Starting with the initial adoption, farmers' age, family labour, FBO, extension, input market, farm size, telephone, field demonstrations, and temperature were found to have positive significant effects on Mandee, Jasmine, Agra, Afife and Salma-Saa adoption. Similarly, sex, FBO, farm credit, farm size, telephone, and field demonstrations were found to have negative significant effects on the initial adoption of Agra, Jasmine, Mandee, and Salma-Saa.

Morever, the disadoption of Afife, Agra, Jasmine, Mandee and Salma-Saa were found to be positively and significantly affected by farmers' age, family labour, FBO, farm credit, extension, farm size, field demonstrations and government policy. The disadoption of Mandee, Afife, Agra, Jasmine and Salma-Saa were also found to be negatively and significantly affected by farmers' age, family labour, FBO, input market, farm size, telephone, field demonstrations, temperature, and government policy.

Finally, the current adoption of Mandee, Salma-Saa, Jasmine, Agra and Afife were found to be positively and significantly influenced by farmers' age, FBO, extension, input market, farm size, telephone, field demonstrations, temperature and government policy. Farm credit, farmers' age, farm size, FBO, and field demonstrations were found to have negative and significant effects on the current adoption of Jasmine, Agra, Mandee, and Salma-Saa.

6.6 Effect of improved rice variety adoption among farm households in the North

The fifth objective of the thesis assessed the effect of adoption of improved rice varieties among farm households in the Northern Region of Ghana, using the PSM approach. It is divided into four sections. The first section (6.6.1) looks out for overlaps and common support in the propensity score distribution, using a histogram. The second section (6.6.2) presents propensity score test (t-test) of variables in the model. The third section (6.6.3) gives an overall quality test of factors before and after matching while the final section (6.6.4) presents estimates of the impact of improved rice varieties adoption among the farm households in the region.

6.6.1 Overlapping and common support in the propensity score distribution

Observed differences in the characteristics between adopters and non-adopters of improved rice varieties were checked using the PSM approach. The observed differences between treated and untreated groups were detected using the common support region. The minima and maxima were used to figure out the validity of the common support region. The principle is that if the propensity scores estimate points are less than the minimum and/or greater than the maximum, the opposite group is eliminated from the data points (Caliendo and Kopeinig, 2005). However, the restriction of the overlap region between the propensity scores of the two groups, might result in discarding an enormous number of observations. Therefore, the trimming procedure was employed as a remedy to that challenge, of the region of common support, where P has positive density within both Y = 1 and Y = 0 distributions (Smith and Todd (2005). The common support condition was employed to match the region of common support for the treated and untreated groups. The counterfactual condition was met by using the common support region condition. The presence of acceptable overlap between the treated and untreated groups was accordingly checked. The matching distribution of the propensity scores after matching for treated and untreated are as shown by the histogram in Figure 6.1. The bottom half of the figure shows the propensity scores distribution for the untreated, while the upper-half refers to the treated individuals. The densities of the scores are on the y-axis. A closer look at the figure shows that the common support region is a well-balanced match for the entire sample. This signifies adequate overlap between the two groups and implies that the matching has produced counterfactual that are statistically related to the adopters. The findings are consistent with those of Zakaria et al. (2019), Martey et al. (2015) and Elias et al. (2013).

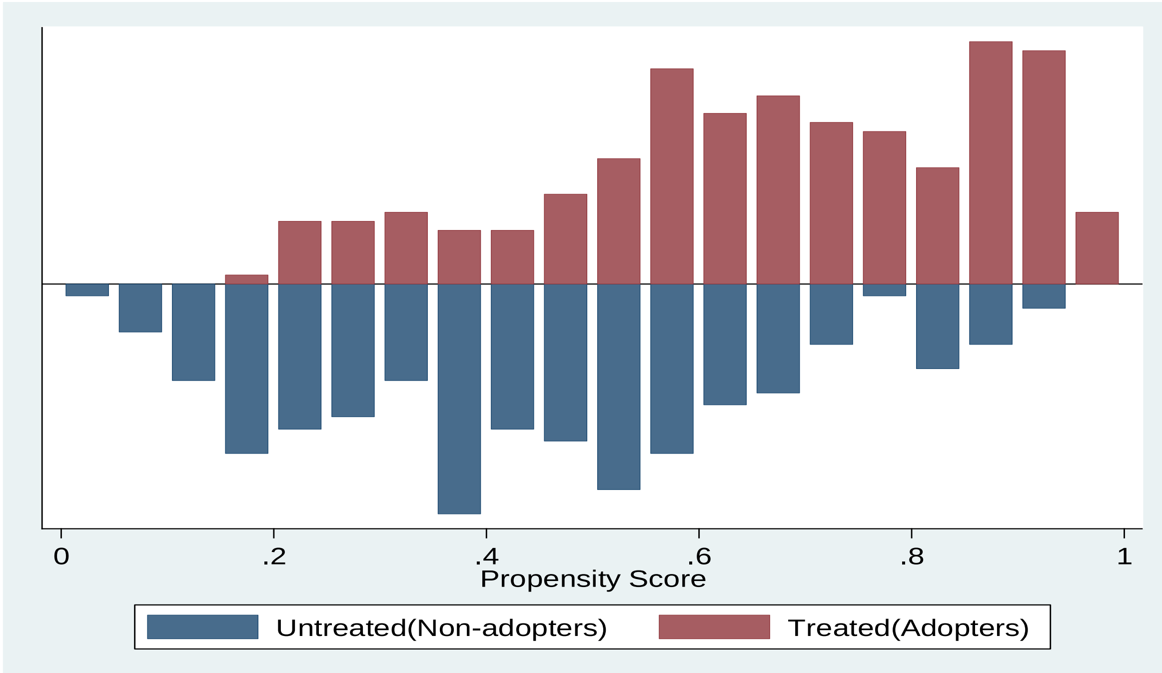

Figure 6. 1: Propensity score distribution

Source: Survey data, 2020

6.6.2 *Propensity score test of variables in the model*

The propensity score tests of variables in the model, consisting real adopting (treated) and non-adopting (control) households, using both the matched and unmatched samples are as shown in appendix F. The socio-economic and institutional characteristics considered were gender, age, electricity, education, family labour, FBOs, credit, extension, input market, farm size, telephone, field demonstration, temperature, mechanization and government policy. The average age of the real adopters (from the treated households) was about 41 years whereas those of the non-adopters (from the control households) was found to be 39 years. The age difference between the two households is statistically significant. Zakaria et al. (2019) also found a significant difference between the average ages of farmers from diversified households (40 years) and those from non-diversified households (39 years). The other variables were also significant with various associations with adopters and non-adopters.

6.6.3 Overall quality test of factors before and after matching

Table 6.15 reports the summary statistics of the overall quality test of factors before and after matching. The mean biasness of the unmatched (adopters) and matched (non-adopters) were 108.6 and 55.4 respectively. Both means were significant at 10%, meaning there was selection biasness of the adopters and non-adopters of improved rice varieties in the study area. The percentage reduction of biasness in the sample was 48.98%.

Table 6. 15: Overall quality test of factors before and after matching

Sample	Ps	R2	LR	chi2	p>chi2	Mean Bias	Percentage reduction of bias
Unmatched	0.184	101.380	0.000	26.800	26.400	108.6*	48.98
Matched	0.057	36.350	0.002	13.200	9.00	55.4*	

Source: Survey data, 2020. * indicates significance at 10%

6.6.4 Impact of improved rice varieties adoption

Table 6.16 presents estimates of impact of improved rice varieties adoption among farm households in the study area. All the variables were statistically significant except nearest-neighbour matching for the average treatment effect on the control (ATC), which means future projects on adoption of improved rice varieties are not likely to help improve rice output. The propensity score matching was significant at 1% for the average treatment effect (ATE), average treatment effect on the treated (ATT) and the average treatment effect on the control (ATC). This means that other things being equal, farmers' output will increase if they adopt improved rice varieties. It confirms that adopters of improved rice varieties were better off than the non-adopters. The nearest-neighbour matching was significant at 5% for both the ATE and ATT but insignificant for the ATC. The inverse-probability weights were significant at 1% for the ATE (8.209) but at 5% for the ATT (7.710), meaning adoption of improved rice varieties had a positive impact on farmers' output. The regression adjustment was significant at 1% for both the ATE and ATT respectively. The various significant levels of the variables are indicative of the fact that there were significant impacts of improved rice variety adoption on output of the farm households in the Northern Region.

Table 6. 16: Estimates of impact of improved rice varieties adoption

Estimator	Treatment status		
	ATE	ATT	ATC
	Coefficient (Std. Err.)		
Propensity score matching	7.705*** (1.763)	8.390*** (2.478)	6.782*** (2.549)
Nearest-neighbour matching	4.151** (1.805)	5.321** (2.378)	2.573 (1.649)
Inverse-probability weights	8.209*** (2.779)	7.710** (3.446)	
Regression adjustment	8.844*** (2.015)	8.481*** (2.255)	

Source: Survey data, 2020. *** and ** indicate significance at 1% and 5% respectively

Positive impact was realized for all the matching methods at either the 1% or 5% levels of significance suggesting consistency in the results. Conditional independence was therefore assumed in this study, which implied that adoption was based on observable characteristics since variables jointly influencing adoption were observed. The results corroborate the findings of Martey et al. (2015), Abate et al. (2013) and Elias et al. (2013). Generally, the positive impact could be attributed to the demonstration plots of MoFA on practices relating to the adoption of improved rice varieties and access to input markets, among others, in the region. These benefits served as incentives to improve their adoption of improved rice varieties and their related practices to maximize output. The result justifies investment in agricultural innovation dissemination projects to increase adoption rates of improved rice varieties among farmers in the region so as to ensure maximum rice output.

6.7 Constraints to improved rice variety adoption in Northern Region

This section discusses the constraints to improved rice variety adoption by farmers in the Northern Region. The constraints to adoption facilitated disadoption of improved rice varieties among the farmers. The results in Table 6.18 show that the highest constraint to improved rice variety adoption in the study area was high cost of inputs (95.80%) followed by lack of money to farm/lack of access to credit (91.60%) and lack /unavailability of skilled labour (90.60%). These three constraints topped the list of factors hindering farmers' adoption of improved rice varieties in the Northern Region because they had to do with finances. The constraints to improved rice adoption in the study area are therefore typical of the challenges of peasant farmers in Ghana today, corroborating MoFA-PFJ (2017); DAI, (2015), Ragasa et al., (2013) and NRDS (2009). Smallholder farmers are normally saddled with financial insecurity and they usually complain of lack of funds to farm. So, anytime they are required to part with or raise money for their farming activities, it becomes a problem for them. Hence, they easily embrace innovation packages with financial incentives attached to them or they pretend they lack financial stability so as to win public sympathy.

Table 6. 17: Constraints to improved rice variety adoption

Constraint	Response			
	Yes		**No**	
	Frequency	Percent	Frequency	Percent
High cost of inputs (seeds, chemicals, land, labour, fertilizers)	387	95.80	17	4.20
Lack of money to farm/Lack of access to credit	370	91.60	34	8.40
Lack /Unavailability of skilled labour	366	90.60	38	9.40
Pests/Diseases Infestations/Bad weather	358	88.60	46	11.40
Lack of Incentives/government policies for rice	351	86.90	53	14.10
Lack of access to productive land/ Poor soil fertility	345	85.40	59	14.60
Competition from imported rice /other cereals	330	81.70	74	18.30
Lack of access to tractor/ Mechanization Services	317	78.50	87	21.50
Lack of feedback from farmers to researchers	306	75.70	98	24.20
Poor Infrastructure/Poor Road Network	301	74.50	103	25.50
Politics	295	73.00	109	27.00
Lack of knowledge on associated technologies	274	67.80	230	32.20
Lack of information/unavailability of improved seed	163	40.30	241	59.70
Unwillingness to use new farming methods /practices	113	28.00	291	72.00
Unwillingness to use new improved seeds	106	26.20	298	73.80

Source: Survey data, 2020 N=404

From Table 6.17, the 86.90% of the farmers cited lack of incentives or government policies for rice and lack of access to tractor/mechanization services (78.50%) as some of their prominent constraints, similar to financial considerations. These explain the fact that the farmers normally expect interventions and handouts from the government, NGOs and other philanthropists, corroborating Mustapha et al. (2012) and Diagne et al. (2010). This is consistent with the fact that the agricultural sector in Ghana has benefited from myriad of interventions that seek to improve yield, reduce poverty and increase incomes of farmers (Ragasa et al., 2013; MoFA, 2010). Some of the farmers explained during FGDs that they at times had money to hire tractor and mechanization services but those services were not readily available in their communities. So, they requested if the government could provide them with either free or subsidized tractor/mechanization services to enhance their adoption and largescale production of improved rice varieties. Their non-financial constraints are as shown in Table 6.17.

As can be seen from Table 6.17, most of the farmers had no problems with issues that required no financial commitment from them. Hence, 73.80% of them said 'unwillingness to use new improved seeds' was not a constraint to their farming enterprises. Similarly, 72% of them said they were not unwillingness to use new farming methods/practices. They gave these responses to confirm the fact that most of these new seeds and farming technologies either come to them free of charge or are normally associated with incentive packages such as subsidized fertilizers, corroborating Azumah and Zakaria (2019), and Salifu, (2016). They are therefore always expectant of receiving innovations so as to derive the potential benefits associated with them (Lamptey, 2018). They confirmed this notion during FGDs by saying; "We do not reject new things (innovations). We only trial them for some time and if we are not satisfied with them, then we leave them for other ones." According to them, it is impolite and improper to reject an offer (innovation) even if you do not like it. So, they embrace new farming ideas and later decide whether to adopt or reject them. That is in tandem with Rogers (2005) assertion that rejection of an invention is probable at any stage of the innovation-decision-process.

CHAPTER SEVEN

SUMMARY, CONCLUSSIONS AND RECOMMENDATIONS OF FINDINGS

7.0 Introduction

This chapter presents summary and conclusions of the background information, statement of the problem, the objectives and the main findings of the study. In addition, it presents recommendations (policy implications and areas for further research) and contributions to the body of literature.

7.1 Summary and conclusions of findings

Rice is a very important crop in Ghana because it is widely cultivated across the country and is the number two crop in terms of area planted. It also serves as a major food and cash crop, contributing significantly to consumer diets. In spite of the relative importance of rice in Ghana, the industry is characterized by low productivity challenges resulting from low use of improved rice seeds and inputs.

Rice farmers in Ghana have therefore, over the years, benefited from the dissemination of high-yielding crop varieties in addition to other complementary technologies. However, the adoption rates of improved rice varieties in the study area have been very low with alarming rates of disadoption. While, studies on adoption of improved seed varities abound in Ghana, there is none on the factors affecting disadoption of improved rice varieties, to the best of the resaercher's ability.

The main objective of this study was to investigate the factors influencing the adoption and disadoption of improved rice varieties among farmers in the Northern Region of Ghana. The specific objectives were to: (1) Identify the main innovation communication channels and methods used to educate farmers on improved rice varieties. (2) Identify the levels of adoption and disadoption of the main rice varieties in the Northern Region from 2009 to 2019 cropping seasons. (3) Analyze the reasons, processes and types of improved rice varity adoption and disadoption among farmers in the Northern Region. (4) Analyze the factors affecting initial adoption, current adoption and disadoption of improved rice varieties in the Northern Region of Ghana. (5) Evaluate the effect of improved rice variety adoption on rice output among farm households in the Northern Region of Ghana.

The findings of the study show that the main innovation communication channel used to promote improved rice varieties in the study area was farmer-to-farmer, followed by extension officers and researchers, and certified seed sellers and input dealers. NGOs/FBOs were the least channels of promoting improved rice varieties among the farmers. It means farmers stand a better change of promoting the adoption of improved rice varieties than NGOs, FBOs, researchers, extension agents, certified seed sellers and input dealers. Similarly, the main agricultural innovation communication methods used to educate farmers on improved rice varieties in the study area were farm and home visits, results demonstrations, method demonstrations, group discussions and meetings, radio and television broadcasts, and newsletters. This suggests that, targeting farmers through a combination of the individual, group and mass teaching methods would be a surest way of educating them on agricultural innovations. It means individual extension teaching methods are as cost effective as the group and mass media methods.

The adoption levels were generally low with the most adopted improved rice varieties being Agra (77.33%), Sakai (50%), Jasmine (40.64%) and Afife (23.17%), and the rest falling below 20% each. The disadoption levels on the other hand were very high, with the six most disadopted improved rice varieties being GR-18 (94.23%), Nerica (94.18), Digang (87.72%), Tox (87.18%), Mandee (81.82%) and Faro-15 (80.90%). The disadoption rate of Kpokpula, a traditional variety, was 96.00%, which was higher than the disadoption rates of any of the improved rice varieties. It means the farmers had disadopted both improved and traditional rice varieties, and were more inclined towards the adoption of the newly improved ones, especially Jasmine and Agra. Disadoption of improved rice varieties in the study area can twart government developmental agenda for the rice sub-sector of this country.

The five most important reasons farmers gave for adopting improved rice varieties were, ready market for the produce (81.68%), resistance to pests and diseases (76.73%), higher demand for produce (56.93%), advised by extension staff to cultivate (51.98%) and advised by researchers to cultivate (50.00%). Only 4.95% of them said they adopted the varieties because they got free seeds from promoters. It means adopters were mostly motivated by the marketability of the produce after harvest, because rice had become a commercial crop in Ghana. The farmers' main reasons for disadopting improved rice varieties were high input requirements (95.80%), absence of ready market for the produce (69.31%), output being no longer demanded by consumers (51.98%) and when seeds made the crops too susceptible to droughts (42.08%). The least reason they gave for their disadoption of improved rice varieties was that they were advised by extension staff to stop (26.49%). These reasons confirm the fact that farmers readily adopt high-yielding rice varieties when introduced, but they significantly abandon them in subsequent years, partly due to liquidity constraints.

The presence of several improved rice varieties in the study area made the farmers exhibit "replacement discontinuance", by disadopting some varieties to adopt other superior varieties. The farmers also exhibited "disenchantment discontinuance", by disadopting some varieties with or without replacement, due to dissatisfaction with performances of those varieties. Thus, the reasons for the disadoption of improved rice varieties in the study area were multi-faceted. Adoption of improved rice varieties in the study area followed a dichotomous process of awareness, trial, acceptance and usage but the disadoption assumed a protracted pattern. The processes of improved rice variety disadoption in the study areas comprised withdrawal, disengagement, discontinuity, abandonment, desertion and rejection. The study revealed three types of innovation disadoption in the region, with the farmers at the centre stage. Namely; farmer-initiated disadoption of rice varieties with unsustainable practices, institutional initiated disadoption of rice varieties with undesirable characteristics, and nature induced disadoption of rice varieties caused by farmers' death, relocation, change of occupation, or the effects of climate change.

The fourth objective of the thesis provided empirical evidence of the factors that affect initial adoption, current adoption and disadoption of improved rice varieties in Northern

Region of Ghana. The generalized multivariate regression model revealed that the initial adoption and current adoption decisions for almost all the rice varieties had common signs (positive) while disadoption decisions had opposite signs (negative). These indicate that the same factors influenced adoption and disadoption but in different directions.

The initial adoption of Mandee, Jasmine, Agra, Afife and Salma-Saa were found to have been positively and significantly affected by farmers' age, family labour, FBO, extension, input market, farm size, telephone, field demonstrations, and temperature. Similarly, sex, FBO, farm credit, farm size, telephone, and field demonstrations were found to have negative significant effects on the initial adoption of Agra, Jasmine, Mandee, and Salma-Saa.

Moreover, the disadoption of Afife, Agra, Jasmine, Mandee and Salma-Saa were found to be positively and significantly affected by farmers' age, family labour, FBO, farm credit, extension, farm size, field demonstrations and government policy. The disadoption of Mandee, Afife, Agra, Jasmine and Salma-Saa were also found to be negatively and significantly affected by farmers' age, family labour, FBO, input market, farm size, telephone, field demonstrations, temperature, and government policy.

Besides, the current adoption of Mandee, Salma-Saa, Jasmine, Agra and Afife were found to be positively and significantly influenced by farmers' age, FBO, extension, input market, farm size, telephone, field demonstrations, temperature and government policy. Farm credit, farmers' age, farm size, FBO, and field demonstrations were found to have negative and significant effects on the current adoption of Jasmine, Agra, Mandee, and Salma-Saa.

In all, FBO membership was the single most important factor that significantly affected the initial adoption, current adoption and disadoption decisions of all the rice varieties modelled, either negatively or positively.

The fifth objectives of the thesis also provided empirical evidence of the effect of improved rice variety adoption on rice output among farm houlseholds in Northern Region of Ghana. The PSM model revealed a positive impact of improved rice variety adoption on farmers' output, which means farmers could achieve maximum output if they make efforts to increase their adoption of improved rice varieties in the study area. This could translate into reducing food and nutrition insecurity and the importation of rice.

7.2 Recommendations

The study recommends that, the AEAs of MoFA and other agents of innovation dissemination in the study area should target farmers through a combination of individual, group and mass media methods, as the surest way of educating them. It is also very necessary for the government of Ghana to formulate and implement agricultural policies aimed at empowering the AEAs of MoFA, both technically and financially, to perform their roles as the primary agricultural innovation communicators in farming communities in this country. That would help to salvage their dwindling public image and reputation in agricultural extension service delivery in Ghana. The government of Ghana should also seek to foster and facilitate close collaboration between MoFA and other agents of innovation communication to enhance extension service delivery in this country. The government, should as well, channel more resources to boost the most common individual, group and mass ETMs, especially farm and home visits, method demonstrations and radio broadcasts prevailing in the study area.

The government, through MoFA, could increase the levels of adoption of Agra, Sakai, Jasmine and Afife, but decrease the levels of disadoption of GR-18, Nerica, Digang, Tox, Mandee and Faro-15 by subsidicing their input requirements and providing ready markets to them through the School Feeding Programme. Researchers at SARI should also breed improved rice varieties that are adaptable to prevailing climatic conditions in the study area, to be promoted by the AEAs of MoFA and their collaborators. The government, through MoFA, should come out with approved and recommended varieties to be adopted and ensure their compliance. That would help to regulate proliferation of improved rice varieties in the study area and control the diffusion of existing varieties before new ones are introduced. MoFA should also make conscious efforts to increase adoption rates of improved rice varieties among the farmers and minimize the impact of the extraneous factors that influence non-adoption and disadoption. Also, policies that promote adoption of improved rice varieties and discourage their disadoption among farmers should be vigorously implemented through MoFA and other stakeholders in the rice value chain to ensure food security at household, regional and national levels. Government policy about rice production could then be well designed and communicated to rice farmers, since awareness of government rice policy leads to an increase in improved rice variety adoption.

Since the government finances the dissemination and adoption of improved rice varieties in the study area, they should also finance disadoption studies to help monitor and evaluate the post adoption behaviour of farmers of improved rice varieties. The monitoring and evaluation officers of MoFA should be adequately resourced to carry out this responsibility for the state and give appropriate feedback to the state research institutions like SARI and CSIR. Also, academic researchers in Ghana should be sponsored to study the phenomenon of disadoption, to augument the efforts of MoFA staff.

Since farmers adopt improved rice varieties through awareness, trial, acceptance and usage but disadopt them through withdrawal, disengagement, discontinuity, abandonment, desertion and rejection, these processes should be given credence by researchers, policy makers and extension agents when designing and promoting new agricultural innovations to rice farmers in Ghana. The innovations to be disseminated should therefore be simple, compatible, have triability, observability, profitability, and relative advantage with adaptability or possibilities of re-invention.

The three-fold disadoption of rice varities in the study area has policy implications such that the government and all stakeholders in the rice value chain in this country would have to ensure that farmer-initiated disadoption of unsustainable varieties, institutional initiated disadoption of undesirable varieties, and nature induced disadoption of rice varieties due to the effects of climate change are minimized.

For continuous adoption of improved rice varieties and sustainability of agricultural innovations in the study area, the government and all stakeholders in the rice value chain must ensure that farmer groups are formed and sustained during the dissemination, adoption and post-adoption periods. Every farmer should be encouraged to belong to a farmer group to facilitate his or her adoption. The government as well as NGOs and FBOs in the rice value chain must also ensure that improved rice varieties disseminated have low input requirements, ready markets and less susceptibility to the prevailing climatic conditions, pests and diseases of the study area.

Considering the high probability of adoption by younger farmers, the adoption levels of improved rice varieties can be increased if younger farmers are encouraged to adopt them. This can be done through the government's flagship programmes such as *Feed the Future initiative, Youth in Agriculture, Planting for Food and Job, the NFBSC* and *School Feeding Programme. The* adoption levels of improved rice varieties can also be increased if mechanization services and farming inputs are subsidized, with input markets established in the farming communities by the government. That would also help farmers to decrease their costs of production and maximize output. The construction of irrigation facilities and output markets by stakeholders in the study area would help farmers to overcome the effects of climate change on rice production and encourage large-scale production of rice as well as boost farmers' interest in production credits.

NGOs and FBOs should support farmers to own customized mobile phones at subsidized prices, similar to other farming inputs, to encourage adoption and minimize disadoption of improved rice varieties. Ownership of such phones would help the farmers to access weather information as well as information about government's plicies and programmes. Researchers should also step up their efforts at developing and disseminating new improved rice varieties to overcome the challeneges of climate change, pests and diseases infestations.

Farmers in the study area would maximize their rice output if they maintain their adoption decisions of improved rice varieties. It is therefore prudent for farmers to continue adopting improved rice varieties so as to obtain higher yields and outputs to enhance their lot. That would go a long way to enhance rice productivity and food security outcomes. Hence, it is recommended that the development of enhanced rice varieties, dissemination, and promotion of the varieties should be given priority among stakeholders in the rice value chain. The farmers should be sensitized and encouraged to sell their produce to the NFBSC established by the government of Ghana as an alternative channel of market for farmers. Offices of NFBSC should be established in each district capital of the rice producing areas across Ghana. The study finally recommends that this research be replicated nationwide and also for other major crops.

7.3 Contribution to Literature

Most researchers study adoption and disadoption separately but this research has combined the two in a single study, grouping farmers into initial adopters, current adopters and disadopters. The study investigated initial adoption, current adoption and disadoption levels of rice varieties without lumping them together. It was evident that adoption and disadoption are not mutually exclusive. In many studies, disadopters are considered as non-adopters with the reason that such farmers were not adopting the technology in question as at the time of data collection. However, this is wrong; disadopters are not necessarily non-adopters and therefore their stories are different. One of the contributions of this study to the adoption literature is the distinction it has drawn among initial adopters, current adopters, disadopters and non-adopters of improved rice varieties over a ten-year period (based on farmers' recall). Similarly, the use of multivariate regression model to concurrently estimate the determinants of these four categories (initial adoption, current adoption, disadoption and non-adoption of improved rice varieties) is uncommon in the adoption literature.

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APPENDICES

Appendix A: Introductory Letter

UNIVERSITY FOR DEVELOPMENT STUDIES
FACULTY OF AGRIBUSINESS AND APPLIED ECONOMICS (FAAE)

NYANKPALA CAMPUS

Our Ref :

Your Ref:

P. O. Box TL 1882
Nyankpala Campus
Tamale - Ghana
Tel. +233(0)245728465
E-mail: sdonkoh@uds.edu.gh
Internet: www.uds.edu.gh

OFFICE OF THE DEAN **Date:** ***12th December, 2019***

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

LETTER OF INTRODUCTION: MR. LAMPTEY YAW CLEMENT

Mr. Clement Yaw Lamptey with ID number (UDS/DIC/0003/18) is a PhD Innovation Communication Student in the above Faculty of the University for Development Studies. He is with the Department of Agricultural Extension, Rural Development and Gender Studies.

Mr. Clement Yaw Lamptey has finished his course work and is collecting data on the research topic ***"Adoption and Disadoption of Improved Rice Varieties among Farmers in the Northern Region, Ghana"***.

We would be very grateful if the necessary assistance could be given him to enable him collect the data for his theses.

Thank you in anticipation.

Yours faithfully,

Paul A. Asienab
Faculty Officer
for: Dean

Appendix B: Questionnaire

UNIVERSITY FOR DEVELOPMENT STUDIES

FACULTY OF AGRIBUSINESS AND APPLIED ECONOMICS

Department of Agricultural Extension, Rural Development and Gender Studies

Ph.D. (Innovation Communication)

SECTION 1: DEMOGRAPHIC & SOCIOECONOMIC INFORMATION

1.1 District…………………………………………………………………………….

1.2 Community ………………………………………………………………………….

1.3 Age of respondent: ………………*years.*

1.4 Gender of respondent: *1 = Male* *0 = Female*

1.5 Are you a household-head? *1. Yes ( )* *0. No ( )*

1.6 Do you have access to electricity? *1. Yes ( )* *0. No ( )*

1.7 Do you have access to pipe borne water? *1. Yes ( )* *0. No ( )*

1.8 Please, did you go through the formal system of education? *1. Yes ( ) 0. No ( )*

1.9 Approximate number of years spent in school (formal education) …………………

1.10 **If "no" in question 1.8 above** did you have non-formal education? *1.Yes( )0.No( )*

1.11 What is your household size? *Total number*…………………………………………..

1.12 Indicate your household composition *1. Males 18 and above [ ] 2. Males below 18 [ ] 3. Females above 18 [ ] 4. Females below 18 [ ]*

1.13 Kindly indicate your major livelihood activity (occupation) in the rainy and dry seasons in the past one year. *(use code 1)*

Rainy/Farming Season	Dry/Lean/Off Season

Code 1: *1. Crop production/farming 2. Animal production 3. Petty trading/ Marketing 4. Processing activities 5. Tractor operation 6. Hunting of wild foods 7. Charcoal burning 8. Pito brewing 9. Other (specify)……*

1.14 Do you own livestock? *1. Yes ( ) 2. No ( )*

1.15 Are you a member of any rice farmers' association in your community?

1. Yes ( ) 0. No ( )

1.16 Do you sometimes borrow money to support your rice farming? *1. Yes ( ) 0. No ( )*

1.17 Are you able to buy some of your farm inputs on credit? *1. Yes ( ) 0. No ( )*

1.18 What is the main crop you grow to feed your family? *1. Maize 2. Rice 3. Soybean 4. Cotton 5. Groundnut 6. Cowpea 7. Other (specify)…………………*

1.19 What is the main crop you grow to sell for money? *1. Maize 2. Rice 3. Soybean 4. Cotton 5. Groundnut 6. Cowpea 7. Shea nuts 8. Other (Specify)……………………*

1.20 Have you been interacted with or visited by MoFA extension agents over the past one year? *1. Yes ( ) 0. No ( )*

1.21 If "yes", how many times? ………………………………………………………

1.22 Do you seek information from an NGO or private extension agent? *1. Yes ( ) 0. No ( )*

1.23 Do you have a market (a place or supplier) where you (can) get agro inputs to purchase?

1. Yes ( ) 0. No ( )

1.24 If you have an input supply source, is the market/supplier in this community?

1. Yes ( ) 0. No ( )

1.25 What is the approximate distance from your residence to the input market/supplier?

……………………………….. (in km) and ……………………(in minutes by walking).

1.26 Do you have a market for selling your crop produce in this community?*1.Yes( ) 0.No()*

1.27 What is the approximate distance from your residence to the nearest output market? ....*km* …………………….……………… *(minutes by walking)*

1.28 Which people normally buy your rice? *1. MoFA/SARI 2. NGOs/FBOs 3. AVNASH Co Ltd 4. Processors/Aggregators 5. Market Women 6. Family/Friends 7. Other (specify)*………………………………………………………………….

1.29 Do you practice rice irrigation farming during the dry season? *1. Yes ( ) 0. No ( )*

1.30 Do you think that improved/certified rice seeds are superior to your local/traditional varieties in terms of high yields? *1. Yes 0. No*

1.31 To what extent would you agree that improved / certified rice seeds are adaptable to the local conditions? *1 = extremely not adaptable 2 = not adaptable 3 = normal 4 = adaptable 5 = extremely adaptable*

1.32 Supposed you have been given two crop varieties. One variety produces 15 bags per acre whether the rains fail or not. The second variety produces 25 bags only if there are good rains, but 10 bags per acre if the rains fail. If you are asked to plant only one of these varieties, which one would you prefer? *1 = variety 1 that produces 15 bags with certainty 2 = variety 2 that produces 25 bags with uncertainty*

3 = I don't mind planting any of the varieties

1.33 Rank the extent to which you love to take risk on a scale of 1 to 5, 1 being risk-averse and 5 being risk-loving. *1 = I try to avoid risk as much as possible 2 = I love to avoid risk if possible 3 = I'm neither afraid of risk nor love to take risk 4 = I love to take risk sometimes 5 = I love to take risk all the time*

SECTION 2: INNOVATION COMMUNICATION CHANNELS AND METHODS OF TEACHING FARMERS ON IMPROVED RICE VARIETIES

Innovation Communication Channels

2.1 Please, indicate your information source, seed source, the kinds of incentives you received and your perception of the incentives for each of the following improved/local rice varieties, and **(Please, see codes below the table)**

Rice Variety	Information Source	Seed Source	Incentives Received	Perception of Incentives
Improved Rice Varieties				
DIGANG				
MENDEE				
FARO 15-20				
GR 18-21				
NERICA 1, 2				
JASMINE 85				
AGRA				
AFIFE (TOGO MARSHAL)				
SAKAI				
TOX (NAKOGU/KANTANKA)				
Indigenous Rice Varieties				
SALMA SAA				
KPOKPULA				

Seeds/Information Sources: *1. My own farm 2. Fellow Farmers 3. SARI/MOFA 4. NGOs/FBOs 5. Certified Seed/Input Dealers 6. Market Women 7. Rice Processing Companies 8. Other (specify)*……………………………………………

Incentives: *1=free farming inputs like seeds 2= free fertilizers 3=free tractor/mechanization services 4=free extension services 5=access to loans and credits 6=ready market after harvest 7=Other (Specify)* ……………………………………………

Perception of Incentives: *1=Not useful 2=Useful 3=Very Useful 4=More Useful 5=Most useful*

Innovation Dissemination Methods

2.2 Please, tick the appropriate method(s) that was/were used to introduce each of the rice varieties to you and give your perception about each of the methods used.

Rice Varieties	**Improved Varieties**	DIGANG	MENDEE	FARO 15-20	GR 18-21	NERIC A 1, 2	JASMINE 85	AGRA	AFIFE (TOGO MARSHALL)	SAKAI	TOX (NABOGU/KANT)	**Indigenous Varieties**	SALMA SAA	KPOKPULA		**Perception of Methods**
Dissemination Methods																
Individual Contacts																
Farm and Home Visits																
Result Demonstrations																
Personal Correspondence																
Telephone Calls																
Office Visits																
Group Contacts																
Method Demonstrations																
Meetings/Discussions																
Fora/Durbars																
Tours/ Field Trip																
Field Days/Symposia																
Workshops/Seminars																
Short Courses /Interviews																
Mass Contacts/Media																
News Stories/Newsletters																
Telephone Messages																
Publications/Journals																
Television/Radio/Internet																
Exhibitions & Leaflets																
Posters/Circulars/Bulletin																

Perception of Methods: *1=Not useful 2=Useful 3=Very Useful 4=More Useful 5=Most useful*

SECTTION 3: MAIN RICE VARIETIES ADOPTED AND DISADOPTED IN THE PAST TEN YEARS

3.1 Which of the following rice varieties have you cultivated/stopped cultivating since 2009 and why? (*Enumerator, please allow farmers to mention the varieties*)

Rice Variety	Year Cultivated	**Reasons for Cultivating (Use code)**	Continuous cultivation? *1=yes 2=no*	Year Stopped Cultivation	**Reasons for Stopping Cultivation (Use Code)**
Improved Rice Varieties					
DIGANG					
MENDEE					
FARO 15-20					
GR 18-21					
NERICA 1, 2					
JASMINE 85					
AGRA					
AFIFE (T.M)					
SAKAI					
TOX (NABOGU /KANTANKA)					
Indigenous Rice Varieties					
SALMA SAA					
KPOKPULA					

Reasons for Cultivating: *1= Got free seeds 2 = Higher demanded for product 3=seed more suitable for the soils 4=Crops very resistant to droughts 5=Crops resistant to diseases/pests 6=was advised by researcher to cultivate 7= was advised by extension staff to cultivate 8= Ready market for the produce 9= low input requirements 10 = others (specify)……………………*

Reasons for Stopping Cultivation: ***NOTE: Write N/A if "yes" for continuous cultivation.***

1= Seed too costly 2 = Output of seed no longer demanded by consumers 3=seed no longer suitable for the soils 4= seed makes crops too susceptible to droughts 5=Seed makes crops too susceptible to diseases/pests 6=was advised by researcher to stop 7= was advised by extension staff to stop 8= no ready market for the produce 9= High input requirements 10 = others (specify)…………………………………………………………………………

3.2 Do you sometimes cultivate improved rice varieties again after you stopped cultivating them? *1 = Yes* *0 = No*

3.3 **If "yes"** then please indicate which of the following rice varieties you have cultivated again since you stopped cultivating it. If there are several times of re-adoption, please indicate the last time you re-cultivated it.

Rice Variety	**Year Re-Cultivated**	**Reasons for Re-Cultivation (Re-Adoption)**
Improved Rice Varieties		
DIGANG		
MENDEE		
FARO 15-20		
GR 18-21		
NERIC A 1, 2		
JASMINE 85		
AGRA		
AFIFE (TOGO MARSHALL)		
SAKAI		
TOX (NABOGU/ KANTANKA)		
Indigenous Rice Varieties		
SALMA SAA		
KPOKPULA		

3.4 Name three rice varieties you would have cultivated in the past ten years, if the above improved rice varieties in **Question 2.1** have not been introduced to you? (a)………………………… (b)……………………… (c) …………………………

SECTION 4: FACTORS THAT AFFECT ADOPTION AND DISADOPTION OF THE MAIN RICE VARIETIES IN THE NORTHERN REGION OF GHANA

4.1 What is the total size of your rice farm now? ………………………………………

4.2 Would you be able to use the land for rice farming next year? *1 = Yes 0 = No*

4.3 Please, what is the reason for your answer in question **2.5** above? ………………….

4.4 Have you noticed any long-term changes in the mean temperature over the last 10 years? *1 = Yes* *0 = No*

4.5 Over the last 10 years, has the number of hot days stayed ……………………………?

1 = same 2 = increased or 3 = decreased

4.6 Have you noticed any long-term changes in the mean rainfall over the last 10 years?

1 = Yes 0 = No

4.7 Over the last 10 years, has the number of rainfall days stayed ……………?

1 = same 2 = increased or 3 = decreased

4.8 What adjustments in your farming have you made to these long-term shifts in temperature*? 1=Change rice variety 2=Build a water-harvesting scheme 3=Implement soil conservation techniques 4=Buy insurance 5=Put trees for shading 6=Irrigate more 7=Change from rice to maize 8=Reduce size of rice farm 9=Migrate to urban area 10=Find off-farm job 11=Lease your land 12=Other (specify) …………………………………………………………………………………..*

4.9 What adjustments in your farming have you made to these long-term shifts in rainfall?

1. Change rice variety 2. Build a water-harvesting scheme 3. Implement soil conservation techniques 4. Buy insurance 5. Put trees for shading 6. Irrigate more 7. Change from crop to livestock 8. Reduce number of livestock 9 Migrate to urban area 10. Find off-farm job 11. Lease your land 12. Other (specify) …………

4.10 Identify the following constraints affecting improved rice adoption and indicate the extent to which each constraint affects your adoption of improved rice varieties on a scale of 0-5, with zero (0) being the least affecting adoption and five (5) being the most affecting adoption.

Constraint	Do you observe this constraint? *1=Yes* *0=No*	How does it affect your Adoption? Scale:0-5 *0= least affecting* *5 = most affecting*
Lack of information/unavailability of improved seed		
Lack of money to farm/Lack of access to credit		
High cost of inputs (seeds, chemicals, labour, land etc)		
Lack of skilled labour/High cost of Labour		
Lack of access to productive land/Poor soil fertility		
Lack of access to tractor/Mechanization Services		
Unwillingness to use new improved seeds		
Poor Infrastructure/Poor Road Network		
Unwillingness to use new farming methods/practices		
Lack of knowledge on associated technologies		
Lack of Incentives/government policies for rice		
Competition from imported rice/other cereals		
Lack of feedback from farmers to Researchers		
Pests/Diseases Infestations/Bad weather		
Politics		

SECTION 5: EFFECTS OF IMPROVED RICE VARIETY ADOPTION ON FARMERS' OUTPUT AND FARM INCOME

5.1 Kindly indicate the input and output structure of your rice farm in 2019 as shown in the table below.

Rice Variety	Farm Size (acres)	Type of Tillage Used	Type of labour	Number of Labourers	Cost of Labour (GHc)	Planting Method (code)	Type of Insecticide	Litres of Insecticide	Type Fert used (code)	Bags of 50kg Fert	Qty of Seed Sowed (kg)	Type of weedicide	Litres of weedicide used	Harvesting Method	Bags of Rice Harvested (kg)	Qty consumed by household (kg)	Qty offered as gift	Bags of Rice Sold (kg)	Price/Bag of Rice (GHc)
Improved Rice Varieties																			
DIGANG																			
MENDEE																			
FARO 15-20																			

GR 18-21																			
NERICA																			
JASMINE																			
AGRA																			
AFIFE																			
SAKAI																			
TOX																			
Indigenous Rice Varieties																			
SALMA SAA																			
KPOKPULA																			

Planting Methods: *1 = Broadcasting 2 =Dibbling/Drilling 3 =Nursing & Transplanting 4=Line Planting 5= Proper Spacing (20x20cm) 6= Other*

Type of Fertilizer: *1 = No Fertilizer 2 = Manure 3 = Inorganic Fertilizers 4= Other*

Type of Labour: *1=household labour 2=Hired labour 3=group/exchange labour (nnoboa)*

Type of Tillage: *1= ploughing 2= Harrowing 3= ploughing & Harrowing 4= Hoeing 5=other*

Harvesting Methods: *1= Manual 2=Combined Harvester 3= Manual & Combined Harvester 4=Other*

Types of Insecticides: *1= Emamectin Benzoate 2= Cyhalothrin 3= Cypermethrin 4= Chlorpyrifos 5= Carbendazim 6= Mancozeb 7= Other*

Types of Weedicides: *Propanil 2= Bispyribac Sodium 3= Pretilachlor 4= Pyribenzoxim 5= Oxyfluorfen Glyphosate 6= Bispyribac Sodium 7= Other*

Types of Herbicides: *Glyphosate 2= Paraquat 3= Bensulfuron methyl 4= Cyrosate 5= Pendimethalin 6= Butachlor 7= Other*

5.2 What is the status of your rice output from your farm (per acre) from 2009 to 2019? *1 =decreasing 2=Increasing 3=Remained the same 4 =Sometimes decreases/increases 5 = Cannot tell/remember 6= Other (specify)……………………………………………….*

5.3 If the output per acre from your farm remained the same since 2009, what is/are the reason(s)? *1 = Type of Improved Seeds used 2 = Planting methods used 3 = Quantity of Seed Sowed 4 = Type of Fertilizers used 5 = Agronomic practices used 6. Rainfall/Drought/Weather 7= Other (Specify)……………………………………*

5.4 If the output per acre from your farm since 2009 continued to increase year after year, what is/are the reason(s)? *1 = Good Luck 2 = Good Weather 3 = Good Inputs used 4 = Good Soil 5 = Good agronomic practices 6 = Other (specify)……………*

5.5 If the output per acre from your farm since 2009 continued to decrease year after year, what is/are the reason(s)? *1 = Bad Luck 2 = Bad Weather 3 = Poor Inputs used 4 = Poor Soil 5 = Bad agronomic practice 6 = Other (specify)……………………………*

5.6 If the output per acre from your farm since 2009 sometimes decreased/increased, what is/are the reasons? *1 = Type of Improved Seeds used 2 = Planting methods used 3 = Quantity of Seed Sowed 4 = Type of Fertilizers used 5 Agronomic practices used 6 = Other (specify)……………………………………………………………………………..*

5.7 Comparing the levels of output obtained from 2009 to 2019 planting seasons, what would you attribute your higher yields to? *1 = Type of Improved Seeds used 2 = Planting methods used 3 = Quantity of Seed Sowed 4 = Type of Fertilizers used 5 = Other agronomic practices used 6 = Good Weather/Rainfall*

5.8 Comparing the levels of output obtained from 2009 to 2019 planting seasons, what would you attribute your lower yields to? *1 = Type of Improved Seeds used* *2 = Planting methods used* *3 = Quantity of Seed Sowed* *4 = Type of Fertilizers used* *5= Other agronomic practices used* *6 = Bad Weather/Rainfall*

5.9 Do you think you get more money from rice farming now than five years ago?

1 = yes *2 = no*

5.10 If your level of farm income has increased now, would you attribute the increase to the use of improved rice varieties? *1 = yes 2 = no*

5.11 On a scale of 1 to 5, 1 being no influence at all and 5 being the most influence, rate the extent to which the use of improved rice varieties has influenced your level of income now compared to five years back. *1= no influence at all* *2= lowest influence* *3 = Low influence* *4 = high influence* *5 = highest/most influence*

5.12 In your opinion, what do you think can be done to improve adoption rates of improved rice varieties in the Northern Region of Ghana?

……………………………………………………………………………………

Thank you very much for your time and patience!!!

Appendix C: Focus Group Discussion Guide

UNIVERSITY FOR DEVELOPMENT STUDIES

FACULTY OF AGRIBUSINESS AND APPLIED ECONOMICS

Department of Agricultural Extension Rural Development and Gender Studies

A GUIDE FOR FOCUS GROUP DISCUSSION WITH LEADERS OF RICE FARMERS

Dear Sir/Madam,

This study is purely an academic exercise towards the writing of a Ph.D. Thesis in the above department. Your views and responses as leaders of the rice farmers' association of your community would be treated with utmost confidentiality.

A maximum of 10 persons would be needed for this discussion. The discussion would be held at any location of convenience to the group in your community. A Research Assistant from the University for Development Studies would lead the discussion. Please, feel free to answer the questions that you are comfortable with and allow others to express their views. Please, bear in mind that your participation in this discussion is voluntary and your views should represent the general concerns of farmers in your community/association. The outcome of this discussion would serve as a feedback to researchers, through MoFA, to enhance proper breeding, dissemination and adoption of improved rice varieties in Ghana. The moderator would record the discussions for easy transmission to the researcher. Your maximum cooperation is therefore needed to make this discussion a success.

Thank you.

PROBING QUESTIONS FOR THE DISCUSSIONS

SECTION A: Factors Affecting Adoption/Disadoption of Improved Rice Variety

1. What socioeconomic, institutional, locational and environmental factors affect adoption and disadoption of improved rice varieties in the Northern Region?
2. Which challenges do you face in farming improved rice varieties and how does each challenge affect your adoption of improved rice varieties?
3. What adjustments in your farming have you made to overcome or cope with these challenges?

SECTION B: The Improved Rice Varieties Farmers Have Adopted/Disadopted

4. What are the improved rice varieties you have adopted (cultivated) or disadopted (stopped cultivating) in this community for the past ten years?
5. Why do farmers continue to adopt some improved rice varieties but discontinue to adopt other improved rice varieties?
6. Do you sometimes cultivate improved rice varieties again after you stopped cultivating them?

SECTION C: Differences in Yield between Adopters and Disadopters

7. Are there any output differences between adopters and disadopters of improved rice varieties and what factors are responsible for such differences?
8. What do you think brings about such differences and how can they be prevented them?

SECTION D: Effects of Improved Rice Variety Adoption on Farmers' Yield

9. What are the effects of improved rice variety adoption on rice farmers' output in the Northern Region?
10. What advice do you have for farmers who do not adopt improved rice varieties?

Appendix D: Key Informant Interview Guide

UNIVERSITY FOR DEVELOPMENT STUDIES

FACULTY OF AGRIBUSINESS AND APPLIED ECONOMICS

Department of Agricultural Extension, Rural Development and Gender Studies

KEY INFORMANT INTERVIEW GUIDE

Dear Sir/Madam,

This study is purely an academic exercise towards the writing of a Ph.D. Thesis, and your views as a researcher, lecturer, agricultural extension agent, rice aggregator, rice processor, certified seed seller/input dealer, or opinion leader are needed to verify and authenticate findings from the farmers. Your views would therefore be treated with utmost confidentiality.

This study would provide a feedback to government in enhancing the breeding, dissemination and adoption of improved rice varieties in Ghana.
Thank you.

KEY INFORMANT INTERVIEW GUIDE

SECTION A: Factors Affecting Adoption and Disadoption of Improved Rice Varieties

1. What socioeconomic, institutional, locational and environmental factors affect adoption and disadoption of improved rice varieties in the Northern Region?
2. Comparing improved rice varieties/certified seeds and indigenous rice varieties, which ones would you say are superior? Please explain your answer.
3. Generally, what do farmers look for in rice seeds before adopting/ planting them?

4. Why do farmers stop adopting/planting the seeds at a point in their farming business?

SECTION B: The Improved Rice Varieties Farmers Have Adopted/Disadopted

5. Which improved rice varieties have farmers adopted or been cultivating in this community (district/region) for the past ten years?
6. Which of the improved rice varieties have the farmers stopped cultivating/adopting?
7. Which of the improved rice varieties are the farmers still cultivating/adopting?
8. What do you think can be done to improve adoption rates of improved rice varieties in the Northern Region of Ghana?

SECTION C: Effects of Improved Rice Variety Adoption on Farmers' Output

9. What are the effects of improved rice variety adoption on rice farmers' output in the Northern Region?
10. What advice do you have for farmers who do not adopt improved rice varieties?

SECTION D: Differences in Yield between Adopters and Dis-Adopters

11. How different is the yield of adopters from disadopters of improved rice varieties?
12. What do you think bring about the differences in yield between adopters and disadopters of improved rice varieties?
13. What do you think can be done to prevent the difference in yield between adopters and disadopters of improved rice varieties?
14. Would you say that generally adopters of improved seed varieties have higher yields than non-adopters of improved rice varieties?

15. If yes, why is it that despite the higher yields associated with improved seed varieties, some people do not adopt them?

Appendix E: GPS Coordinates of Selected Communities

DISTRICT	COMMUNITY	GPS CORDINATES	
		LATITUDE	LONGITUDE
Kumbungu	**Kumbungu**	**9.524708333**	**-0.920528333**
Kumbungu	Kukuo	9.525183333	-0.920648334
Kumbungu	Dallung	9.622795000	-1.014168333
Kumbungu	Botanga	9.609226667	-1.038308334
Kumbungu	Kpachi	9.428788333	-0.976360000
Kumbungu	Garizengu	9.446151667	-1.013324999
Kumbungu	Dugu zugu	9.517565000	-0.922086667
Kumbungu	Gbullung	9.484949250	-1.010291480
Kumbungu	Fuo	9.428533333	-0.809736667
Nanton	**Nanton**	**9.549350000**	**-0.730913333**
Nanton	Kugu	9.550406516	-0.726598233
Nanton	Zieng	9.523881667	-0.744296667
Nanton	Jana	9.523880000	-0.744231667
Nanton	Nyamandu	9.694295949	-0.835005133
Nanton	Kpunduli	9.522666567	-0.705408167
Nanton	Guntingli	9.544719633	-0.732091150
Nanton	Balishei	9.499666933	-0.774244933
Nanton	Manguli	9.482253333	-0.789320000
Savelugu	**Libga**	**9.593455000**	**-0.847146667**
Savelugu	Tumahi	9.567024500	-0.797420300
Savelugu	Yemo	9.588225500	-0.787522300
Savelugu	Damdu	9.627408800	-0.782015800
Savelugu	Danda	9.625215600	-0.781129900
Savelugu	Kadia	9.904746363	-0.855141168
Savelugu	Tugban	9.526895000	-0.921476667
Savelugu	Diare	9.872559441	-0.877135569
Savelugu	Nambagla	9.944633905	-0.892816782
Savelugu	Zaazi	9.588281667	-0.861071666
Savelugu	Botingli	9.612424100	-0.788442600
Savelugu	Zaazi Kukuo	9.576080000	-0.865773333
Savelugu	Pong Tamale	9.691523333	-0.830001667
Savelugu	Nabogu	9.699280000	-0.828666667
Savelugu	Pong	9.699318334	-0.828698333
Savelugu	Yepalsi	9.701616666	-0.827426667
Tolon	**Tolon**	**9.421503333**	**-1.044720000**
Tolon	Islamia	9.393188335	-0.981703334
Tolon	Woribogu	9.425115000	-1.041718333
Tolon	Naha	9.395073260	-0.948600810
Tolon	Tunaayili	9.372144403	-0.975514306

Tolon	Gbulahagu	9.351743647	-0.958564534
Tolon	Dundo	9.415350000	-0.998905000
Tolon	Nyankpala	9.353285434	-0.943837391
Tolon	Golinga	9.353127549	-0.943905367
Tolon	Golinga Yapala	9.379199999	-0.954646666
Tolon	Galinkpegu	9.375907810	-0.955419466
Tolon	Galinapgu	9.382286666	-0.953266666
Tolon	Kpalaga	9.446755000	-0.957715000
Tolon	Tingoli	9.375733333	-1.011911665

Appendix F: 1: Propensity score test of variables in the model

Variable	Unmatched(U) Matched(M)	Mean				t-test	
		Treated	Control	% bias	% red. bias	T	p>t
Age	U	39.263	40.942	-15.800	42.200	-1.570	0.1160
	M	39.263	40.233	-9.100		-0.990	0.323
Gender	U	0.888	0.919	-10.400	43.800	-1.020	0.309
	M	0.888	0.905	-5.800		-0.610	0.543
Electricity	U	0.763	0.797	-8.100	-15.500	-0.800	0.424
	M	0.763	0.724	9.300		0.960	0.340
Education (years)	U	2.578	2.791	-4.500	-419.800	-0.450	0.652
	M	2.578	1.470	23.400		2.850	0.005
Family labour	U	1.987	1.247	27.900	15.000	2.750	0.006
	M	1.987	1.359	23.700		2.590	0.010
FBOs	U	0.578	0.320	53.500	83.300	5.300	0.000
	M	0.578	0.534	9.000		0.930	0.351
Credit	U	0.444	0.453	-1.900	-669.500	-0.190	0.850.
	M	0.444	0.371	14.700		1.610	0.109
Extension	U	0.853	0.721	32.700	74.000	3.310	0.001
	M	0.853	0.888	-8.500		-1.110	0.269
Input market	U	0.888	0.797	25.200	52.900	2.550	0.011
	M	0.888	0.845	11.900		1.360	0.173
Farm size	U	1.780	1.058	26.400	-149.500	2.680	0.008
	M	1.780	3.582	-65.900		-3.080	0.002
Telephone	U	0.362	0.105	63.700	98.300	6.140	0.000
	M	0.362	0.358	1.1		0.100	0.923
Field Demo	U	0.526	0.320	42.600	89.500	4.210	0.000
	M	0.526	0.504	4.4		0.460	0.643
Temperature	U	0.978	0.890	36.300	95.200	3.800	0.000
	M	0.978	0.983	-1.800		-0.340	0.737
Mechanization	U	0.741	0.843	-25.200	91.500	-2.470	0.014
	M	0.741	0.750	-2.100		-0.210	0.832
Government policy	U	0.909	0.814	27.900	72.900	2.830	0.005
	M	0.909	0.884	7.5		0.910	0.361

Source: Survey data, 2020