ADOPTION AND INTENSIFICATION FACTORS OF RICE PRODUCTION IN RWANDA

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A THESIS SUBMITTED IN FULFILMENT FOR THE REQUIREMENT OF THE DEGREE OF DOCTOR OF PHILOSOPHY IN ECONOMICS OF THE OPEN UNIVERSITY OF TANZANIA

2018

CERTIFICATION

The undersigned certifies that they have read and here by recommend for acceptance by the Open University of Tanzania a thesis entitled; “Adoption and Intensification factors of rice Production in Rwanda” ” in partial fulfilment of the requirements for the award of Degree of Doctor of Philosophy (PhD) of the Open University of Tanzania.

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DACLARATION

I, Emmanuel Gasana, do hereby declare that this thesis is entirely a result of my own work except where acknowledged in the text. The best of my knowledge the work is this thesis has not submitted to any other university of similar study or any other degree award.

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ACKNOWLEDGEMENTS

I would like to thank my supervisors, Prof. Deus Ngaruko and Dr James Kisoza, for giving me an opportunity to work with them and for their scholarly guidance in spite of their busy schedule. Their insight, perpetual encouragement, and guidance during the design and preparation of the thesis will remain for me a source of inspiration.
This academic work would not have been completed without the support and contribution of many individuals to whom I wish to extend my heartfelt gratitude:

I convey my profound thanks to the farmers' members of COPRIKI for their solicitude providing objective information that made the masterpiece of this work. This page cannot honor me allowing enumerating all persons from whom I have harvest and gather various material and moral support. Namely thanks go straight to the following personalities: the Coordinator of OUT, Ngoma Branch; The Mayor of Kirehe District; The Executive Secretary of Gatore Sector; My wife and my children; Everyone who contributed to this work.

ABSTRACT

This study sought to assess adoption and intensification factors of rice production in Rwanda. Specifically, the study examined adoption factors, intensification factors and productivity factors of rice production in Rwanda. The study used descriptive cross-sectional design and a population including rice farmers and non rice farmers in Kirehe district, in Rwanda. The study used cluster sampling methods and a sample size included 492 respondents. Data were collected using observation, questionnaires. Data collected were compiled and analysed using mainly Statistical Parameters of Social Sciences (SPSS) packages. Data analysis techniques included Factor Analysis using the Principle Component Analysis methodology, Logistic Regression Model to assess the likelihood of the farmers to adopt or intensify rice and Cobb-Douglas Production Model was also applied to find the relationship between production and its factors labor and capital. e findings of the study show that the most significant factors which are likely to contribute to the adoption were the following: grouping into cooperatives, marshlands exploitation and food security among six factors tested. While the most significant factors which are likely to contribute to intensification are extension services, utilities, and seeds availability among nine other factors tested. Finally, findings showed that productivity factors such as labour and capital contribute significantly to rice production. The study recommends to the Government of Rwanda to support smallholder farmers in intensification of rice production by improving skills, inputs and technology related to rice production.

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LIST OF ABBREVATIONS AND ACRONYMS

CARD	Coalition for Africa Rice Development
CIP	Crop Intensification Program
COPRIKI	*Coopérative des Producteurs du Riz de Kirehe* (Cooperative of Rice Farmers of Kirehe)
EAC	East African Community
EDPRS	Economic Development and Poverty Reduction Strategy
FAO	Food and Agriculture Organization
ICRAF	International Center for Research in Agroforestry
IFAD	International Fund for Agricultural Development
IRCS	Intensive Rice Cultivation System
ISAR	*Institut des Sciences Agronomiques du Rwanda* (Rwanda Institute of Agricultural Sciences)
KWAMP	Kirehe Community-based Watershed Management Project
MINAGRI	Ministry of Agriculture and Animal Resources
NRDS	National Rice Development Strategies
PAPSTA	Support Project for the Strategic Transformation of Agriculture
PCA	Principal Component Analysis
PSTA	Strategic Plan for Agricultural Transformation
RADA	Rwanda Agriculture Development Authority
RAB	Rwanda Agricultural Board
RSSP	Rural Sector Support Project
USAID	United States Agency for International Development
WSMC	Water Systems Management and Conservation

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Rice has been gathered, consumed, and cultivated by women and men worldwide for more than 10,000 years - longer than any other crop (Levetin and McMahon, 1999). It is the most important food crop for about half of the human race. Global rice supplies are projected to increase 1.3 percent to a record of 633 million tons , according to Childs .“ That’s due to a 5 percent larger carry in front 2017-2018 and the forecast larger production in 2018-2019”. More than 3.5 billion people depend on rice for more than 20% of their daily calorie intake. Annual rice consumption can be very high, exceeding 100Kg per capita in many Asian countries and in some African countries as well (Walker & Alwang, 2015).

Over 90% of the world’s total rice crop is produced in South and East Asia. In area and production, China is the leading country in the world. Africa accounts for 3% of global production. The major limiting factor for the growth of rice is not climate, but water supply. Rice is the only major crop that can be grown in the standing water in vast areas of flat, low-lying tropical soils and is uniquely adapted for growth in submerged conditions. Rice is grown in the tropical and subtropical regions of most continents. It is cultivated under widely differing conditions because of the great cultivar diversity (EUCORD, 2012).

The adoption of rice as all other crops in Rwanda requires farmers are organizing themselves to get a major production to meet their needs (MINAGRI, 2010). Normally these farmers are grouped into cooperatives so that they can achieve good results, because they say that unit is strength. Cooperatives were initiated by Ministry of Agriculture and Animal Resources (MINAGRI) through the Rwandan government for development of agriculture. The Rwandan government has opted for the adoption to strengthen the implementation of its strategic plan through MINAGRI. The popularization of large scale rice was done and continues to do so in all rice growing areas of the country. The system of rice intensification allows producers to increase productivity and quality of production. It also reduces the amount of seed for sowing, Federation of Unions of Rice Cooperation in Rwanda (FUCORIRWA, 2008).

In many developing countries, agriculture is still an important source of employment. Rwanda's economy is mainly based on agriculture. In 2012, about 93 percent of the economically active population was employed in agriculture and many of the farmers had an average size of less than one hectare of arable land per household. Despite efforts by the government to encourage people to focus on agriculture, it remains by far the main source of employment. Agriculture currently accounts for about 42 percent of GDP in real terms (Michael Morris et al, 2008). Agriculture is the largest sector in the economy of Rwanda in terms of contribution to GDP, employment and foreign exchange earnings. The contribution of agriculture to economic growth is even greater when strong multiplier effects are taken into account.

Agriculture also contributes significantly to the national and more than 90 percent of food self-sufficiency all foods consumed is produced in the country (Michael Morris et al 2008). Rural incomes are derived primarily from the sale of food crops, livestock and crops. Unfortunately, it is clear that over the past two decades, agricultural production was insufficient to meet the needs of the growing population and inducing food insecurity and rising levels of poverty especially in rural areas it is difficult to find the non-agricultural labor (FAO, 2010). It is in this case that the government of Rwanda by the MINAGRI opted for the adoption of rice production as an important component of the agricultural sector in Rwanda that has a strong potential to stimulate economic growth (IFAD, 2009).

Rice was first introduced in Rwanda in 1950 at Bugarama region, Western province of Rwanda. According FUCORIRWA (2008), the wide scale adoption of rice started in 1967 following the trials conducted by Chinese and Taiwan missions at Kabuye, Gasabo district. Also in 1967, significant progress was made and resulted in the development of several rice schemes across the country. Since then, rice has become one of the main food crops in Rwanda, National Rice Development Strategies (NRDS, 2008). Chinese cooperation has contributed to the development of anumber of rice growing areas at Bugarama (Rusizi district), Kabuye (Kigali) and Mukunguli (Muhanga district). By 1972 China developed rice schemes at Rwamagana and managing through the SOPRORIZ (Society of Rice Production), took over management of all rice growing areas mentioned above (MINAGRI, 2011).

In Rwanda, rice is mainly growth in the marshes. They are very favorable for the growth of this crop. In some marshes, rice is the only crop that grows well and produces better performance compared to other cereals (Kathiresan, 2010). The adoption of rice was given a higher priority and the government seeks to increase its intensification factors by improving the flooded marshes that are suitable for this crop. It was also observed that rice is able to give very high over 7tones per hectare per cycle growth returns; which is well above the yield of all other crops than can be planted in marshes. Therefore, the adoption of rice production is considered as the most profitable and offers a viable of poor rural farm family resources in Rwanda (Jagwe et al, 2008).

1.2 Statement of the Research Problem

Different studies conducted on rice adoption and productivity in different areas that help to discuss the findings of this study. In Rwanda, various measures have been taken to improve rice productivity. Nkurikiye Jean Bosco (2016) argued that priority interventions in improving productivity include supplying certified seeds and fertilizers, controlling pests and diseases and improving farm operations, and expanding the capacity of extension system in order to enable efficient transfer of technologies on production, soil and water management, pest and disease management, harvesting, post-harvest handling and storage of rice in marshlands. In short, these interventions concern both labour and capital as demonstrated by the findings of this study.

According to Chinese Scholars Ghimire et al. (2015) the adoption of high yielding crop varieties by farmers helps to improve the income of smallholder farmers in developing countries. In Rwanda most studies conducted on rice adoption have corroborated the findings of this study, especially the fact that the decision of the Government of Rwanda to make marshlands available is a key to rice adoption. The average farm size per cooperative and farmer, across the 31 sampled cooperatives, was 135.3 ha and 0.19 ha, respectively. The farmers' cooperatives not only facilitate farmers' access to inputs and markets, but they also serve as an institutional framework through which the government and its development partners offer different supports to farmers, aimed at increasing farmers' productivity (Nkurunziza, 2015).The extent of adoption of rice crop and factors for intensification of production are scantly addressed. By using Kihere District as a case study, this study attempts to identify factors affecting the uptake and intensification of rice production in the same district

1.3 Objectives

1.3.1 General Objective

The general objective of this study is to assess adoption and intensification factors of rice Production in Rwanda.

1.3.2 Specific Objectives

i. To determine adoption factors that contributed to rice production in Kirehe District
ii. To identify intensification factors that contributed to rice production in the region
iii. To examine productivity factors that affect rice production in Kirehe District

1.4 Research Hypotheses

Research hypothesis is defined as result or outcome that is not yet evaluated or tested, Bialy J.(1987) for his side, argues that a "research is a proposition that is stated in testable form and that has particular relationship between two or (more) variables", and thus, this study finally verified the following hypotheses:

The hypotheses addressing the components of the first specific objective concerning rice adoption are:

i. There is no likelihood of the rice adoption being related to Shift from poor produce, Cater for cash insecurity, Quest for intensive farm employment, Marshlands exploitation opportunities, Farm credit schemes, and regrouping into cooperatives
ii. There is no likelihood of the rice intensification being related to chemical inputs, seeds variety, labor, Size land, climate, utilities, personal skills, extensive services, and access to credit.
iii. There is no significant relationship between important factors affecting rice

1.5 Significance of the Study

This study is significant for advancing knowledge and research in Rwanda and in Africa in general by generating body of knowledge that can help other researchers and academicians to obtain useful information in this field of inquiry. Also this research is significant for policy making process and planning process, especially in the field of agricultural development, food security, and sustainable development. This study is in line with poverty alleviation strategies in most African countries, as well as in line with Development Vision 2020 in Rwanda which puts agricultural development and food security as important factors for human development.

Also this research is significant because it is aligned with the Sustainable Development Goals, especially SDG 1 on poverty eradication and SDG 2 on eradicating hunger and SDG8 on sustainable economic growth. These SDGs are directly captured in this study, because rice is an important crop that ensures national economic growth, income generation and food security for the majority of people in Africa generally, and in Rwanda particularly. Therefore, this study will provide useful knowledge that can be used as evidence based for making decisions related to policy. This study also has a methodological significance since it uses quantitative empirical tests in explaining factors contributing to adoption, intensification and productivity of rice in Rwanda.

1.6 Thesis Structure

Chapter 1 provides an abstract of the research topic and also includes the design of the research methodology. Chapter 2 is concerned by literature review closed related to rice adoption and productivity. Chapter 3 describes the methodology used to support the research and provides a tutorial on the use of the software for this particular research. Chapter 4 provides the discussion of the analysis of the results from the software. Chapter 5 provides discussion about the research findings and Chapter 6 provides conclusion and recommendation of the study. At the end of this work, there are appendices.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

The literature reviewed in the framework of this study tackles the situation of rice cropping in Rwanda as paramount to the background for this research. Literature review on the present situation Kirehe District was conducted and was documented in the following pages. The literature is organized into different parts: there is definition of key concepts, theoretical review, empirical review, policy review and conceptual framework.

2.2 Definition of Key Concepts

2.2.1 Rice Adoption

According to Feder et al.(1985), rice adoption may be defined as the integration of an innovation into farmers' normal farming activities over an extended period of time. Dasgupta (1989) also noted that adoption, however, is not a permanent behavior, it implies that an individual may decide to discontinue the use of an innovation for a variety of personal, institutional, and social reasons one of which might be the availability of another practice that is better in satisfying farmers' needs.

Rogers (1983) defines the adoption process as the mental process through which an individual passes from first hearing about an innovation or technology to final adoption. This indicates that adoption is not a sudden event but a process. Farmers may not accept innovations immediately; they need time to think over things before reaching a decision. Colman and Young (1989) define adoption as it relates to the use or non-use of a particular innovation by individuals (say farmers) at a point in time or during an extended period of time. Adoption, therefore, presupposes that the innovation (technological change) exists and studies of the adoption process analyze the reasons or determinants of whether and when adoption takes place.

In the words of Yapa and Mayfield (1978) the adoption of an entrepreneurial innovation by an individual requires the satisfaction of at least three conditions. These are (i) the availability of sufficient information (ii) the existence of a favorable attitude towards the innovation, and (iii) the physical availability of the innovation.
In the context of aggregate adoption as opposed the final adoption at the individual farmer level, diffusion is defined as the process of spread of a new technology within a region (Rogers, 1983). In other words, diffusion is a cumulative process of adoption measured in successive time periods (Colman and Young, 1989).

2.2.2 Intensification of Agriculture

According to Pretty et al. (2011;7), agricultural intensification is a concept that has a traditional definition articulated in three different ways: increasing yields per hectare, increasing cropping intensity per unit of land or other inputs (water), and changing land use from low value crops or commodities to those that receive higher market prices.

2.2.3 Production Factors

According Osmond Vitez, in economic definition of the factors of production: economic resources are the goods or services available to individuals and businesses used to produce valuable consumer products. The classic economic resources include land, labor and capital. Entrepreneurship is also considered an economic resource because individuals are responsible business environment. These economic resources are also called the factors of production. The factors of production describe the function that each resource performs in the business environment. British Dictionary defines factor as a resource or input entering the production of wealth, such as land, labor, capital, etc. also called agent of production.

2.2.4 Rice

The rice is one of the most cereals like maize, millet, wheat, sorghum, etc. Since a large portion of maize crops is growth for purposes other than human consumption, rice is the most important grain with regard to human nutrition and caloric intake, providing more than one fifth of the calories consumed worldwide by the species (Grigg B. 1974). The rice plant can grow to 1-1.8m tall, occasionally more depending on the variety and the soil fertility. It has long, slender leaves 50-100 cm long and 2-2.5 cm broad. Rice production is well-suited to countries and regions with low labor costs and high rainfall, as it is labor-intensive to cultivate and requires ample water. Rice can be growth practically anywhere, even on a steep hill or mountain. Although its parent species are native to Asia and certain parts of Africa, centuries of trade and exportation have made it common place in many cultures worldwide.

2.2.4.1 Origin and Classification of the Rice

First attested in English in the middle of the 13th century, the world “rice “ derives from the old French ris, which comes from Italian ”riso”, in turn from the Latin Oryza, which derives from the Greek “oruza”. The Greek word is the source of all

European words Welsh reins. The commonly accepted view is that rice was first domesticated in the region of Yangtze River valley in China, Horgan F (2011). It has been the staple food of China for long time and is consumed in many ways; boiled, streamed, fried of rice wine. Chinese immigrants to Luzon in the 2^{th} millennium B.C must have introduced paddy cultivation to the Philippines, for the intricate terraced fields on the hills are just like those of southern China rice cultivation also spread to Java, Malaysia and the rest of south-East Asia.

Today, the fifth greatest rice product countries are: China, the greatest rice producer in the world, with 36% of rice production, India with 20%, Indonesia 6%, and both Bangladesh and Japan, with 5% of production. Therefore, Khiev B. 1999 argues that there are hundreds of sub-species of paddy but these falls into two groups, namely, wet paddy and dry paddy, which differ in their growing requirements. In recent years , as result of genetic research and plant breeding, new and better strains of paddy have been devised, such as the IR8 and IR20 and 22 Miracle Rice of Philippines, discovered at the Rice Research Institute of Mania.

2.2.4.2 Ecological Requirements

The different varieties are raised in different parts of the world and the methods of cultivation also vary between that sown and dry hillside and flood fields. Farming methods also differ between oriental countries and between eastern and western producer. Generally, as Rakngan (2005) asserts, the rice needs water supply rather than other cereals where. It is restricted to areas with at least 1145 mm of annual rainfall, within the tropics where the rate of evaporation is great, as much as 1780 mm, flooded conditions, with the depth of water varying from over 25mm.

Furthermore, the easiest and the best way of meeting water requirements of the rice is by constructing irrigation canals that lead from rivers or streams into the fields. The irrigation also is useful to dry the land seasonally as, it eases harvesting operations, and at the same time releases the nitrogen and phosphorus nutrients in the soil.

In addition, the rice is the best growth in the region of high light intensities and thus it is widely grown within the tropics and the warmer latitudes of the sub-tropics where the average temperature during the growing season is between 20^0C and over 21^0C during its period of germination. Soils, also such as the mud of coastal swamps, saline, desert soils or lateritic earth, are needed for the well growing of the rice the same as Gatore sector.

2.1.2.5 Origin and Importance of Rice

The rice is one of the most important cereal crops in Africa alongside maize, millet, wheat, sorghum, etc. With regard to human nutrition and caloric intake, rice is the most important grain as it provides more than one fifth of the calories consumed worldwide (Grigg B. 1974). The rice plant can grow up to 1-1.8m tall, depending on the variety and the soil fertility. It has long, slender leaves 50-100 cm long and 2-2.5 cm broad. Rice production is well-suited to countries and regions with low labor costs and high rainfall, as it is labor-intensive to cultivate and requires ample water. Rice can be growth practically anywhere, even on a steep hill or mountain. Although its parent species are native to Asia and certain parts of Africa, centuries of trade and exportation have made it common place in many cultures worldwide.

First attested in English in the middle of the 13th century, the world "rice " derives from the old French ord "*ris*", which comes from Italian "riso", in turn from the Latin "*Oryza*", which derives from the Greek "oruza". The scientific name for rice *is* ***Oryza sativa***. The commonly accepted view is that rice was first domesticated in the region of Yangtze River valley in China, Horgan F (2011). It has been the staple food of China for long time and is consumed in many ways; boiled, streamed, fried or rice wine. Chinese immigrants to Luzon in the 2th millennium B.C must have introduced paddy cultivation to the Philippines, for the intricate terraced fields on the hills are just like those of southern China rice cultivation also spread to Java, Malaysia and the rest of south-East Asia.

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2.3 Global Rice Production

World culture and staple food nearly half the world's population, rice contributes more than 20% of world supply calories consumed. More than two billion people in Asia will get 80% of their calorie (FAO, 2001). In Asia, 95% of the world's rice is produced and consumed, Europe and North America, the rice has a growing importance in the markets as a food (FAO, op.cit). According to Hirsch (1999), Asian region still accounts for over 90% of world rice production, ahead of South American (3.2%) and Africa (2.8%). The paddy production is estimated at 591 million tons in 2001. The leading five producers are China, India, Indonesia, Bangladesh and Vietnam. According to FAO (2001), twenty-six largest producing countries produce over 96% of global rice production. Eighteen countries are located in the South, Southeast and East Asia. The remaining other eight countries - Brazil, USA, Russia, Egypt, Madagascar, Colombia, Iran and Nigeria- together produce less than 6% of the world's rice.

2.3.1 Production and Demand of Rice in Africa

The African continent has become the leading importer of rice, with about one-quarter of world imports. This owes to low net production in the continent accounting to 1.5% of the world production (Ohoyo, 1996). According to Adegbola and Sodjinou (2003), Egypt is the largest producer of rice in Africa followed by Nigeria and Madagascar. In West Africa, Nigeria is the largest producer of rice followed by Ivory Cost and Guinea with 48%, 17% and 10% of total production in the region (Adegbola and Sodjinou, op.cit). Yet the demand for rice has not been satisfied, which resulted in a 400% increase in rice imports over the last 25 years (FAO, 2000).

2.3.2 Adoption of Agriculture Innovations

The introduction of agricultural innovation into a given geographical area in a given period of time may be through both private and public initiatives and the rate of diffusion depends on, among other things, extension communication, the extent to which farmers discuss agricultural issues among themselves on a day to day basis and consistency of performance with the message (Fliegel, 1984). Following a lucid and extended of an innovation Presser (1969) concluded that an innovation is something new and novel in human knowledge and experience.

Van den Ban and Hawkins (1988) define innovation as an idea, method, or object which is regarded as new by an individual, but which is not necessarily the result of recent research. An innovation has a point of origin in place and time. At its point of origin, it must be an innovation, but it is more commonly called an innovation, a research result, or a new development of some older idea(s). In time, as knowledge and use of the innovation diffuse to other people in the surrounding area, the idea ceases to be an innovation in that area.

The rate of adoption is defined as the percentage of farmers who have adopted a given technology. The intensity of adoption is defined as the level of adoption of a given technology. The number of hectares planted with improved seed (also tested as the percentage of each farmer planted to improved seed) or the amount of input applied per hectare referred to as the intensity of adoption of the respective technologies (Konya et al,.1997). The importance of agricultural innovation in the transformation process of economies of developing countries has become, without doubt, the major concern of governments, citizens and development agencies alike. Agricultural economists in the development field have made a particular study of the adoption and diffusion of technical innovation because of the opportunities for increased output and higher levels of income which technological change can offer (Colman and Young, 1989).

2.3.3 Theoretical Framework

2.3.3.1 Production Theory

In the 1920s the economist Paul Douglas was working on the problem of relating inputs and output at the national aggregate level. A survey by the National Bureau of

Economic Research found that during the decade 1909–1918, the share of output payed to labor was fairly constant at about 74%, despite the fact the capital/labor ratio was not constant. He enquired of his friend Charles Cobb, a mathematician, if any particular production function might account for this. This gave birth to the original Cobb–Douglas production function.

This study used a growth theory approach. According to Badel and Huggett (2016), the Cobb-Douglas production function is one of the most widely used functions in economics. It is a practical functional form that has constant returns to scale and diminishing marginal products. In addition to these properties, the Cobb-Douglas has the property that the share of output paid out to the capital input is always equal to a constant β, independent of the quantities of capital and labor employed.

Economist and politician Paul Douglas was interested in finding a mathematical production function that could represent the U.S. production side of the economy. Douglas provided initial evidence that factor shares in U.S. data have no strong trend movements although they fluctuate at business cycle frequencies. Thus, economists view constant factor shares as a realistic assumption. Douglas and the mathematician Charles Cobb found all the production functions that had constant returns to scale and constant factor shares. The result is the Cobb-Douglas production function.

2.3.3.2 Agricultural Change Theory (ACT)

This theory was first developed in 1798, by a British clergyman Thomas Malthus argued for an intrinsic imbalance between rates of population increase and food production. This provided a scientific thought with a particular model of agricultural change which encouraged agricultural sector to operate at the highest level allowed by available technology.

The theory was also advanced in 1965 by Danish agricultural economist Ester Boserup who held that extensive agriculture with low overall production concentration is commonly practiced when rural population density is low enough to allow it, because it tends to be favorable in total workload and efficient (output : input). Rising population density requires production concentration to rise and fallow times to shorten. Changing agricultural methods to raise production concentration at the cost of more work at lower efficiency what Boserup describes as agricultural intensification.

Agricultural change theory was later carried far beyond the simple outlines presented in 1965. Boserup initially stressed that intensification costs came in the field as fallows were shortened, but Boserup (1981, p.5) and others have also identified other modes of intensification. Capital-based intensification is characteristic of industrialized societies. The amount of human labor required to produce food generally decreases, whereas the total direct and indirect energy costs can climb to exceedingly high levels. In infrastructure based intensification, the landscape is rebuilt to enhance, or remove constraints on, production.

Land improvements used well beyond the present cropping cycle—such as terraces, ridged fields, dikes, and irrigation ditches—are termed 'landesque capital' (Blaikie and Brookfield 1987). Since landesque capital depends on long-term control (although not necessarily formal ownership and alienability), Boserup posited a general association between intensification and private land tenure, which has been supported in subsequent research (Netting 1993).

2.3.4 Factors for Adoption of Rice Crop

According Rwanda Agriculture Board (RAB,July 2014), the factors influencing the adoption of improved rice varieties by small- scale rice farmers in Rwanda. The Conditional Logit Model (CLM) was applied to explore the variety attributes and farm household characteristics influencing the farmers' choice among different alternatives. The model is based on random utility maximization and makes the probabilities of the choice of variety dependent on variety-specific attributes and farm household-specific characteristics.

A sample size of 180 rice farmers interviewed was randomly selected from six rice growing marshlands. Results revealed that a majority of rice farmers (78 %) had adopted improved varieties but the proportion of land cultivated to these varieties was still low (ranging from 0.05 to 0.2 ha). The maximum likelihood analysis showed that the prices of seeds and of paddy and the yield are variety-specific attributes that significantly influence the farmers' choice of an improved rice variety. The higher the price of seed, the lower the likelihood of adoption; the higher the price of paddy and yield, the higher the likelihood of adoption.

Also, farm size, labor availability within a farm household, and access to financial facilities significantly influence farmers' decisions to adopt improved rice varieties. The findings suggest that future policies should make efforts to improve the seed supply system among farmers to increase the intensity of use of improved varieties.

In addition, the prices of paddy should provide a market incentive that increases the likelihood of adoption through market development.

There are generally four categories of factors conditioning rice adoption worldwide. These include socio-economic, ecosystems, technical and institutional, and government policies (Walker & Alwang, 2015). The major constraints to the spread of modern rice varieties in the early green revolution period were lack of infrastructure for reliable irrigation, poor drainage, the risk of flooding, and an underdeveloped marketing infrastructure. Socio-economic factors such as farm size, tenurial status, and access to credit did not constrain the adoption of modern rice varieties as much as adverse environmental factors (risks of floods, droughts, etc.) and technical factors (lack of irrigation facilities).

The financial constraint to adoption was softened by the supportive public policies of extending credit on easy terms and subsidizing fertilizer and water (Pingali & Hossain, 1998). On economic point of view and compared with small-scale farmers and sharecropping tenants, large-scale farmers find it easier to meet the significantly increased working capital requirements involved in adopting improved rice varieties. Also, in the absence of a well-functioning insurance market, the risks of adopting an unknown technology would have to be borne by the farmers themselves.

The larger farmers are more able to bear this risk because of their superior access to information and markets and greater capacity to absorb losses. Thus the larger farmers would be able to take advantage of the new technology to a greater extent than the smaller ones. The differential rate of adoption would not only accentuate the existing income inequalities but would lead to absolute impoverishment of non-adopting, small-scale farmers. The non-adopters would face lower prices for the output but be unable to benefit from the reduced unit costs of growing the new varieties.

Non-adopters' land would be bought up by large-scale farmers eager to spend a part of their increased wealth on more land. The tenant farmers would be the losers because there would be an incentive for landowners to evict them and hire labor or machinery to cultivate their own land, as the cultivation of modern rice varieties was more than traditional varieties (Pingali & Hossain, 1998). Regarding ecosystems, adoption of rice improved varieties enjoy almost full adoption in irrigated areas, followed by upland ecosystems, followed by lowlands rain-fed ecosystems, and mangrove ecosystems (Walker & Alwang, 2015). With respect to adoption, the percentage of area planted to improved varieties starts on low basis but has steady growth such that improved varieties occupy dominant areas in the future in most regions (Evenson & Gollin, 2003).

According to Walter and Alwang (2015), institutional factors regard mainly varieties improvement research centers, endowed with required scientific capacity in order to perform breeeding, certification and release of worked out improved varieties. Few data have been available on rice and wheat varietal adoption in sub-Saharan Africa. As a result, there has been little systematic work attempting to evaluate crop improvement in developing countries (Evenson & Gollin, 2003). The financial constraint to adoption is softened by the supportive public policies of extending credit on easy terms and subsidizing fertilizer and water (Pingali & Hossain, 1998).

By 1990, adoption of modern varieties had hit 46%, and by 1998, the most recent year for which data were available, adoption levels hit 63%. Moreover, in many areas and in many crops, first-generation modern varieties have been replaced by second- and third-generation modern varieties (Evenson & Gollin, 2003).

2.3.5 Concept of Sustainable Smallholder Agriculture Intensification

Sustainability is a word emanating from different schools of thought with a series of interpretations and meanings. These various meanings of the term 'sustainability' as applied in agriculture have been classified according to the issues motivating concern, their historical and ideological roots (Hansen, 1996). This leads to the fact that the definition of sustainability becomes part of the problem due to lack of common agreement on how to define it as any attempt to a precise definition is flawed (Pretty, 1994).

Consequently, sustainability is not a scientific concept which can be measured according to some objective scale, or a set of practices to be fixed in time and space (Röling and Pretty, 1998), but a quality that results from people's application of their intelligence to maintain the long-term productivity of the natural resources on which they depend (Sriskandarajah *et al.* 1991). This implies that reaching the goal of the sustainability of a given system is the responsibility of all participants in the system. These include, in agriculture sector, producers, products' 3 traders, policymakers and agricultural development stakeholders with their respective role to play to sustain the sector. A report by the African Development Bank (AfDB) attempts to give the meaning of sustainable agriculture. AfDB (2013) defines it as "an integrated system of plant and animal production practices having a site-specific application that over the long term will: satisfy human food and fiber needs; enhance environmental quality and the natural resource base upon which the agricultural economy depends; make the most efficient use of non-renewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls; sustain the economic viability of farm operations; enhance the quality of life for farmers and society as a whole." In brief, sustainable agriculture is not a simple model or package to be imposed but a process of learning and adaptation (Pretty,1995) that considers together the environment, economic and social dimensions.

2.3.6 Agricultural Intensification and Sustainable Smallholder Agriculture Intensification

According to Pretty *et al.* (2011), agricultural intensification is a concept that has a traditional definition articulated in three different ways: increasing yields per hectare, increasing cropping intensity per unit of land or other inputs (water), and changing land use from low value crops or commodities to those that receive higher market prices. This concept has been of a wide use since the need to increase agricultural production was evidenced around the world.

Although intensifying agriculture is seen as a solution to meet the liberalization requirements and the country's food growing demand, authors argue that it is a constraining approach especially in many African countries where, according to Snyder and Cullen (2014), smallholders are living and exercising under considerable pressure. This view is not fully shared by other authors who affirm that intensification of agricultural production is one of the strategic pillars for agricultural and economic growth in Sub-Saharan Africa (NEPAD, 2003), and a must in the more densely populated areas in order to feed the rapidly growing and urbanizing population (Vanlauwe *et al.*, 2014). In support of this idea, it can be argued that for small-scale farmers with limited access to formal financial services, improved agricultural technologies, and high-yield seeds and other inputs, agricultural intensification appears as an alternative solution with regard to food needs experienced indifferent regions of Africa.

With regard to 'sustainable intensification', like sustainable agriculture, it does not have a very clear definition. Garnett and Godfray (2012) understand the concept as a form of production where in yields are increased without adverse environmental impact and without the cultivation of more land. In agriculture, sustainable intensification has been put forward as a means to simultaneously address the goal of enhancing agricultural production while conserving and protecting the environment (Petersen and Snapp, 2015).

Though it is criticized for its use and lack of common and clear definition (for example, Zhou, 2010 and Garnett and Godfray, 2012), this concept received increasing attention and has been widely used by many development and government agencies as a necessary approach to food production and to address high food demand (Petersen and Snapp, 2015). Moreover, it is denoted a commonly accepted framework where intensification is desirable (Vanlauwe *et al.*, 2014).

As 'sustainable agricultural intensification' is regarded to address the food security needs (Garnett *et al.*, 2013), the issue of smallholder agriculture has to have its meaning and place here for its great role in feeding the population especially in developing countries. Indeed, in these countries where agriculture is characterized by small-scale farms, challenges like continuing population and economic growth in the face of scarcities of agricultural land and water and the dangers posed by climate change, agricultural pollution and biodiversity loss (Buckwell *et al.*, 2014) are also experienced.

Therefore, there is need to intensify in a sustainable way the smallholder agriculture as it is regarded (not only for now but even in the future) as the main source of food for both rural and urban residents. Moreover, in poor and labour-abundant economies, small farm development can be a “win-win” proposition for growth and poverty reduction (Hazell, 2013), and based on their immense collective experience and intimate knowledge of local conditions, smallholders hold many of the practical solutions that can help place agriculture on a more sustainable and equitable footing (IFAD, 2013).

2.3.7 Rationale of Sustainable Smallholder Agriculture Intensification in Rwanda

Pretty *et al.* (2011) contend that continued population growth, rapidly changing consumption patterns, and the impacts of climate change and environmental degradation observed around the world are driving the limited resources of food, energy, water and materials towards critical thresholds. This reality is likely to be substantial in Rwanda, one of the most densely populated countries in Africa with 416 inhabitant per square kilometer and an average annual population growth of 2.6% (NISR, 2012b). Rwandan agriculture is characterized by the limited use of fertilizers, the low use of improved seeds and other inputs, and the high risk of erosion with 90% of domestic cropland on slopes ranging from 5% to 55% (MINAGRI, 2013). Food insecurity is another issue experienced by rural population as evidenced by the study conducted by NISR (2012) which reveals that, in 2012, more than half (51%) of all households reported some type of difficulty in accessing food and 14% of households experienced usual and almost year round chronic difficulties in accessing food for their families. Such a situation insinuates that dealing with food insecurity in Rwanda remains one of the top priorities.

Therefore, the development of agriculture too continues to be an outstanding requirement. In the medium term, the goal is to move Rwandan agriculture from a largely subsistence sector to a more knowledge-intensive, market-oriented sector, sustaining growth and adding value to products (MINAGRI, 2013). As stressed by Cantore (2011), improving agricultural productivity and preventing food insecurity in Rwanda will rely on incorporating environmental sustainability interventions into the planning process to ensure investments are adequately allocated to address environmental priorities within the relevant sectors. Therefore, Rwanda needs an intensive and sustainable smallholder agriculture that optimizes environmental management and natural resources use, ensure food security for all the population and generate increased agricultural output and income for farmers. 5

2.4 Empirical Literature

An empirical study of adoption and diffusion of innovation through interviews with potential uses of the innovation, according to Van den Ban and Hawkins (1988) is an important approach to investigate and find answers to the following set of questions; (i) what decision making path ways do individuals follow when considering whether or not to adopt an innovation? Which sources of information are important? (ii) What are the differences among people who adopt innovations quickly or slowly? (iii) How do the characteristics of innovations affect the rate of adoption? (iv) How do the potential users communicate among themselves about these innovations? Who plays the important role of opinion leader in this communication process? And (v) how does an innovation diffuse through a society over time? Because of these a number of empirical studies have been conducted by different peoples. Until 1980 more than 3000 publications have appeared, of which over 2000 represent results of empirical research on adoption of innovations and detailed analyses of differences between adopter categories with respect to a host of personal, social and cultural characteristics (Rogers, 1983).

Views and findings are not, however, consistent with respect to the role of these factors on adoption behavior of farmers and the subject is of considerable controversy around the globe. No single conclusion has been drawn with respect to the key factors which favor or impede adoption decision at given time and place becomes less important or even induce an impediment on the adoption behaviors of farmers at another time and /or place. Hence review of empirical models works is important for various reasons. First, it helps to assess the present state of knowledge of the adoption process. Second, it helps to enhance the interpretation of empirical models and their results and its implications as against the conceptual or theoretical models (Feder et al., 1995).

However, the study are mainly conducted around major cereals and due to this study conducted in the area of coffee, perennial crop is scanty. As a result of this, the review mainly included the studies conducted mainly on cereals, particularly maize and wheat with very few related horticultural crops. For ease of grouping, the variables so far identified as having relationship with adoption are categorized as household personal and demographic variables, socio-economic factors, technology related factors, intervening (psychological) variables and institutional factors.

According unpublished PhD Thesis, 2012 by Julie Van Damme, from Catholic University of Louvain "Systematic analysis of innovation processes in the agricultural systems of the Great Lacks Region based on the culture of banana" In its report World Development report, the World Bank pleaded for a 'Green Revolution' for sub-Saharan Africa, pointing particularly to the importance of including smallholder farmers. This article focuses on the banana cropping system in Rwanda, and on the agricultural innovations introduced within this system.

Banana is a common crop for the majority of smallholders in the region, and therefore a privileged entry point for studying agrarian systems. The importance of banana for Rwandan's smallholders rests on the multiple functionalities of the crop as food and cash crop; but also agronomic aspects in terms of prevention of erosion and renewing of soil fertilization. In line with its regionalization policy, the Rwandan government wants to break a tradition of banana growing at the level of each household, and to concentrate banana production in a few regions with suitable agro-ecological conditions. Moreover, policy makers aim to significantly innovate production methods in order to increase overall output. The methodology is based upon in upon in-depth qualitative research and interviews with farmers. Most of them grow banana, but they live in three diverse agro-ecological environments.

In the first phase, in 2009, they conducted semi-structured interviews with farmers living in Gatore sector (Kirehe district) in the Eastern province of Rwanda. The sample in each setting included farmers adopting ‘traditional’ cultivation patterns, and others ‘innovative’ farmers who adopted practices used in the banana-based cropping system. The information getting on the rationale behind their cultivation practices, and on the constraints they faced in sustaining their daily livelihoods.

Whereas innovations can be introduced at all levels and for many different crops, this article focuses on the banana cropping system. A classic banana plantation in the Great Lakes region is a plot in which different crops and different banana types are mixed. Intercropping increased during the 1950s-1960s when rising democratic pressure reduced the available cultivated land area per household. Banana groves (intercropped with food crops like beans, for example) are generally located near the house; other scattered fields, on which farmers practice complex intercropping, are located away from the homestead (on farm fragmentation). There are three types of banana: the beer banana, the cooking banana, and the dessert banana.

According to an estimate by Ministry of agriculture, in 2005 these different crops represented 60, 30, and 10 percent of acreages, respectively. The beer banana is used to make juice or beer, the latter having a particular role in Rwanda social life. Cooking banana is a staple food but can also provide an important source of revenue when sold on the market. Dessert banana is most often grown in the proximity of larger markers and can be an important source of income in those regions. When consumed at the local level, the main consumers are children. Some varieties of dessert banana can also be used in beer brewing for sweetening.

In 2005, the Rwanda government adopted a banana program-in line Strategic Plan for the Transformation, that aimed to reduce the proportion of beer banana (from 60 to 40 percent) while raising the proportion of cooking bananas (from 30 to 45) and dessert bananas (from 10 to 15 percent) between 2005 and 2010. This policy was based upon policy maker's dislike of the consumption of traditional banana beer, because drunk people are perceived to fight, and the tradition of banana beer is accordingly not in line with the state's objective of creating a modern society. As emerged clearly during one of focus group discussions: in past, the inns (cabarets) served banana beer and it was a source of income. Now, the government bans the traditional transformation process. Authorities would like to industrialize the process.

The Rwandan government's banana policy does not only foresee the replacement of beer bananas with cooking or dessert bananas; it also aims for the adoption of 'modern' production techniques. It seeks, for example, to replace intercropping (combination of different crops in the same plot) with mono-cropping, in line with the overall agricultural policies mentioned previously. This implies a considerable change in traditional banana-based cultivation systems.

Indeed, traditionally, the banana plantation is located close to the house when different varieties of banana are intercropped with shadow crops, mainly beans. The intercropping system is the product of a long process of intensification of land use by the peasants. The cultivation of several crops in the same fields requires constant attention and intense labor, but the diversification of crops also allows farmers to balance their diet and manage more adequately the risks imposed by climatic conditions or crop diseases affecting particular crops. In addition, the adoption of mono-cropping techniques implies an increase of labor. Women are particularly conscious of this aspect because they are in change of annual crops (while men are responsible for banana).

During the second field in June 2010, they learnt that a Rwanda Agriculture Development Authority (RADA) training course was being planned for September 2010 in Gatore sector (Kirehe district), to promote 'correct' practices of intercropping banana and beans. At the end of October 2011, during the next field trip, a local official (umudugudu) in Gatore reported that the end this did not take place as the authorities had changed their mind again. This lack of consistency in policy guidelines enhances farmers' reluctance to follow nationally defined policy objectives.

In this case, most of farmers are radically and quite openly, opposed to mono-cropping requirements, as these do not suit local realities. In the end, most of them reluctantly adopted the approach because of extensive government control; however, policy makers were made aware of the problems with the mono-cropping system and the strength of opposition appears to have caused the government to rethink. Most analyses assessing the success of an externally induced innovation highlight the obvious efficiency of a straightforward solution, but ignore the secondary effects. This article shows that, even for technical implementation, there should be many more channels for hidden discourses to reach the surface. It is important to consider the trade-off between the positive effects of an innovation, and its possible negative direct and indirect effects. This should be done ex-ante, but also ex-post to learn from on –the ground experience and adapt accordingly.

In the assessment, local farmers know how and knowledge is of crucial importance to the success of agricultural reforms and should be taken into account at all levels. This allows policy makers to consider the relevance of an innovation not only on the technical and agro-ecological level, but also on the economic and social level. A complicating factor is that there are multiple types of farmers, for whom these technical, agro-ecological, economic, and social contexts differ profoundly. Given this, what is required is a flexible and comprehensive approach that allows these complexities to be taken into account.

Rwandan policy makers should be much more responsive to innovations that arise' from below'. Indeed, the best solutions to local problems often do not come from outside. Farmer's unique expertise is based upon generations of experience of survival in extremely complex agro-ecological and social circumstances. This makes Rwandan farmers the most skilled experts, specialized in all the possible threats and challenges with which Rwandan farming systems may be confronted. They should not be ignored or treated in paternalistic ways by policy makers and outside 'innovators'; on the contrary, their voice should be the main reference point for assessing the relevance of externally inducing innovations.

2.4.1 Rice Development Research and Diffusion

The International Rice Research Institute (IRRI) was established in 1960 by the Ford and Rockefeller Foundations with the help and approval of the Government of the Philippines. Today IRRI is one of 16 nonprofit international research centers supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is cosponsored by the Food and Agriculture Organization of the United Nations (FAO), the International Bank for Reconstruction and Development (World Bank), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP). Its membership comprises donor countries, international and regional organizations, and private foundations (Pingali & Hossain, 1998).

Breeding of rice began shortly thereafter. Drawing on the experience of the Rockefeller Foundation's wheat breeding programme in Mexico, IRRI scientists sought to develop a set of short stiff-straw rice varieties that would respond well to fertilizer applications. At the time, most tropical rice varieties were tall and tended to fall over (lodge) when fertilizer was applied. As a result, IRRI breeders quickly moved to introduce semi-dwarfism into indica rices . Most Asian countries have national breeding programmes that date back further still, with some tracing their roots to colonial institutions founded as long as 100 years ago. Research in both China and Japan can be traced back still farther; the importance of rice improvement was widely recognized in these countries long before the science of genetics was formalized (Evenson & Gollin, 2003).

Genetic improvement of rice in Africa can be traced back to mid – 1930s with the Rokupr Research Station in Sierra Leone for regional mangrove improvement (Walker & Alwang, 2015). In China, breakthroughs in varietal improvement and technological progress happened much earlier than in other Asian nations. The first semi-dwarf rice variety was bred in 1957, and by 1965 almost all of the early-season rice area was sown to high-yielding varieties in Guangdong Province, Research on hybrid rice was also initiated in China, and the breakthrough was made in 1974.

The potential 15-20% yield advantage of hybrid rice over conventional high-yielding varieties caused a rapid expansion of area under hybrid rice for indica varieties (to 41% of the total rice area by late 1980s), which was the main factor behind the expansion of rice yield since 1976. The development of seed production capacity in the public sector was the main factor contributing to rapid expansion of hybrid rice production in China (Pingali & Hossain, 1998). The following table depicts the milestones of green revolution and improvement in rice cropping.

Table 2.1: Milestones of Green Revolution and Rice Cropping Improvement

Phases	**Improved seed and increased input use**
Phase I	IR8 and the beginning of high yielding varieties
	Investment in irrigation
	Policies to support inputs of nutrients and pesticides
	Seed multiplication infrastructures and seed distribution by extension systems
	Training of rice scientists
	Rice genetic resources collected and conserved
Phase II	**Increased input use intensity**
	Shorter duration, photoperiod-insensitive rice cultivars
	Protecting yield gains from pests
	Increased mechanization for land preparation and threshing
	Introduction of the farming systems methodology
	International sharing and testing of rice germplasm
Phase III	**Shifting the yield frontier, input efficiency, and sustainability**
	Requirements of new green revolution

Source: (Pingali & Hossain, 1998)

For the phase I, rice research leading to the green revolution is well known. It was characterized by a focus on increasing the “pile of rice” through shifting the yield frontier of rice in the tropics, providing irrigation infrastructure and inputs of nutrient and pesticides, and training local extension technicians in the ways of the new generation of rice production technologies. For the second phase II, this phase concentrated on reducing the growing period of cultivars. A consequence of the crop improvement process to increase yields and to develop cultivars that were photoperiod-insensitive (i.e., broadly adopted over large areas) was a shortening of the duration of the crop.

The variety IR8 showed advantages over many traditional rice varieties in shorter growth duration (130 vs 160-170 d to maturity); it was photoperiod-insensitive and produced about 70 kg of rice per day. Later IR varieties, such as IR36, IR64, and IR72, which are now widely grown, are also photoperiod-insensitive, mature in 100 d, and produce about 90 kg/day (Pingali & Hossain, 1998). By the late 1960s, two IARC programmes – the International Rice Research Institute (IRRI) was credited by the popular press with achieving a Green Revolution in rice production. This Green Revolution was identified with the development of improved ‘high-yielding’ varieties of rice and with the rapid adoption of these varieties by farmers in Asia and Latin America (Evenson & Gollin, 2003).

Despite all reported potentialities and achievements, rice demand growth outpaces rice economic production and requires development of HYVs resistant to floods, droughts, and problem soils; the required increase in the rice yield of the irrigated ecosystem is still about 8.0t/ ha by the year 2025 (Pingali & Hossain, 1998). Today agricultural research takes place in a context profoundly different from the one that pertained decades ago. Astonishing new technologies have emerged, and scientific knowledge has advanced beyond any prediction. Most notably, the emergence of biotechnology – and the associated advances in our basic understanding of biological processes – has vastly changed the toolkit available to plant scientists. Along with these new technologies, changing legal views of intellectual property rights have contributed to significant shifts in the organization of agricultural research. In rich countries, private-sector firms have undertaken large investments in agricultural research based on biotechnology methods (Evenson & Gollin, 2003).

Monitoring the adoption of rice varieties began also on continental scale in sub-Saharan Africa earlier for any other crop. The semi-dwarf, short-duration high yielding varieties of rice from Asia have entered Africa as early as the late 1960s. By the 1990s, diffusion of improved varieties was sufficient to support rate of return studies and impact assessment research with a specific focus on a handful of countries (Walker & Alwang, 2015). Global rice cultivation is estimated at 150 million ha. Rice yields recorded worldwide include 5.8 MT/ha in Japan, 5.6 MT/ha in China and 4.3 MT/ha Indonesia1. Comparing these yields with the world average of about 3.5 MT/ha, it is evident that there is great potential to improve rice yields elsewhere. The development of rice therefore presents an opportunity to reduce the number of food-insecure people that presently stand at 860 million, by half by 2015, and to achieve MDG (i.e., to eradicate poverty and hunger) (EUCORD, 2012).

2.4.2 Introduction of Rice in Rwanda

Rice was first introduced into Rwanda in the 1950s with initial trials being made by the Chinese, through their mission known as “Formose”, in at Bugarama in Cyangugu and Kabuye regions. By 1967, significant progress had been made which resulted in the development of several rice schemes across the country (Jagwe, Okoboi, Hakizimana, Tuyisinge, & Rucibigango, 2003). During the 1970s, Rwanda's rice sector received significant support from the Chinese government. The Chinese rice variety Keng Diao 3 was introduced and spread throughout the entire country within a decade, but by the end of the 1980s rice blust infected this rice variety and Rwanda suffered dramatic losses in its rice production. Because of this, Rwanda's agricultural research centers swiftly carried out test cultivations of rice varieties from Madagascar, Cameroon, Korea, Japan, and a vast number of Chinese varieties.

As a result, three varieties of rice from China were selected: Xinan (Xinun) 175, YunKeng136, and Yunertian01 for their high yields. Yun Keng 136 and Yunertian 01. These varieties were derived from Xinan175. Xinan 175 originating from Japonica varieties developed by Taiwan's Xinan Agricultural Research Institute during 1950's. During the 1980s, Basmati rice and varieties of long-grain rice grown in parts of Western Africa were introduced to Rwanda (Promar Consulting , 2012, p. 60).

2.4.3 Adoption of Rice in Rwanda

Marshland ecosystems in Rwanda are comparable to the favorable lowland rain fed ecosystems found elsewhere in Asia. The marshlands are situated at various altitudes ranging from 1,000 m to more than 1,700 m above mean sea level (MSL). High relative humidity, cool night temperatures (10 to 15ºC), warm day temperatures (20 to 30ºC), and frequent rains are the salient features of the marshlands. Rwanda has two rainy seasons from September to November (Planting season A) and from

March to April (Planting season B). Rice is cultivated in marshlands predominantly in these two seasons. Although rice is not a traditional crop in Rwanda, characteristics of rice grains such as long shelf-life, ease of cooking and transportation, and less requirement of cooking fuel (compared to traditional food such as potato) has made rice becoming a popular choice of food in schools, homes, restaurants, and public ceremonies. Rice in income levels, growing urban population, and changing lifestyles is further increasing the demand for rice (MINAGRI, 2013).

Having recognized the importance of the rice crop, the government of Rwanda has declared rice as a 'priority crop' under its agriculture sector development (Karthiresan, 2010). The Strategic Plan for Agricultural Transformation (PSTA) forms the framework for enhancing agricultural development, aligning its achievements on the goals of Rwanda's Vision 2020 and its medium-term strategies, such Economic Development and Poverty Reduction Strategy (EDPRS) (Bockel & Touchemoulin, 2011).

The Kirehe Community-based Watershed Management Project (KWAMP) as well as others projects, are a first step toward the full implementation of the PSTA strategy. Those projects are used to ensure that the Government's program of investment in agriculture is planned in a systematic and coordinated manner and in consistency with long-term national development objectives. The Support Project for the Strategic Transformation of Agriculture (PAPSTA) overall objective is to increase the agricultural income and improve the nutrition of poor rural population by implementing the PSTA within the frame of innovative partnerships with stakeholders (Bockel & Touchemoulin, 2011).

2.4.4 Adoption of Rice in Kirehe District

Kirehe possesses the second largest marshlands area of 9,457 ha after Bugesera which holds marshlands covering 13,644 ha (MINAGRI, 2013), owing to the fact that throughout all Rwanda, through a number of high profile agricultural development projects, the MINAGRI has revamped and rendered several marshlands to farmers for rice cultivation (Bockel & Touchemoulin, 2011). Kirehe District, alongside Gatsibo, Nyagatare, and Bugesera have allocated larger land to rice cropping compared to the rest of the country.

Kirehe also counts a great number of low-input and low-risk smallholders abundant in rice farming (SFSA, 2012). The government has also facilitated the delivery of inputs such as seeds, fertilizers and pesticides. With the help of some modest outputs from international research collaborations, the farmers are able to tap the benefits of new rice cultivars and production conditions under marshland ecosystem (Bockel & Touchemoulin, 2011). The adoption of rice production owes also to the enhancement of food security as staple food and its commercial viability (KireheDistrict , 2015)

2.4.5 Rice Intensification in Rwanda

Rice productivity in Rwanda, like that of other crops is enhanced by agricultural development strategies and policies. Developments in terms of efficient agricultural use of arable land have had substantial effects. “Imidugudu” policy (moving farmers away from the traditional scattered style of settlements to living in designated grouped settlements facing roads), crop intensification program (banning the cultivation of crops other than the designated crop for a specific area), and the prohibition of intercropping (moving away from intercropping of banana with crops such as coffee or maize to modernized mono-cropping cultivation) continue to drastically change the landscape of rural villages. With the introduction of the crop intensification program, the maintenance of marshland irrigation and drainage systems, along with fertilizer supply, has improved (Promar Consulting , 2012).

To nurture rice productivity, the sustainable management of the watersheds is meant to take into account an upstream to downstream response that equally takes into account the wetlands. Towards this end, the PAPSTA and KWAMP projects adopted the Intensive Rice Cultivation System (IRPS) for the sustainable development of wetlands. The Intensification of Rice Production System is a rice production process which combines different techniques that helps in ensuring (i) an intensive, (ii) sustainable production (iii) at minimal costs. The formation of this triptych is made possible through the combination of the following complementary techniques: (i) seed preparation, (ii) preparation of paddy-fields, (iii) sowing, (iv) transplanting, (v) water management, (vii) weekly weeding, (viii) fertilizer application, (ix) disease and pest control (insects, weeds), (x) paddy-field security (xi) harvest.

The mastery and application of these additional farming techniques helps in increasing the yield to between 6 and 8 tons per hectare (as opposed to between 2 and 3 tons for the traditional rice production system) with much less labor, seed quantity and water consumption. The Sustainable Rice Intensification (SRI) therefore allows the enhancement of the wetlands through sustainable intensification of rice production (Derrahi, 2014). The National Rice Production Program (2006-2016) included the goal of increasing rice production to 170,000 MT by the end of 2016 (Promar Consulting , 2012).

The NRDS aims to achieve self-sufficiency in rice production by 2018, and to substantially raise the competitiveness of Rwanda rice in local and regional markets. It is envisaged that the approaches will raise the productivity level from 5.72 t/ Ha in 2012 to 7.0 t/ Ha by 2018 and expand the area under cultivation to 28,500 by 2018. It is emphasized that an integrated approach on interventions in the key sub sectors along the rice value chain can provide the sustainability to the targeted increases in productivity and area under cultivation. The proposed strategies are aligned with the overarching national, regional and global perspectives on economic development and poverty reduction (MINAGRI, 2013).

2.4.6 Development of Rice Varieties in Rwanda

The Chinese varieties have been the most commonly grown for the past 30 years or more in Rwanda. These were introduced in the 1960s and when the government introduced large-scale production of paddy. Of recent, varieties such as Basmati, BG, IITA, IRON and FAC have been introduced in Rwanda and some of them are on high demand due to some of their attributes which include; good grain quality, good aroma, length of grain (long preferred), tolerance to diseases and yield (Jagwe *et al,* 2003).

The rice growers in Rwanda currently have only a few varietal options. While the farmers in established old marshlands grow long and slender type (indica) varieties, farmers in new marshlands cultivate traditional varieties that are short and bold type (japonica) due to shortage of seed supply. Trends in local markets suggest that consumers prefer indica rice. However the narrow choices of long grain varieties (released in 2002) increases the vulnerability of rice cultivation in old marshlands to biotic and a biotic pressures in an ecosystem which is already under pressure. Thus there is an urgent need for development of new rice varieties in Rwanda. The current research activities engaged in such activities in Rwanda largely depend on a strategy of introducing and testing of rice varieties that have been developed elsewhere. However, the microclimatic variations in Rwandan marshlands require breeding and selection of varieties that are suited to the local ecosystem (Karthiresan, 2010). An investigation carried out in 2001-2002 by the ISAR and WARDA shows that as of 2002, there were 24 rice varieties planted in Rwanda. The main varieties are listed on the following table (Promar Consulting , 2012).

Since 2002, in order to cultivate the popular long-grain rice varieties in Rwanda, WARDA (now the Africa Rice Center) and the Institut des Sciences Agronomiques du Rwanda (ISAR) tested around 900 rice varieties for their suitability. Rice varieties such as the WAT series developed by WARDA showed considerable resistance towards Rwanda's cold weather and diseases, yielding 10 tons/ha. 35 Consequently, RAB's has recommended the following rice varieties depending on elevation above sea-level: IR 64, WAT 54, BASMATI 137 (fragrant rice), and IR 65192 -4B-17-3 (fragrant rice) are recommended for low elevations located around Bugarama; Gakire (Tox 4331 Wat 91-3-1-1-1), Instinzi (Tox 4331 Wat 86-3-4-2-2-1), Instindagirabigega (Wat 1395-B-24-2), WAB 543-45-2, and some other varieties are recommended for areas with a medium elevation.

RAB is working hard to expand cultivation of the recommended rice varieties. What is interesting is that in an attempt to promote the recommended rice varieties, local names such as *Ga*kire (rich), Intsinzi (victory) and Intsindagirabigega (full storage) have been given to the successful WAT rice varieties to encourage their cultivation (Promar Consulting , 2012). Recently, the government has taken several steps toward deregulation of seed industry in Rwanda. In a wider move to increase private investments, the government has invited seed companies in the region to import and/or produce and disseminate seeds to local farmers. RAB, the only institution with a mandate for research & development in rice seed has begun to supply basic seeds of improved rice varieties to private entrepreneurs and farmer cooperatives.

Table 2.2: Main Rice Varieties Grown in Rwanda (as of 2002)- move to Appendix

Name	Rice scheme where variety is grown	Origin of the variety	Characteristics
Zhong Geng (Kigori)	Rwamagana, Cyili, Kabuye, Nyagatare, Bugesera , Mukunguri	Unkown	Short grain, Resistant to rice blast and leaf sheath browning
Yung Keng 136	Rwamagana, Cyili, Kabuye, Nyagatare, Bugesera , Mukunguri	Natural crossing from Xinun 175 (1970)	Short grain, Resistant to rice blast and leaf sheath browning
Yun Yin 4	Rwamagana	Unkown	Short grain,Not resistant to rice blast and leaf sheath browning
Yunertian 01	Rwamagana, Cyili, Kabuye, Nyagatare, Bugesera , Mukunguri	Natural crossing from Keng 2 91974)	Short grain, Resistant to rice blast and leaf sheath browning
Xinun 175	Nyagatare, Rwamagana	Japonica introduced fromTaiwan (1975)	Short grain, Extremely prone to rice blast and leaf sheath browning
Fac V 046	Cyili	Unknown	Short grain,Resistant to rice blast and leaf sheath browning
Basmati 370	Bugarama	Basmati introduced from India	Long grain, Fragrant, low yield; Resistant to rice blast and leaf sheath browning
IRON 280	Bugarama	Unknown	Short grain,Resistant to rice blast and leaf sheath browning
BG400-1	Bugarama	Unkown	Long grain, Resistant to rice blast and leaf sheath browning
IRAT	Bugarama	IRAT (an Institute in Niger)	Long grain, Resistant to rice blast and leaf sheath browning

Source: (Promar Consulting , 2012, Jagwe *et al*, 2003)

However, the basis of selection of seed multipliers within neither farmer co-operatives nor entrepreneurs is not clearly outlined. Absence of training programs for seed multipliers and supervision of seed production practices impedes the implementation of rigorous standards in seed production. This is mainly due to lack of adequate human capacity and technical competence. Thus these challenges hinder the impact of government's efforts in deregulating the rice seed industry (MINAGRI, 2013). The NRDS envisages manifold expansion of area under rice cultivation in order to raise rice production from 66,000 MT of paddy (42,900 MT of milled rice in 2008) to the 369,000 MT/year (239,850 MT milled rice) for 2018. This requires strengthening of seed supply systems in Rwanda. To achieve coherence, the required actions are classified under the following sets of objectives, expected outputs and proposed activities (MINAGRI, 2013).

2.4.7 Rice breeding in Rwanda

The Chinese varieties have been the most commonly grown for the past 30 years or more. These were introduced in the 1960s and when the government of Rwanda introduced large-scale production of paddy. Of recent, varieties such as Basmati, BG, IITA, IRON and FAC have been introduced in Rwanda and some of them are on high demand due to some of their attributes which include; good grain quality, good aroma, length of grain (long preferred), tolerance to diseases and yield (Jagwe *et al,* 2003).

The rice growers in Rwanda currently have only a few varietal options. While the farmers in established old marshlands grow long and slender type (indica) varieties, farmers in new marshlands cultivate traditional varieties that are short and bold type (japonica) due to shortage of seed supply. Trends in local markets suggest that consumers prefer indica rice. However the narrow choices of long grain varieties (released in 2002) increases the vulnerability of rice cultivation in old marshlands to biotic and a biotic pressures in an ecosystem which is already under pressure. Thus there is an urgent need for development of new rice varieties in Rwanda.

Table 2.3: Main Rice Varieties Grown in Rwanda (as of 2002)

Name	Rice scheme where variety is grown	Origin of the variety	Characteristics
Zhong Geng (Kigori)	Rwamagana, Cyili, Kabuye, Nyagatare, Bugesera , Mukunguri	Unkown	Short grain, Resistant to rice blast and leaf sheath browning
Yung Keng 136	Rwamagana, Cyili, Kabuye, Nyagatare, Bugesera , Mukunguri	Natural crossing from Xinun 175 (1970)	Short grain, Resistant to rice blast and leaf sheath browning
Yun Yin 4	Rwamagana	Unkown	Short grain,Not resistant to rice blast and leaf sheath browning
Yunertian 01	Rwamagana, Cyili, Kabuye, Nyagatare, Bugesera , Mukunguri	Natural crossing from Keng 2 91974)	Short grain, Resistant to rice blast and leaf sheath browning
Xinun 175	Nyagatare, Rwamagana	Japonica introduced fromTaiwan (1975)	Short grain, Extremely prone to rice blast and leaf sheath browning
Fac V 046	Cyili	Unknown	Short grain,Resistant to rice blast and leaf sheath browning
Basmati 370	Bugarama	Basmati introduced from India	Long grain, Fragrant, low yield; Resistant to rice blast and leaf sheath browning
IRON 280	Bugarama	Unknown	Short grain,Resistant to rice blast and leaf sheath browning
BG400-1	Bugarama	Unkown	Long grain, Resistant to rice blast and leaf sheath browning
IRAT	Bugarama	IRAT (an Institute in Niger)	Long grain, Resistant to rice blast and leaf sheath browning

Source: (Promar Consulting , 2012, Jagwe *et al*, 2003)

The current research activities engaged in such activities in Rwanda largely depend on a strategy of introducing and testing of rice varieties that have been developed elsewhere. However, the microclimatic variations in Rwandan marshlands require breeding and selection of varieties that are suited to the local ecosystem (Karthiresan, 2010). An investigation carried out in 2001-2002 by the ISAR and WARDA shows that as of 2002, there were 24 rice varieties planted in Rwanda. The main varieties are listed on the following table (Promar Consulting , 2012).

Since 2002, in order to cultivate the popular long-grain rice varieties in Rwanda, WARDA (now the Africa Rice Center) and the Institut des Sciences Agronomiques du Rwanda (ISAR) tested around 900 rice varieties for their suitability. Rice varieties such as the WAT series developed by WARDA showed considerable resistance towards Rwanda's cold weather and diseases, yielding 10 tons/ha. 35

Consequently, RAB's has recommended the following rice varieties depending on elevation above sea-level: IR 64, WAT 54, BASMATI 137 (fragrant rice), and IR 65192 -4B-17-3 (fragrant rice) are recommended for low elevations located around Bugarama; Gakire (Tox 4331 Wat 91-3-1-1-1), Instinzi (Tox 4331 Wat 86-3-4-2-2-1), Instindagirabigega (Wat 1395-B-24-2), WAB 543-45-2, and some other varieties are recommended for areas with a medium elevation. RAB is working hard to expand cultivation of the recommended rice varieties. What is interesting is that in an attempt to promote the recommended rice varieties, local names such as Gakire (rich), Intsinzi (victory) and Intsindagirabigega (full storage) have been given to the successful WAT rice varieties to encourage their cultivation (Promar Consulting , 2012). Recently, the government has taken several steps toward deregulation of seed industry in Rwanda.

In a wider move to increase private investments, the government has invited seed companies in the region to import and/or produce and disseminate seeds to local farmers. RAB, the only institution with a mandate for research & development in rice seed has begun to supply basic seeds of improved rice varieties to private entrepreneurs and farmer cooperatives. However, the basis of selection of seed multipliers within neither farmer co-operatives nor entrepreneurs is not clearly outlined. Absence of training programs for seed multipliers and supervision of seed production practices impedes the implementation of rigorous standards in seed production. This is mainly due to lack of adequate human capacity and technical competence.

Thus these challenges hinder the impact of government's efforts in deregulating the rice seed industry (MINAGRI, 2013). The NRDS envisages manifold expansion of area under rice cultivation in order to raise rice production from 66,000 MT of paddy (42,900 MT of milled rice in 2008) to the 369,000 MT/year (239,850 MT milled rice) for 2018. This requires strengthening of seed supply systems in Rwanda. To achieve coherence, the required actions are classified under the following sets of objectives, expected outputs and proposed activities (MINAGRI, 2013).

2.4.8 Intensification of Rice Sector in Rwanda Wetlands

Marshlands/wetlands in Rwanda are highly conducive for growing rice crop. In some marshlands, rice is the only crop that thrives well and produces better yield than any other traditional crops during main season. National estimates show that farmers obtained yield of 3.354 tons per Ha on an average, the highest in the East African Community (EAC) region, in 2008 (Karthiresan, 2010). Having acknowledged the potential of rice production in marshlands and the trends in consumer demand, the Government of Rwanda declared rice as a priority crop in 2002 (MINAGRI, 2013). By 2003, there were in Rwanda seven formal rice-producing schemes (Jagwe *et al* , 2003).

Table 2.4: The Rice Growing Schemes in Rwanda by 2003

Scheme	**Rice grown by area (ha)**	**Altitude**	**Edaphic conditions**
Bugarama	830	Low altitude <1,200 M	Alluvial and clay soils
Butare	1,239	Mid altitude1,200 – 1,700 M	Low organic matter content; High risk of iron toxicity
Mukunguri	240	Mid altitude 1,200 – 1,700 M	Sandy soil with eroded material
Rwamagana	670	Mid altitude 1,200 – 1,700 M	Well maintained organic material content in soils
Mutara	280	Mid altitude 1,200 – 1,700 M	Alluvial soils with vertisols that break down in dry season
Bugesera	200	Mid altitude 1,200 – 1,700 M	Low organic matter content
Kabuye	230	Mid altitude 1,200 – 1,700 M	Well maintained organic material content in soils

Source: (Jagwe, Okoboi, Hakizimana, Tuyisinge, & Rucibigango, 2003)

By 2003, these rice schemes covered nearly 4,000 hectares of mainly marshlands and were designed to meet the food needs of the growing urban population. The rest of the rice was produced on out grower fields and these covered about 1,500 hectares and this made the total production area countrywide to be about 5,500 hectares. In Bugarama, the People’s Republic of Korea participated in the Rice development program at Butare, and the American government through ACDI / VOCA has contributed financially towards the construction of hydro agricultural infrastructure of some of the rice schemes managed by CODERVAM (Cooperative de Dévelopement Rizicole des Vallées du Mutara) (Jagwe *et al*, 2003). In the 2000s, the Rwandan government vigorously carried out its marshland development strategy and improved irrigation systems in marshlands at a fast pace.

Table 2.5: Distribution of Marshlands along the Three Major Rivers in Different Districts of Rwanda

Nº	Akagera river		Akanyaru river		Nyabarongo river	
	District	**Area (ha)**	**District**	**Area (ha)**	**District**	**Area (ha)**
1	Bugesera	13,644	Gisagara	5,372	Karongi	163
2	Kicukiro	1,989	Nyanza	1,848	Gakenke	557
3	Nyarugenge	609	Ruhango	415	Ngorero	568
4	Rwamagana	777	Kamonyi	1,524	Nyarugenge	1,348
5	Ngoma	7,428	Bugesera	1,821	Ruhango	236
6	Kirehe	9,457			Muhango	849
7					Kamonyi	1,548
8					Rulindo	298
Total	**6**	**33,904**	**5**	**10,980**	**8**	**5,567**

Source: MINAGRI (2013)

Rural Sector Support Project (RSSP) lasted from 2001-2008; RSSP II then started in 2008 and ended in 2011. The two programs improved irrigation system for 6,000 hectares of marshland. In Bugesera, an ADB-funded irrigation program enhanced irrigation systems covering 1,500 hectares; and in Kirehe, an IFAD-funded project repaired irrigation systems for 200 hectares of marshland (Promar Consulting , 2012).

The high price of rice was an incentive for farmers to grow rice, and with the combination of industry development policies set by the government to increase rice production, the production level was on the rise. In 2009, production levels reached a record level of 110,000 tons, but this was not sustained. In 2010, production area decreased as did total production level. Although irrigation systems are in place, their effectiveness and the total area they can irrigate heavily depends on the level of rainfall. Rice production volumes are therefore still unstable (Promar Consulting , 2012). In Rwanda the Government regulates the prices of fertilizer, assisting cooperatives to source inputs (Sygenta Foundation , 2012).

2.4.9 Commodity Chain Development of Rice in Rwanda

Government of Rwanda has since invested substantial amount of resources through several high profile development projects for the rice sector in the country. As a result, the total domestic rice production has increased 32-fold in the lately, the highest increase amongst the East African Community (EAC). Such a significant increase in rice production was contributed by the several initiatives taken by MINAGRI in marshland reclamation and facilitation of inputs to farmers (MINAGRI, 2013).

Despite the leap in production however, the consumer demand for rice has also been raising in Rwanda. Currently the local markets respond to such increase in requirement through importation of milled rice grains from countries such as Tanzania, Uganda, Pakistan and Vietnam (MINAGRI, 2013). It is therefore timely that the Coalition for Africa Rice Development (CARD) has led an initiative to develop a strategic framework for development of rice sector in Rwanda.

Table 2.6: Comparative Table of Milled Rice in EAC from 1970s to 2000s ('000t)

Decade	Rwanda	Burundi	Kenya	Uganda	Tanzania	EAC
1970s	1.85	4.44	24.56	12.4	184.05	227.3
1980s	4.64	15.41	30.19	17.29	329.54	397.07
1990s	6.53	29.75	31.58	54.47	446.29	568.62
2000s	213.03	199	475	1394	7646	9927.03

Source: (MINAGRI, 2013)

The National Rice Development Strategies (NRDS) lay emphasis on the following approaches:

a. Facilitation of research for development of rice value chain;

b. Expansion and diversification of land area under rice cultivation;

c. Improvement in productivity of small holder farms through efficient distribution and use of inputs;

d. Establishment of new- and rehabilitation/maintenance of old infrastructures in marshlands;

e. Enhancement of quality and competitiveness of locally produced grains in domestic and regional markets;

f. Creation of favorable environments for the sustenance of rice sub-sector through effective policy and regulatory frameworks (Karthiresan, 2010)

2.5 Policy Review

2.5.1 Rwanda Agriculture Policies and Strategies

Since agriculture plays a large role in the economy of Rwanda, some strategies have been put in place for reinforcement. Agricultural policies and strategies have been integrated into the national development planning process anchored on the vision

2020. The Economic Development and Poverty Reduction Strategy (EDPRS), as continuation of Poverty Reduction strategy Paper (PRSP1, 2002) sets targets for agricultural sector, but some of these targets seem to be to challenging even after the end of the first phase of the Strategic Plan for Agricultural Transformation (SPAT1, 2002-2008).

Table 2.7: Some EDPRS Targets for Agriculture

Target			**Baseline (2006)**		**Target (2012)**	
			2%		7%	
Marshland reclaimed Credit to the agriculture sector for			11,000		20,000	
agricultural used (ha)						
% of farming households using			12% (chemical)		25% (chemical)	
Improved methods (fertilizer)			7% (organic)		25% (organic)	
Output of key food security and			Maize 91,813		Maize 125,000	
export crops			Rice 62,932		Rice 81,800	
			Wheat 19,549		Wheat 30,000	
			Tea 73,008		Tea 94.900	
Are under irrigation			15,000		24,000	
Use of improved seeds			24%		37%	

Source:EDPRS,2007

So far, the key policy initiative has been the four-year Strategic Plan for Agricultural Transformation (SPAT1), adopted in 2004 and which ran from 2005-2008, SPT1 had four interrelated programs, intensification and development of sustainable production system, Support for Building producers Capacities, Promotion of “commodity chains” and development of agri-business, Institutional development.

2.5.2 Institutional Development

The Strategic Plan for Agricultural Transformation (SPAT1) assigned an important role to MINAGRI and its stakeholders of promoting a regulatory framework this saw a number of laws have being adopted (animal health, fishing and fins farming). Others are yet to be adopted including seed, plant health, agro chemical, reforms and institutional support to public services plus extension services to farmers. Coordination, monitoring and evaluation of the agricultural sector which targeted Restructuring of MINAGRI and its Agencies: Rwanda Agriculture Board.

By setting rice as a priority crop, the government of Rwanda has sensitized the importance of the development of rice sector amongst farmers, local administrative authorities, research and developmental agencies in the country, non-governmental organizations and developmental partners. The government has helped farmers set up rice cooperatives in all rice production areas. The government treats cooperatives as ‘delivery nodes’ of various inputs and services meant for the development of rice sector. Although the government has put extension workers in place to deliver the technical guidance to farmers, the network of extension services is insufficient and does not provide a strong linkage with farmers.

To increase the efficiency of reaching out to the farmers, the government provides the technical and financial provisions also to the local district authorities and non-governmental organizations. Rwanda Institut des Sciences Agronomiques du Rwanda (ISAR) is responsible for introducing and promoting technologies on rice production and post harvest processing amongst rice growers. The research functions are largely carried out by a specialized rice unit of Rwanda Agricultural Board (RAB) through various regional and international collaborations (Karthiresan, 2010). According to investigations conducted in 2001-2002 by the West African Rice

Development Association (WARDA) and the *Institut des Sciences Agronomiques du Rwanda* (ISAR), there were numerous cooperatives, producing on a total of 5,500 hectares of marshlands throughout the country (Promar Consulting , 2012, p. 57). In 2009, people engaged in rice cultivation were 44,907. Farmers belonged to a total of 60 cooperatives, distributed within 29 rice schemes country-wide {Western (2), Southern (12), Eastern (13), and Kigali City (2)}9. Each cooperative covers rice farmers in a watershed (MINAGRI, 2013).

At the national level, the monitoring and evaluation of developments in the rice sector is carried out by Ministry of Agriculture and Animal Resources (MINAGRI). MINAGRI is responsible for streamlining external and internal budgets for the rice sector. Through its four main programs, MINAGRI coordinates and implements various activities within the rice sector. Crop Intensification Program (CIP) is a flagship program of MINAGRI that focuses on the intensification of rice crop. CIP aims to significantly increase total production of rice in the country by raising productivity in small holder farms. It intends to accomplish this goal by facilitating access to inputs (seeds and fertilizers), consolidation of land use, proximity extension services and post harvest handling and storage.

In general, the initiatives of the MINAGRI on development of rice sub-sector and that of the various national economic development and poverty reduction strategies are consistent with NRDS. The activities and targets stated under NRDS are also in agreement with major development orientations envisaged at the national and international level (Karthiresan, 2010).

2.5.3 Crop Intensification Program (CIP)

This program focuses on soil protection and conservation as well as modern breeding methods for increase livestock production as crucial factors to agricultural transformation. In line with Crop Intensification Program (CIP) which started in 2007 increased the use of inputs for priority crops i.e. fertilizer and improved seeds and promoted land consolidation as a part of the green revolution. Irrigation master plan under scrutiny; soil erosion control; marshland development program (more land being reclaimed for cultivation),animal breeding and nutrition strategies being reviewed; one cow program distributing heifers to poor households (target is 668,763 heifers by 2017),food security strategy led to a significant increase in production of main food security crops under the crop intensification program.

2.5.4 Support for Building Capacity of Producers

The aim is to reinforce the capacity of farmers as a priority for turning traditional agriculture into a market-oriented and revenue generating activity. This program focused on, agriculture extension strategy for enhancing professionalism to farmers is in place. Training of farmers in horticulture (mainly sericulture) RARDA (Artificial insemination, bee keeping) and coffee (coffee processing) have been some of the key achievements of the SPAT1. ‘’ Agasozi ndatwa’’ as pilot and sensitization tool, helped farmers to professionalize their practices, while income generation programs such as HIMO, RSSP played a key role in diversification of income generating activities.

2.5.5 Promotion of “Commodity Chains “and Development of Agribusiness

The main objective of this program was to increase the competitiveness of agricultural sector through commodity diversification and infrastructure development. This program includes horticulture strategy aiming at generating 20M USD by 2010 as well as diversification of cash crops under horticulture (Patchouli, Geranium, Sericulture …) are some of the achievements. Another issue was transform the competitiveness of agricultural products by improving quality, example rice, coffee, tea strategies, construction of rearing houses, pack houses and cold rooms was necessary for creation of a conducive business environment and enterprise promotion (Rwanda ranked 239 in 2009 compared to 148 in 2008).

2.6 Conceptual Framework

In Kirehe like elsewhere in Rwanda, there is an enormous political support towards a rapid increase rice production. The reasons forwarded by government for prioritizing rice production in Rwanda are that rice will:

i. Offer an efficient utilization of the abundant natural resource (marshlands);
ii. Increased employment of the abundant labor force;
iii. Improve incomes to stakeholders in the rice sub sector;
iv. Provide sustainable food security;
v. Improve the balance of trade position through exporting rather than importing rice (Jagwe, Okoboi, Hakizimana, Tuyisinge, & Rucibigango, 2003)

KWAMP project is a project developed in the second phase of the PAPSTA Project throughout the Kirehe District, located in the Eastern Province. Like PAPSTA which focused among other things to watersheds protection and crop production in wetlands and lasted through 2013, KWAMP aimed at serving as an adjusted and enhanced duplication of PAPSTA. The KWAMP Project is projected to last for a period of seven years (late 2008-2016) (Derrahi, 2014). Under the KWAMP Project (KWAMP), 500 ha for rice cultivation have been included into the 28,000 ha concerned by various activities of the projects (Bockel & Touchemoulin, 2011).

In 2008, Kirehe overwhelming majority of people were rural. Just over 86% of households owned less than 1.0 ha of land; 46% owned less than 0.5 ha and nearly 13% owned no land at all. Some 70-90% of households faced periods of food shortages every year (IFAD , 2008). Thus, the grouping into rice cultivation schemes via rice cooperatives gave to poorer opportunity to access marshlands to grow rice on. Kirehe district has benefited from KWAMP project which managed to avail 500 ha for rice cultivation (Bockel & Touchemoulin, 2011), this allowed to reach the performance of rice productivity of 5,694 Kg/ha in 2013 and that of 2% of crop share in total harvested areas (MINAGRI, 2013).

Overall, the PAPSTA and the KWAMP Projects aim to improve the long-term food and nutrition security of the rural poor in the districts in question. More specifically speaking, the PAPSTA and KWAMP Projects seek to: (1) gradually increase agricultural incomes as well as income from related economic activities; (2) improve the marketing of agricultural and livestock products; (3) establish and maintain irrigation infrastructure available to a huge number of poor people and landless farmers in the project area; (4) ensure sustained improvement in management of natural resource in the selected watersheds (Derrahi, 2014). From the above theoretical framework, a conceptual framework has been drawn:

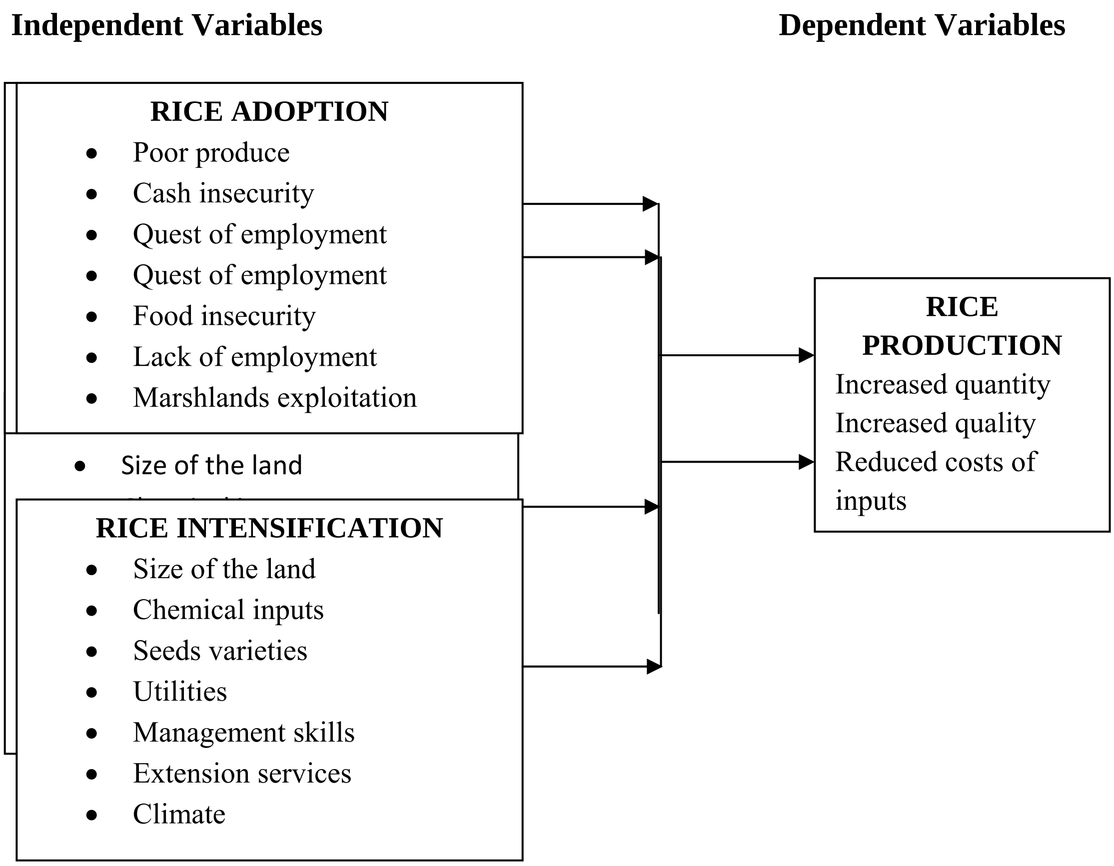

Figure 2.1: Conceptual Framework

Source: Research Findings, 2018

From the above conceptual framework, there are concepts/variables that explain the adoption, intensification and production of rice in Kirehe District. These are lack of land, food security, lack of employment, and opportunities for the exploitation of marshlands for adoption. There are also factors for intensification of rice in Kirehe District. These are size of land, chemical inputs, seeds varieties, utilities, management skills, extension services, and climate. There are also factors influencing rice productivity in terms of increased farm yield and these factors are labor and capital. It is in this framework that this study has been conducted.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Description of Study Area, Kirehe District

Kirehe is one of the 30 districts that make up the Republic of Rwanda. It is also one of the seven districts that compose Eastern Province (MINALOC, 2007).

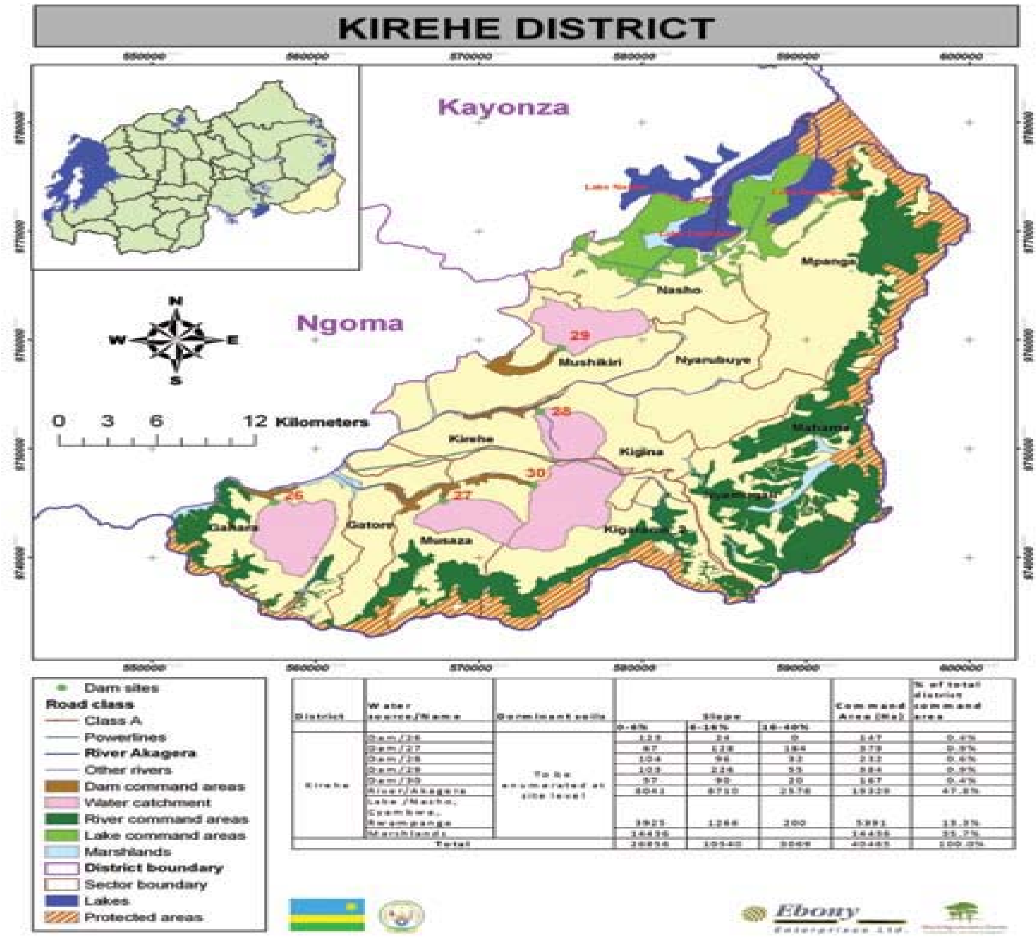

Figure 3.1: A Map of Rwanda Showing the Location of Kirehe District

Source: (Bockel & Touchemoulin, 2011)

This district covers an area of 1,118.6 sq kilometers, it counts 12 administrative sectors (Gahara, Gatore, Kigarama, Kigina, Kirehe, Mahama, Mpanga, Musaza, Mushikiri, Nasho, Nyamugari, Nyamabuye , and Nyarubuye). These administrative sectors have 60 administrative cells (MINICOM , 2012). Biophysically, Kirehe District, in the South-East of Rwanda, as shown on the map 1, the district is located on two of the three main altitudinal regions of Rwanda: the lowlands (1000-1500m) and the middle altitudes of the central plateau (1500-2000m).

The average climate is a tropical temperate climate, with average temperatures of 20-21°C on the plateau and more than 21°C in the lowlands. The north of the district is drier than the south, with an average rainfall precipitation of less than 900mm compared to 900-1100mm. As a result, the climate of Kirehe is between tropical montane dry in the north and tropical montane moist in the south (Bockel & Touchemoulin, 2011). On the point of view of its Potential of Irrigation Areas (PIAs), The PIAs for Kirehe district are in dam, river, lake and marshland domains with a total command area of 40 465 ha and irrigation water demand of 303.5 Mm^3 (Derrahi, 2014).

3.2 Research Philosophy

Research philosophy tries to comprehend lived experience or concrete action and is concerned with an inquiry that begins from given experience or body of knowledge and seeks the intelligible conditions of its possibility (Singh, 2006). The philosophy for this research is post-positivism (post-modernism) arguing that one can make reasonable inferences about a phenomenon by combining empirical observations with logical reasoning (Bhattacherjee, 2012). This perspective gives to this study a quantitative approach. This study has gathered empirical observations which have been analysed through statistical tools.

3.3 Research Design

A design of research is developed for collection of data or evidences for testing the hypotheses. It involves method, sample and techniques of research (Singh, 2006). Research design is a comprehensive plan for data collection in an empirical research project (Bhattacherjee, 2012). The study employed descriptive cross-sectional study design. Therefore, this study is descriptive in nature, and used statistical parameters to show adoption and intensification of rice in Kirehe District.

3.4 Study Population, Sample Size and Sampling Procedure

3.4.1 Study Population

A population is a set of all elements of interest in a particular study (Anderson, Sweeney, & Williams, 2002). The target population in this study is interesting in is composed of rice farmers members of COPRIKI in Kirehe District. Rice farmers are regrouped into the COPRIKI, an abbreviation for French name "Coopérative des Producteurs du Riz de Kirehe" or Cooperative of rice farmers in Kirehe District. The number of COPRIKI farmers in Kirehe district was about 4,062 farmers.

3.4.2 Sample Size

Sampling size in fact means the joint procedure of selection and estimation minimizing error of estimation (Singh, 2006). This study used both probability and non-probability for selecting samples. Sample size is determined by two broad categories of techniques: probability (random) sampling and non-probability sampling. Probability sampling is ideal if generalizability of results is important for your study (Bhattacherjee, 2012, p. 65) . To estimate closely how the sample approximates the population two parameters are necessary: margin of error and confidence interval. The margin of error indicates the range of values that can result in error when you use a sample to estimate the population.

The risk of being wrong within the margin of error is known as confidence level (Anderson, Sweeney, & Williams, 2002). The confidence interval comprising estimate mean of the population being studied (Anderson, Sweeney, & Williams, 2002). The sample size for an interval estimate of a population is given by the following formula (Anderson, Sweeney, & Williams, 2002):

$n_0 = \frac{z^2 \times pq}{e^2}$, -- (1)

where:

n_0 = Sample size.

z = Abscissa of normal curve (Anderson, Sweeney, & Williams, 2002) that cuts off an area α at the tails.

e = Acceptable sampling error.

p = Estimated proportion of an attribute (Rubin & Babbie, 2008) that is present in the population.

q = is 1 – p -- (2)

When the researcher doesn't know the proportion of studied variable, it is recommendable to use p = 0.5 and the product of p (1-p) cannot be bigger than 0.25,which is the maximum estimate of variance (Naiman, Rsenfeld, & Zirkel, 1996). The researcher used the commonly used confidence interval in social research which is 95% and chose the maximum estimate of variance. Value for selected alpha level being 0.25 in each tail = 1.96 when interval confidence is 95%, the pq =

maximum estimate of variance = 0.25. While conducting this research, the researcher bore in mind the production of precise information about the estimate parameters (Anderson, Sweeney, & Williams, 2002), hence the minimization of margin of error held his great attention. He decided to minimize margin of error below 5%. It is reason why he chose to tolerate a margin of error of 4.5% (or 0.045). Then, the computed representative sample became $n_0 = \frac{(1.96)^2 \times (0.5)(0.5)}{(0.045)^2} = 474.27.$ since the calculation indicates the minimum of sample size required, 474.27 has been rounded to 475. The study used the sample of 492 respondents, a bit more than the calculated sample.

3.4.3 Sampling Procedure

3.4.3.1 Cluster Sampling

Cluster sampling occurs when the researcher faces a population dispersed over a wide geographic region. In such case, it may be reasonable to divide the population into "clusters", usually along geographic boundaries, randomly sample a few clusters, and measure all units within that cluster (Bhattacherjee, 2012). As aforementioned, the target population was the all farmers' members of COPRIKI, say 4,062. The researcher proceeded to cluster sampling the targeted 492 farmers using random sampling within the cluster.

3.5 Data Collection Methods

3.5.1 Survey Questionnaire

The questionnaire was used to collect data on rice adoption, rice intensification and rice productivity. The questions that were used are shown in the questionnaires and were used for the measurement of factors of adoption, factors of intensification and productivity factors. Most questions were closed ended. This way of questioning allowed avoiding the vague responses useless to the objectives of the study. A group of people who can read; understand and respond unassisted received questionnaires which were self administered. However, those who have trouble responding because of not knowing writing had questionnaires to be assisted by their neighbors.

3.6 Data Analysis Methods

Data were analyzed using quantitative methods. Data analysis was conducted according to objectives and hypothesis of the study. Some demographic data were analyzed using descriptive analysis methods whereby frequencies, means and crosstabs were used.

3.6.1 Data Analysis Methods for Objective and Hypothesis on Adoption Factors

Data obtained on adoption factors were analysed using logistic regression model. Logistic regression has been adopted as appropriate analytical tool, since it is a mathematical modeling approach that can be used to describe the relationship of several explanatory variables to a dichotomous dependent variable. Logistic regression is by far the most popular modeling procedure used to analyze data when the measure is dichotomous (Kleinbaum & Klein, 2010). The logistic regression model was used to analyze the contribution of individual factors to the productivity of the rice in the study area. Logistic regression model has been chosen to assess the likelihood of factors to predict the adoption or intensification. This model is going to analyze how each factor is contributing to the adoption and intensification if it contributes positively or negatively.

Logit Regression is used to capture the dependency of the dependent variable (Y_i) on independent variable (X_i). The dependent variable Y_i is taken as a function when there are several explanatory variables

$Y_i = \alpha + \beta X_i + \varepsilon_i$ --- (3)

Where : Y_i = The binary dependent variable

α = The Y_i intercept

β = The Slope

X_i = The independent variable

ε_i = The random error

If $E(Y_i) = \alpha + \beta X_i = \Pi_i$ --- (4)

is the expected value of Y_i, and Y_i can take only the value of 0 and 1 (binary) while the error (ε_i) is dichotomous (not normally distributed)

If $Y_i = 1$ which occur with the probability Π_i

$1 = E(Y_i) + \varepsilon_i$ -- (5)

$\varepsilon_i = 1 - E(Y_i)$ -- (6)

$= 1 - (\alpha + \beta X_i)$ --- (7)

$= 1 - \Pi_i$ --- (8)

Alternatively if $Y_i = 0$ which occur with the probability Π_i

$0 = E(Y_i) + \varepsilon_i$ -- (9)

$\varepsilon_i = 0 - E(Y_i)$ -- (10)

$= 0 - (\alpha + \beta X_i)$ -- (11)

$= 0 - \Pi_i$ -- (12)

$= -\Pi_i$ --- (13)

The dependence of Y_i on X_i for the Expected value of Y_i ==> $E(Y_i)$ is given by:

$$E(Y_i) = Odd = \Pi(Y/X) = \frac{\text{Probability of the event}}{1 - \text{Probability of the event}} = \frac{\Pi_i}{1 - \Pi_i} = e^{(\alpha + \beta_1 X_1 + \beta_2 X_2 + \dots \beta_k X_k)}$$

--- 14)

In this study:

Y: Dependent variable adoption was used as 1= adopted rice and 0=not adopted rice

α, β: Population regression coefficients to be estimated from the data

X_1: Shift from poor produce – labeled Shift_Prod,

X_2: Cash insecurity – labeled Cash_Insec,

X_3: Quest for intensive farm employment – labeled Quest_Empl

X_4: Marshlands exploitation opportunities – labeled Marsh_Expl,

X_5: Farm credit schemes – labeled Farm_Credit,

X_6: Regroup into cooperatives – labeled Regr_Coop.

$$Logit\ E(Y_i) = Logit\ \Pi_i(Y/X) = \ln \frac{\Pi_i}{1 - \Pi_i} = \alpha + \beta_1 X_1 + \beta_2 X_2 + \dots\dots + \beta_k X_k$$

-- (15)

In this study:

Logit E (Yi) = α + β1 Shift from poor produce + β2 Cash insecurity + β3 Quest from intensive farm employment + β4 Marshlands exploitation opportunities + β5 Farm credit schemes + β6 Regroup into cooperatives

3.6.2 Data Analysis Methods for Objective and Hypothesis on Intensification Factors

The raw data collected from the survey was used as data for Factor Analysis and after the extraction procedures; the results have been tabulated. There are three main stages for conducting principle component analysis (PCA). These stages consist in data preparation, observed correlation matrix, statistics to assess suitability of dataset of PCA, factor extraction, factor rotation, factor name attribution, and factor score interpretation. To inquire into quintessential factors for rice adoption in Kirehe District six questions/factors have been used. Among those factors three are linked to get out from chronic poverty (Shift from poor produce – labeled Shift_Prod, Cater for cash insecurity – labeled Cash_Insec, Quest for intensive farm employment – labeled Quest_Empl) and three others are related to government's policies incentives (Marshlands exploitation opportunities – labeled Marsh_Expl, Farm credit schemes – labeled Farm_Credit, Regroup into cooperatives – labeled Regr_Coop).

Survey has been conducted among rice farmers in Kirehe District. 492 farmers were targeted. The information obtained through the completed survey served as the data for analysis. The data were used as an input for PCA. The spread worksheet is provided on the appendix 5 of this study. The Principal Component Analysis (PCA) was applied to prepare these strata. This is a form of factor analysis used to reduce a large number of variables into few ones (Mwageni et. al., 2005). The formula that was applied to construct household socio-economic values as suggested by Filmer and Pritchett, (1998) as follows:

$$Aj=f1 \times (a_{ji}-a_1)/(s_1+\ldots+f_N \times (fa_{jN} - a_N)/ (s_N) \text{ -------------------------------- } (16)$$

Where:

f= factor scoring weights for each variable

Aji= number of specific item the household owns

S_N=standard deviation of each variable

a_1=mean value of each item

Factor analysis has been adopted as appropriate analytical tool for this objective, since it is a mathematical modeling approach that can be used to describe the relationship of several explanatory variables to a dichotomous dependent variable (Kleinbaum & Klein, 2010).

3.6.3 Data analysis Methods for Objective and Hypothesis on Production Factors

The Cobb-Douglas production function was used to assess production. This is a widely utilized methodology for evaluating production. The Cobb-Douglas production function is defined as:

$Q = A L^{\beta} K^{\alpha}$ -- (17)

$\text{Log } Q = \log A + \beta \log L + \alpha \log K$ -- (18)

Where

Q = total production (the real value of all goods produced in a year or 365.25 days)

L = labor input (the total number of person-hours worked in a year or 365.25 days)

K = capital input (the real value of all machinery, equipment, and buildings)

Definition of buildings need clarification. In the context of Capital, buildings include labor. Instead, commodities should be added.

A = total factor productivity and your usual depreciation by utility in day after

α and β are the output elasticities of capital and labor, respectively. These values are constants determined by available technology.

In this study:

Q = Respondents' Annual Product of rice in tones

L = Number of people in the household

K = Total number of assets the respondents held in Rwandan Francs (RWF) where K involved the land, machinery, animals.

Output elasticity measures the responsiveness of output to a change in levels of either labor or capital used in production, ceteris paribus. For example, if $\alpha = 0.45$, a 1% increase in capital usage would lead to approximately a 0.45% increase in output.

CHAPTER FOUR

RESEARCH FINDINGS AND DISCUSSIONS

4.1 Chapter Overview

This chapter provides the discussion of the analysis of the results from the software. It has a link with chapter two which was concerned by literature review closed related to rice adoption, rice intensification in Rwanda, especially in Kirehe district. Chapter three described the methodology used to support the research. Chapter five provides discussion about the research findings and chapter six provided conclusion and recommendation of the study. This study showed that there have been some factors that have influenced the adoption of rice and others factors that have favored the intensification and production of rice in the Kirehe district.

4.2 Respondents Demographic Characteristics

The sample demographics varied from respondents characteristics. The profiles of respondents are explored in this section as part of assessment of the data. As this research used survey interview, response error (Highman, 1986) was not an issue as the research has control over how it was completed. Four characteristics have been considered in the framework of this study: gender, age, education, and size of farm. The variable gender has been considered a research to assess the proportions of male and female members of rice farming cooperatives.

The variable age has also interested the researcher when conducting this research. Age is an important variable in any social research. Age goes with physical growth and a number of social experiences. The researcher resorted to this variable to see different opinions from surveyed people according to their respective experiences.

The categorization of respondents according to their level of education falls into four categories: illiterate, primary school level, secondary school level, and university or higher institution level. The choice of this indicator served to analyze underlying motivational factors leading to farming activities. Finally, regarding size of farms, it is known that most of Rwandan agriculture is composed of small size farm holdings. This research has sought to investigate about the issue in order generate in-depth information on the perspectives of farming activities in Rwanda.

Table 4.1: Socio-Demographic Characteristics of Respondents

Characteristic	Attributes	Frequency	Percentage
Sex	Male	285	58.0
	Female	207	42.0
Age	Over twenty five	187	38.0
	Under twenty five	305	62.0
Level of Education	Primary school	197	40.0
	Read and write	138	28.0
	Secondary School	118	24.0
	University	39	8.0
Farm Size	Between half and One	187	38.0
	Between one and two	39	8.0
	Under half hectare	266	54.0
Total Sample Size		492	100

Source*:* Primary Data, 2016

Table 10 shows that the sample was mostly composed up by females 58% against 42% of males. This is true since the majority of Rwanda's people engaged in agriculture is reported to be mostly that of women. It also shows that people under 25 years old constituted the quintessence of surveyed people with 62% whereas the people aged over 25 years accounted for 38%. This also is a reality since the youth constitute 53% of all people according to the third integrated households living conditions survey. Other notable aspects is the fact that people who can read and write and who have primary school level constitute the considerable majority with 62%, those who has secondary schools account for 24% and the rest, University or High Institutions amounts for 8%. This translates to the fact that, farming is almost practiced by low-level educated people. Finally, concerning the possession of land, the majority, 54% possess land which is less or equal to a half hectare, those who possess a land ranging between half hectare and one hectare amount for 38% and the rest, i.e 8% is made up by people whose land possession exceeds one hectare.

4.3 Findings on Rice Adoption Factors in Kirehe District

The logistic regression model was used to assess the likelihood of the adoption being related to factors such as shift from poor produce, farm credit schemes, Marshlands exploitation opposition, lack of employment, food insecurity, and regrouping into cooperative. The procedure involved coding variables into categories.

Table 4.2: Categorical Variables Codings

		Frequency	Parameter coding
			(1)
Regroup into cooperatives	No	186	.000
	Yes	306	1.000
Food insecurity	No	205	.000
	Yes	287	1.000
Lack of employment	No	143	.000
	Yes	349	1.000
Marshlands exploitation	No	184	.000
	Yes	308	1.000
Farm credit schemes	No	152	.000
	Yes	340	1.000
Shift from poor produce	No	131	.000
	Yes	361	1.000

Source*:* Primary Data, 2016

Variables were given binary codes referring to the presence or absence. SPSS helped to record variables and data. Then data analysis was conducted using binary logistic regression where adoption was taken as dependent variable and other variables were taken as independent variables. The findings given in the output document of the SPSS are hereby presented in figure 4.2. Categories chosen included shift from poor produce, farm credit schemes, marshlands exploitation opposition, lack of employment, food insecurity, regrouping into cooperatives. All these variables were also coded using No = 0 and Yes = 1.

Table 4.3: Variables in the Equation

		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 0	Constant	.345	.092	14.200	1	.000	1.412

Source*:* Primary Data, 2016

Table 4.4 Variables not in the Equation

			Score	Df	Sig.
Step 0	Variables	Shift(1)	97.459	1	.000
		Food(1)	260.781	1	.000
		Employment(1)	88.610	1	.000
		Marshlands(1)	320.827	1	.000
		Farm(1)	69.111	1	.000
		coop(1)	348.207	1	.000
	Overall Statistics		356.716	6	.000

Source*:* Primary Data, 2016

The Table of variables in the Equation gives us information about the contribution of each of our predictor variables. The test that is used here is known as the Wald test. The significance level is supposed to be below 0.05. In this test, all the independent variables are significant since their values are less than 0.05.

Table 4.5: Omnibus Tests of Model Coefficients

		Chi-square	Df	Sig.
Step 1	Step	423.800	6	.000
	Block	423.800	6	.000
	Model	423.800	6	.000

Source*:* Primary Data, 2016

The Omnibus Tests of Model Coefficients gives us an overall indication of how well the model performs. This is the goodness of fit test.

Table 4.6: Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	243.845[a]	.577	.778

a. Estimation terminated at iteration number 6 because parameter estimates changed by less than .001.

Source*:* Primary Data, 2016

This table of model summary refers to the usefulness of the model. The Cox & Snell R square and the Nagelkerke R Square provide information on the amount of variation in the dependent variable explained by the model. The two values of 0.577 and 0.778 mean that between 57 and 0.778 per cent are explained by the variability of this variable.

Table 4.7: Hosmer and Lemeshow Test

Step	Chi-square	Df	Sig.
1	13.297	4	.010

Source*:* Primary Data, 2016

The table of Hosmer and Lemeshow Test shows another way of testing model fitness. In this test of model fitness, poor fit is indicated by the value below 0.05 while the good fit is above 0.05. The model is good fit since the significance level is 1.000 which is above 0.05, therefore the model fits very well.

Table 4.8: Classification Table[a]

			Predicted		
			Adoption		
	Observed		No	Yes	Percentage Correct
Step 1	Adoption	No	178	26	87.3
		Yes	10	278	96.5
	Overall Percentage				92.7
a. The cut value is .500					

Source*:* Primary Data, 2016

This Classification Table is used to compare with the other classification table in block 0 to observe changes brought about by the predictors.

Table 4.9: Contingency Table for Hosmer and Lemeshow Test

		Adoption = No		Adoption = Yes		Total
		Observed	Expected	Observed	Expected	
Step 1	1	5	5.900	1	.100	6
	2	87	86.394	2	2.606	89
	3	63	61.327	1	2.673	64
	4	24	26.835	17	14.165	41
	5	5	8.162	50	46.838	55
	6	20	15.382	217	221.618	237

Source*:* Primary Data, 2016

Finally, this table called variables in the Equation gives information on the contribution or importance of each predictor variable. The value of each predictor is considered significant by looking at the Wald test. In this table three variables contribute most in the equation. These variables are: food insecurity with coefficient equals 1.212 and sig. equals to 0.004, marshland exploitation with coefficient equals to 1.522 and sig. equals to 0.003 and grouping into cooperatives with coefficient equals to 3.027 and sig. equals 0.000.

Table 4.10: Variables in the Equation

		B	S.E.	Wald	Df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 1[a]	Shift(1)	.744	1.167	.406	1	.524	2.103	.214	20.698
	Food(1)	1.212	.442	7.537	1	.004	3.362	1.415	7.990
	Employment(1)	.994	.720	1.905	1	.168	2.703	.659	11.093
	Marshlands(1)	1.522	.578	6.925	1	.003	4.580	1.475	14.224
	Farm(1)	-1.370	.963	2.025	1	.155	.254	.039	1.677
	coop(1)	3.017	.607	24.736	1	.000	20.422	6.220	67.046
	Constant	-3.501	.448	61.066	1	.000	.030		

a. Variable(s) entered on step 1: Shift, Food, Employment, Marshlands, Farm, coop.

Source*:* Primary Data, 2016

From the logistic regression model conducted, it can be concluded that three factors are more likely to influence the rice farming adoption, these factors are food insecurity, marshland exploitation and grouping into cooperatives

The logistic model equation can be written as follow:

Logit (*Adoption*) = -3.501 + 3.017 *Cooperatives* + 1.522 *Marshland exploitation* +1.2 *Food insecurity* -- (18)

The interpretation of this relationship shows that there is 30% contribution of cooperatives to adoption process. Also there is 15% contribution of Marshland exploitation on adoption and 12% contribution of food insecurity to adoption process. There is also the margin of error.

4.4 Factors for Rice Intensification

A survey was conducted for 492 rice farmers in Kirehe District. The data obtained were used as an input for Principle Component Analysis (PCA. The spread worksheet is provided on appendix 5 of this study. Where are these steps? If any then the steps are supposed to be listed in the research methodology chapter.

Table 4.11: Factor Analysis Correlation Matrix for Rice Intensification

		Chem_Inp	**Seeds_Var**	**Labor**	**Size_Land**	**Climate**	**Utilities**	**Pers_Skills**	**Extens_Serv**	**ccess_Credit**
orrelation	hem_Inp	1.000	.124	.050	.096	.201	.002	.377	.130	.151
	eeds_Var	.124	1.000	-.030	.009	.146	.113	.106	.049	-.023
	abor	.050	-.030	1.000	-.091	.074	.064	.057	.008	.041
	ize_Land	.096	.009	-.091	1.000	-.018	.029	-.008	.108	.036
	limate	.201	.146	.074	-.018	1.000	-.002	.050	.109	.038
	tilities	.002	.113	.064	.029	-.002	1.000	-.022	.108	.063
	ers_Skills	.377	.106	.057	-.008	.050	-.022	1.000	-.007	.153
	xtens_Serv	.130	.049	.008	.108	.109	.108	-.007	1.000	.004
	ccess_Credit	.151	-.023	.041	.036	.038	.063	.153	.004	1.000
ig. (1-tailed)	hem_Inp		.003	.135	.017	.000	.481	.000	.002	.000
	eeds_Var	.003		.254	.422	.001	.006	.009	.138	.306
	abor	.135	.254		.022	.051	.077	.103	.432	.183

	ize_Land	.017	.422	.022		.344	.260	.429	.008	.211
	limate	.000	.001	.051	.344		.484	.133	.008	.198
	tilities	.481	.006	.077	.260	.484		.314	.008	.080
	ers_Skills	.000	.009	.103	.429	.133	.314		.437	.000
	xtens_Serv	.002	.138	.432	.008	.008	.008	.437		.464
	ccess_Credit	.000	.306	.183	.211	.198	.080	.000	.464	
Determinant = .686										

Source: Primary Data, 2016

For correlation matrix to sub-serve the PCA analysis, the extreme multicollinearity of factors must be prevented. One simple heuristic is that the determinant of R-matrix should be greater 0.0001 (Field, 2009, p. 680). In our case the determinant is 0.686, which is a good condition.

Table 4.12: KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	.551	
Bartlett's Test of Sphericity	Approx. Chi-Square	183.920
	Df	36
	Sig.	.000

Source: Primary Data, 2016

KMO and Bartlett's Test have been applied. Kaiser – Meyer- Olkin measure of sampling adequacy is recommended to be greater than 0.5 (Kaiser, 1974). In our case this measure is 0.551. the KMO's criterion is well met. Bartlett's Test of sphericity should be significant (the value of significance should be less than 0.05) (Field, 2009, p. 660). In our case this value is 0.001, which is significant. The interpretation of output is about descriptive statistics, communalities, eigenvalues and Scree Plot, un-rotated factors loadings, rotation, and naming the factors.

Table 4.13: Descriptive Statistics

Descriptive Statistics			
	Mean	Std. Deviation	Analysis n
Chem_Inp	2.9309	1.51412	492
Seeds_Var	3.2236	1.55903	492
Labor	3.1362	1.39382	492
Size_Land	2.8374	1.45467	492
Climate	2.9797	1.43267	492
Utilities	3.0102	1.48375	492
Pers_Skills	3.0325	1.45501	492
Extens_Serv	3.0447	1.51235	492
Access_Credit	2.7480	1.50000	492

Source: Primary Data, July 2016

From this preceding table it can be seen that statistics simply shows the means, standard deviations and sample size for each variable. It appears that the average score for all the tests is almost similar and all have an almost comparable spread. It is worth recalling that the Lerket scale used looks as follows: 1 = I strongly desagree, 2 = I desagree, 3 = No opinion 4 = I agree, 5 = I strongly agree. The means for seeds varieties, labor, utilities, personal skills predominate the bare minimum = 3. In the contrary, the means for chemical inputs, size of land, climate, access to credit rally opinions laying below the bare minimum = 3. The following table is about communalities.

Table 4.14: Communalities

	Initial	Extraction
Chem_Inp	1.000	.638
Seeds_Var	1.000	.475
Labor	1.000	.589
Size_Land	1.000	.617
Climate	1.000	.473
Utilities	1.000	.621
Pers_Skills	1.000	.607
Extens_Serv	1.000	.458
Access_Credit	1.000	.535
Total		5.013
Average		$\frac{5.013}{9} = 0.557$
Extraction Method: Principal Component Analysis.		

Source*:* Primary Data, 2016

Communalities are the measure of the proportions of variance explained by the extracted factors (Field, 2009, p. 637), that is estimates that part of the variability in each variable that is shared with others, and which is not due to measurement error or latent variable influence on the observed variable. The average of communalities is 0.626625. From the principal factor analysis, the number of factors that needs to be extracted can be found out. Kaiser and the Scree test help with this factor extraction (Kaiser, 1974).

Table 4.15: Total Variance Explained

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.652	18.353	18.353	1.652	18.353	18.353	1.495	16.611	16.611
2	1.188	13.197	31.550	1.188	13.197	31.550	1.227	13.628	30.239
3	1.116	12.397	43.947	1.116	12.397	43.947	1.162	12.916	43.155
4	1.059	11.768	55.714	1.059	11.768	55.714	1.130	12.560	55.714
5	.985	10.944	66.659						
6	.874	9.709	76.368						
7	.833	9.260	85.628						
8	.724	8.048	93.675						
9	.569	6.325	100.000						
Extraction Method: Principal Component Analysis.									

Source*:* Primary Data, 2016

Table 4.15 shows the importance of each variable of the six principal components. Only the first three have eigenvalues over 1.00, and together these explain almost 66%? of the total variability in the data. This leads us to the conclusion that a four factor solution probably fits the rice productivity in Kirehe District. This conclusion is supported by the Scree Plot (which is actually simply displaying the same data visually): We have now carried out, and answered the first part of the question "Conduct a principal component analysis to determine how many important components are present in the data"

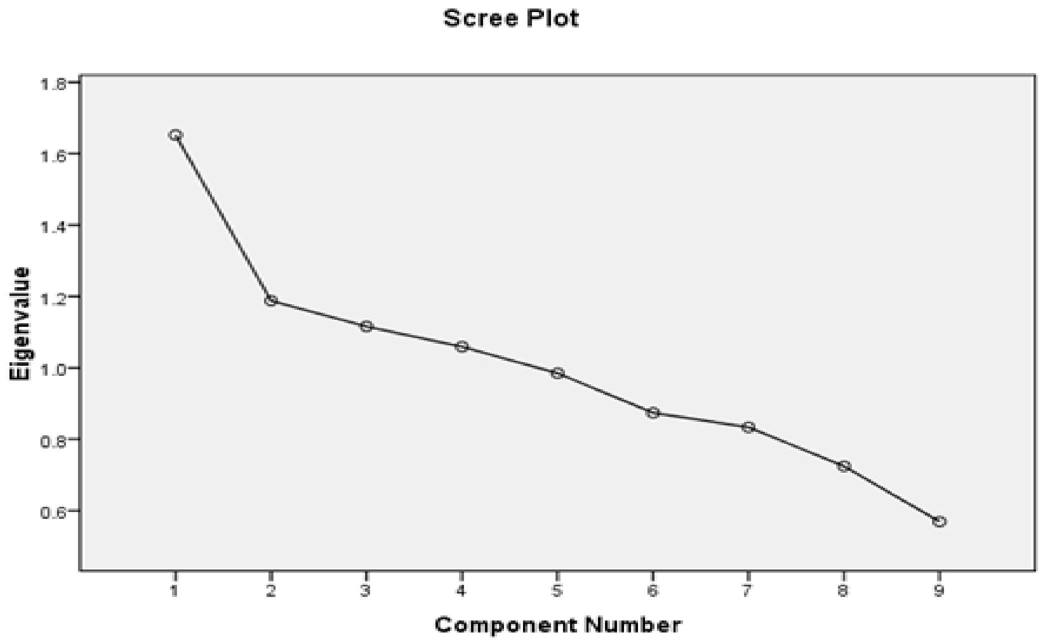

Figure 4.1: Scree plot for Rice Productivity in Kirehe District
Source: Primary Data Output, July 2016

4.4.1 Un-Rotated Factors Loadings

The un-rotated factor loadings show the expected pattern, with positive and negative loadings on the factors:

Table 4.16: Component Matrix for Rice Intensification

Component Matrix[a]				
	Component			
	1	2	3	4
Chem_Inp	**.764**	-.130	-.175	-.082
Seeds_Var	**.383**	**.310**	**.238**	-.420
Labor	**.170**	-.234	**.603**	**.377**
Size_Land	**.152**	**.429**	-.621	**.155**
Climate	**.458**	**.140**	**.338**	-.360
Utilities	**.157**	**.472**	**.328**	**.516**
Pers_Skills	**.633**	-.424	-.162	-.035
Extens_Serv	**.307**	**.591**	-.008	**.123**
Access_Credit	**.375**	-.255	-.179	**.545**
Extraction Method: Principal Component Analysis.				
a. 4 components extracted.				

Source: Primary Data, 2016

It appears that all variables load positively on the first factors and they load both positively and negatively on the second and third factor. The next table shows the extent to which the original correlation matrix can be reproduced from four factors:

Table 4.17: Reproduced Correlations for Rice Intensification

		Chem_Inp	Seeds_Var	Labor	Size_Land	Climate	Utilities	Pers_Skills	Extens_Serv	Access_Credit
Reproduced Correlation	Chem_Inp	.638[a]	.245	.024	.156	.303	-.041	.570	.149	.307
	Seeds_Var	.245	.475[a]	-.022	-.022	.450	.068	.087	.247	-.207
	Labor	.024	-.022	.589[a]	-.391	.113	.308	.096	-.045	.221
	Size_Land	.156	-.022	-.391	.617[a]	-.136	.103	.009	.324	.143
	Climate	.303	.450	.113	-.136	.473[a]	.062	.189	.176	-.121
	Utilities	-.041	.068	.308	.103	.062	.621[a]	-.172	.387	.161
	Pers_Skills	.570	.087	.096	.009	.189	-.172	.607[a]	-.059	.355
	Extens_Serv	.149	.247	-.045	.324	.176	.387	-.059	.458[a]	.033
	Access_Credit	.307	-.207	.221	.143	-.121	.161	.355	.033	.535[a]
Residual[b]	Chem_Inp		-.121	.026	-.060	-.101	.043	-.192	-.018	-.156
	Seeds_Var	-.121		-.008	.031	-.304	.045	.019	-.198	.184
	Labor	.026	-.008		.300	-.039	-.244	-.039	.053	-.180
	Size_Land	-.060	.031	.300		.118	-.074	-.017	-.216	-.107
	Climate	-.101	-.304	-.039	.118		-.064	-.139	-.068	.159
	Utilities	.043	.045	-.244	-.074	-.064		.150	-.280	-.098
	Pers_Skills	-.192	.019	-.039	-.017	-.139	.150		.052	-.202
	Extens_Serv	-.018	-.198	.053	-.216	-.068	-.280	.052		-.029
	Access_Credit	-.156	.184	-.180	-.107	.159	-.098	-.202	-.029	

Extraction Method: Principal Component Analysis.

a. Reproduced communalities

b. Residuals are computed between observed and reproduced correlations.
There are 25 (69.0%) non-redundant residuals with absolute values greater than 0.05.

Source*:* Primary Data, 2016

The small residuals (31%) show that there is very little difference between the reproduced correlations and the correlations actually observed between the variables. On the other hand, the residuals greater that 0.05 (69%) show that there is a noticeable difference between the reproduced correlations and the correlations actually observed between the variables. However, Filed assured that there no hard and fast rules about what proportion of residuals should be below 0.05 (Field, 2009) The four factor solution provides a very accurate summary of the relationships in the data. We have now carried out, and answered the second part of the question "To what extent are the important components able to explain the observed correlations between the variables?"- components not well clarified.

4.4.2 Rotation

The next table shows the factor loadings that result from Varimax rotation:

Table 4.18: Rotated Component Matrix

Rotated Component Matrix				
	Component			
	1	2	3	4
Chem_Inp	.722	.321	.022	.115
Seeds_Var	.027	.681	.093	.045
Labor	.150	-.029	.271	-.702
Size_Land	.149	-.123	.288	.705
Climate	.147	.656	.059	-.133
Utilities	-.059	.007	.770	-.155
Pers_Skills	.746	.126	-.177	-.051
Extens_Serv	.026	.268	.557	.274
Access_Credit	.588	-.354	.241	-.082
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.				
a. Rotation converged in 6 iterations.				

Source*:* Primary Data, 2016

We have now carried out, and answered the third part of the question "Which tests have high loadings on each of the rotated components?" These four rotated factors are just good at rotated component matrix compared to the initial situation in explaining and reproducing the observed correlation matrix. In the rotated factors, chemical inputs, personal skills, access to credit have high positive loadings on the first factor, seeds varieties and climate have high positive loadings on the second factor, utilities and extension services have high loads on the third factor, finally size of land is the only factor displaying high loading on the fourth factor.

Table 4.19 show that the eigenvalues and percentage of variance are explained again. The middle part of the table shows the eigenvalues and percentage of variance explained for just the four factors of the initial solution that are regarded as important. Clearly the first factor of the initial solution is much more important than the rest. However, in the right hand part of the table, the eigenvalues and percentage of variance explained for the three rotated factors are displayed.

Table 4.19: Total Variance Re-Explained for Rice Intensification

Total Variance Explained									
	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.652	18.353	18.353	1.652	18.353	18.353	1.495	16.611	16.611
2	1.188	13.197	31.550	1.188	13.197	31.550	1.227	13.628	30.239
3	1.116	12.397	43.947	1.116	12.397	43.947	1.162	12.916	43.155
4	1.059	11.768	55.714	1.059	11.768	55.714	1.130	12.560	55.714
5	.985	10.944	66.659						
6	.874	9.709	76.368						
7	.833	9.260	85.628						
8	.724	8.048	93.675						
9	.569	6.325	100.000						
Extraction Method: Principal component Analysis.					**55.715**			**55.715**	

Source*:* Primary Data, 2016

Whilst, taken together, the three rotated factors explain just the same amount of variance as the three factors of the initial solution, the division of importance between the three rotated factors is very different. The effect of rotation is to spread the importance more or less equally between the two rotated factors. Note in the above table that the eigenvalues of the rotated factor are 1.495, 1.227, 1.162, and 1.130 , compared to 1.652, 1.188, 1.116, and 1.059 in the initial solution. I hope that this makes it clear how important it is that you extract an appropriate number of factors. If you extract more than are needed, then rotation ensured that the variability explained is more or less evenly distributed between them. If the data are really the product of just four factors, but you extract and rotate five, the resulting solution is not likely to be very informative. The next table gives information about the extent to which the factors have been rotated.

Table 4.20: Component Score Coefficient Matrix

Rotated Component Matrix[a]				
	Component			
	1	2	3	4
Chem_Inp	**.722**	.322	.018	.116
Seeds_Var	.026	**.682**	.088	.045
Labor	.152	-.028	.271	-.701
Size_Land	.149	-.121	.287	**.705**
Climate	.146	**.657**	.055	-.134
Utilities	-.056	.011	**.771**	-.154
Pers_Skills3	**.746**	.126	-.180	-.050
Extens_Serv	.027	.271	**.555**	.274
Access_Credit	**.589**	-.352	.241	-.080
Extraction Method: Principal Component Analysis. Rotation Method: Quartimax with Kaiser Normalization.				
a. Rotation converged in 6 iterations.				

Source*:* Primary Data, 2016

SPSS now produces a decent plot of the six variables on axes representing the three rotated factors. In conclusion, it is reasonable to identify the first rotated factor as "Knowledge –based inputs", as chemical inputs, personal skills inputs, and access to credit have high loadings on it. The second rotated factor can be identified as "Bio-physical inputs", as of seeds varieties and climate have the high loading on it, the third factor “Institutional factors”, as utilities and extension services have high loadings on it. Finally, the fourth factor is Size of land, which has high loading on itself.- the discussion should then based of these derived categories of factors.

4.5 Rice Production in Kirehe District

This study used the Cobb-Douglas Production Function to measure the relationship between inputs and outputs. The study used data collected concerning labor, capital, and outputs. The Excel Program was used to record outputs and inputs. Since labor, capital, and outputs were known, therefore, the Cobb-Douglas production function helped to calculate the coefficient of alpha and beta. These coefficients help to determine the elasticity of the equation. To predict how the change in inputs affect the change in outputs.

The multiple regression analysis was used to calculate alpha and beta. The equation was transformed using the logarithms. The output/Yield (Y) was considered as the dependent variable; and the inputs labor (L) and capital (K) were considered as independent variables. The results given by the multiple regression analysis is shown in table 4.21. Table 4.21 shows the variables entered and these variables were the natural log of capital, natural log of labor, i.e. the independent variables.

Table 4.21: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.620[a]	.385	.382	.16450390
a. Predictors: (Constant), Natural Log of Capital, Natural Log of Labour				

Source: Primary Data, 2016

The table model summary presents the values of R square. The table found that the R square was 0.385 and the adjusted R Square was found to be 0.382 or 38.5% and

38%.

Table 4.22: ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	8.255	2	4.127	152.515	.000[b]
	Residual	13.206	488	.027		
	Total	21.461	490			

a. Dependent Variable: Natural Log of Output
b. Predictors: (Constant), Natural Log of Capital, Natural Log of Labour
Source: Primary Data, 2016

The analysis of variance (ANOVA) table shows that the relationship is significant with sig. less than 0.05, the table shows sig. = 0.000

Table 4.23: Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	-5.970	.398		-14.988	.000
	Natural Log of Labour	.436	.038	.424	11.445	.000
	Natural Log of Capital	.320	.034	.348	9.410	.000

a. Dependent Variable: Natural Log of Output
Source: Primary Data, 2016

The Coefficients table presents the coefficients obtained for alpha and beta. There is significant relationship between the dependent and independent variables since sig. is less than 0.05. Looking at the column B, it shows that the coefficient for alpha is 0.436 and beta is 0.320 and the value of intersect or constant is -5.970

Based on these findings obtained using the Cobb-Douglas function:

$Ln (Y) = -5.970 + 0.436 L + 0.320 K$ -- (18)

$Y = e^{-5.970} * L^{0.436} * K^{0.320}$ --- (19)

This equation shows elasticity in terms of labor and capital. This shows that increase by 0.4 of labor leads to increase of 1 in production; also the equation shows that increase of 0.3 capital leads to increase of 1 in production.

4.6 Discussion of Results

Table 4.24: Discussion of Results

Author & Year	Study Objective(s)	Context/study location	Method	Findings	Recommendations
Mutware, J.S and Burger, K. (2014)	Investigating factors influencing the adoption of improved rice varieties by small scale rice farmers in Rwanda	Households in Six Rice growing marshlands Rwanda	Conditional Logit Model	The maximum likelihood analysis showed that the prices of seeds and of paddy and the yield are variety-specific attributes that significantly influence the farmers' choice of an improved rice variety. Price, farm size, labor availability, access to financial facilities significantly influence farmers' decisions to adopt improved rice varieties	Improve seed supply systems among farmers to increase intensity of use of improved varieties.
Cantore, N. (2011)	Assessing crop intensification program in Rwanda, using sustainability analysis	Protect the soil against erosion frequent in Rwanda	Qualitative interviews and quantitative analysis Linear Regression Model	Soil protection, organic fertilizers, chemical fertilizers, pesticides, traditional seeds, improved seeds, labour, equipment expenditures, hectares of arable land, irrigation rate, education levels	Further research is needed to assess the effectiveness of public investments against soil erosion and to verify the best measures to control erosion in Rwanda. The effort is needed to explore the best actions to decide when, where and how much to spend to promote the right policy measure in the agricultural and all the

					sensible economic sectors in a forward looking 28 perspective.
Raju Ghimire et al,(2012)	Factors affecting adoption of Improvement Rice Varieties among Rural Farm Households in central Nepal	To improve high yielding crop varieties for reducing hunger and food insecurity in development of Nepal	Linear Regression Model	The results showed that technology specific variables (e.g. yield potential and acceptability) are significant for explaining adoption behavior	Planners and decision makers need to consider farmers' preferences on varieties, land-types to be cultivated, and demonstrations at farmers' field to enhance and promote the adoption
Mahabub Hossain et al,(2006)	Adoption and productivity Impact of Modern Rice variety in Bangladesh	Improvement of Varieties in Bangladesh	Production Function /Cob-Douglas	The results showed that some varieties have high yield but low resistance to insects and diseases. Others have low yield, grain quality with resistance to insects and diseases.	To find varieties that have large production, quality grains and are resistant to insects and diseases.
Gasana (2018)	Adoption and Intensification Factors of rice in Rwanda	Introduction of Rice in Rwanda	Production Function/Cob-Douglas	This study showed that there have been some factors that have influenced the adoption of rice and others factors that have favored the intensification and rice production in Rwanda/ Kirehe district.	To improve productivity by not only increasing their capital and labor but also by reducing cost of inputs and by mechanization of agriculture.

Source*:* Primary Data, 2016

All these authors were very interested in the adoption of rice varieties in the different countries. This shows that the intensification comes after having satisfied the adoption of each culture. In his study, Conditional Logit Model, Mutware Recommends the Improvement of Varieties and land size. Two authors, Cantore and Ghimire, used the Linear Regression Model to do their analysis. Ghimire recommend improvement of varieties, erosion control and pesticide use. Hossain in his analysis, Production function (Cob-Douglas) recommended the improvement of varieties and productivity. All these authors have used different econometric analyzes to obtain the results, but only Hossain have used Production Function/Cob-Douglas. This study used also this analyse for production function and recommended to improve productivity.

According to Chinese Scholars Ghimire et al. (2015) the adoption of high yielding crop varieties by farmers helps to improve the income of smallholder farmers in developing countries. In Rwanda most studies conducted on rice adoption have corroborated the findings of this study, especially the fact that the decision of the Government of Rwanda to make marshlands available is a key to rice adoption. According to Stryker, (2010) marshlands are opportunities that must be profitably exploited to produce rice and sell it as a cash crop.

The land reform has a major impact on adoption. Wania et al. (2013) argued that land reform measures such as marshlands liberalization helps to encourage capital formation and generate other necessary factors for improving technology adoption of input-use at the farm. Also MINAGRI (2010) confirmed that rice has emerged as the most suitable crop for marshlands and inland valleys in the recent years. Rice is the only crop that thrives well and produces better yield than any other traditional crops especially during rainy season or when it uses the irrigation schemes. In the same line, Nkurunziza (2015) confirmed these findings by arguing that wetlands have potentials to reduce prevailing rice deficit in the domestic and regional markets.

Different studies have also confirmed that cooperatives played an important role in rice adoption and intensification. Wania et al. (2013) confirmed that cooperatives could benefit individual members by way of providing timely inputs associated with the cultivation and help them to dispose off their surpluses. In the same trend, Nkurikiye (2016) stated cooperatives help in reaching individual farmers in order to get inputs and other elements of value chain of rice.

Farmers borrow inputs from the cooperatives. At the end of season, cooperatives collect grains equivalent of inputs from farmers. It is therefore necessary to strengthen extension services in cooperatives in order to improve farm management practices in cooperatives because there is a big gap in farm operations done in rice production among rice cooperatives and labor is disproportionately spent on production activities across cooperatives. It is shown that farmers' cooperatives have improved the level of horizontal and vertical linkages within the rice subsector (Nkurunziza, 2015).

In the same line, MINAGRI (2010) confirmed the importance of cooperative by stating that cooperatives as energized input delivery points. Since the farmers' co-operatives have close links with individual farmers, the co-operatives are input delivery points for the farmers. Instead of agents for such services, the cooperatives help in delivery at suggested prices. Cooperatives help to enter into a legal agreement whereby bad debts can be settled through local courts, seizure of land holdings for instance.

To show the importance of cooperatives in Rwanda, statistics show that the number of rice farmers in Rwanda was estimated at 94,275 (NISR, 2014). Each of these farmers is a member of one of 95 cooperatives (RAB, 2014). Rice farmers in each rice marshland are integrated into one or more cooperatives, depending on the size of the marshland. In the Eastern Province, rice is produced in over 32 marshlands, under 40 rice farmers' cooperatives (RAB, 2014). The average farm size per cooperative and farmer, across the 31 sampled cooperatives, was 135.3 ha and 0.19 ha, respectively. The farmers' cooperatives not only facilitate farmers' access to inputs and markets, but they also serve as an institutional framework through which the government and its development partners offer different supports to farmers, aimed at increasing farmers' productivity (Nkurunziza, 2015).

The studies on rice intensification refer mainly on system of rice intensification (SRI). These studies explain system of rice intensification as early single transplanting, intermittent irrigation, wide spacing and use of organic nutrients (Ndirangu, 2015). This system of rice intensification is similar to rice intensification methods identified in this study which include knowledge-based inputs, bio-physical inputs, institutional factors, and land size. There are different studies conducted on rice productivity in different areas that help to discuss the findings of this study. In Rwanda, various measures have been taken to improve rice productivity. Nkurikiye Jean Bosco (2016) argued that priority interventions in improving productivity include supplying certified seeds and fertilizers, controlling pests and diseases and improving farm operations, and expanding the capacity of extension system in order to enable efficient transfer of technologies on production, soil and water management, pest and disease management, harvesting, post-harvest handling and storage of rice in marshlands. In short, these interventions concern both labour and capital as demonstrated by the findings of this study.

It was argued that the qualitative competitiveness of local rice production is one of the major constraints meeting the goal of self-sufficiency and reduced rice import in Sub Saharan Africa (Stryker, 2010). This situation corroborates the findings of this study since the quality of rice production highly depend much on labour, as well as capital. Also Wania (2013) confirmed the findings of this study using examples from China by arguing that growing demand for rice in national and international markets has caused huge stress on natural resources, especially land and water. To achieve sustainable resource exploitation, productivity of existing crop land needs to be improved sustainably.

Also Nkurunziza Benjamin (2015) argued that in order to improve domestic rice production capacity and competitiveness, without compromising efficiency, it is imperative for rice farmers to adopt labour saving technologies. This technology adoption would allow for an increase in the area on which rice can be grown efficiently, due to a reduced social production cost. This is in line with the findings of this study since labour and capital improvement contribute to improving productivity. Given the rising demand for rice consumption in Rwanda, the present levels of production and competency of locally produced rice grains, if left unattended, could prove detrimental to the rice sub-sector in the weakening country's economic growth through trade imbalance and loss of revenues on tariff free/less importation of rice grains from other countries, and missing the opportunity for the export potential of Rwanda rice to regional and international markets (MINAGRI, 2010)

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of Findings

The main research objective of this study was to explore adoption and intensification factors of rice production in Kirehe District. This study assessed these factors by using different methodologies including factor analysis, regression analysis and production functions. Principle Component Analysis methodology has been used to explore factors using Factor analysis. This method help to restructure the data specifically by reducing the number of variables; and such an approach is often called "data reduction" or "dimension reduction" technique. What this basically means is that one starts off with a set of variables, and then by the end of the process one has a smaller number but which still reflects a large proportion of the information contained in the original dataset.

The way that the 'information contained' is measured by considering the variability within and co-variation across variables, that is the variance and co-variance (i.e. correlation). Either the reduction might be by discovering that a particular linear compensation of our variables accounts for a large percentage of the total variability in the data or by discovering that several of the variables reflect another 'latent variable'. This process can be used in broadly three ways first to simply discover the linear combinations that reflect the most variation in the data. Second, to discover if the original variables are organized in a particular way reflecting another 'latent variable. Third, to confirm a belief about how the original variables are organized in a particular way.

The study used the logistic regression model to assess the likelihood of different factors to influence adoption of rice in Kirehe District. The factors which were considered included poor produce, cash insecurity, quest of employment, food insecurity, lack of employment, marshlands exploitation opportunities. Findings showed that among them, only three factors grouping into cooperatives, marshland exploitation and food insecurity are most likely to influence rice adoption in Kirehe district in Rwanda.

The intensification of rice has been explored using 9 variables relating to inputs factors (chemical inputs, seeds varieties, and labour); endowment factors (size of land, climate and utilities); institutional inputs (personal skills, extensions services, and access to credit). Using regression analysis, factors that are likely to contribute to intensification of rice production were found to include only: extension services, utilities and seeds varieties. The study also revealed the relationship between inputs and outputs of rice production in Kirehe district.

5.2 Conclusions

5.2.1 Rice Adoption in Rwanda

This study was able to explore factors influencing the likelihood of adopting rice farming In Rwanda, especially in Kirehe District and factors that showed statistically significant likelihood to influence adoption process were cooperatives, marshlands exploitation, and food insecurity. Since most areas in Africa are facing the challenges of food insecurity due to drought, floods, and shrinking arable land, farmers are devising new methods of farming to meet the growing needs for food. The GoR has allowed farmers to exploit marshlands in the region, this decision prompted farmers to find opportunities to plant rice which is more appropriate and suitable to marshland. Farmers had acquired information from other areas about production of rice and its cost benefit advantages. Those who were able to obtain the portion of the land in Marshland were able to organize themselves into cooperatives so that they may produce together and support each other in different ways.

As a results, rice farmers were able to produce a satisfactory quantity of rice that has improved the well being of the farmers and has improved food security in the region. The model used by this study helps to identify factors that have high likelihood of rice adoption. Therefore, it is possible to advance the thesis that the desire of farmers to overcome food insecurity, coupled with Government support to make marshland available to farmers, and the ability of farmers to effectively organize themselves into cooperative to manage well production process are more likely to influence the adoption process in this region and other regions.

5.2.2 Rice Intensification in Rwanda

To boost agricultural production and cater for food insecurity in the region, farmers work hard to find ways of improving their production through intensification process. They use various ways including using different seeds varieties, using chemicals and fertilizers, improving skills, getting credit, labor mechanization, and other practices with the aim of increasing productivity. This study was able to explore factors that have influenced rice intensification in Rwanda, especially in Kirehe district. Starting with many factors, the study was able to reduce them into few factors that are most important in influencing intensification process.

Some factors that influence intensification were based on knowledge and these are chemical inputs, personal skills inputs, others were based on bio-physical inputs, these are seeds varieties and climate, other factors were based on institutional inputs, these are utilities and extension services and finally, there are factors based on size of the land. Therefore, from these categories of factors that influence intensification, the study advances the thesis that farmers require more knowledge and skills, improved bio-physical inputs, more institutional support and more land to intensify rice production in the region.

5.2.3 Rice Productivity in Rwanda

Production process involves inputs and activities that combine inputs in order to generate outputs. This process is also applicable to agriculture where inputs such as land, labour and capital are combined to produce output or yield. Using Cobb-Douglas production function, the study was able to find a relationship that exist between inputs and output in the study area. The degrees of elasticity was also identified.

The production function helped to understand that by increasing labuor and capital, you also increase productivity. It can also be stated that by increasing inputs you also increase outputs. Therefore, given this positive relationship between inputs and outputs, this study advances the thesis that increasing the agricultural inputs such as land, labor and capital, farmers are going to improve rice production. That is why more efforts should be done in providing agricultural inputs in order to improve productivity and alleviate poverty in the area.

5.3 Recommendations

5.3.1 Policy Implications

This study agrees with the findings by Nkurunziza (2015) who argued that in general, the government of Rwanda uses protectionist policies to provide incentives for domestic rice production. These policies consist of farm input subsidization, paddy rice price regulation, and rice import tariffs. On the other hand, the land policy that limits private ownership and usage rights pertaining marshlands has the potential to create disincentives for rice production.

Since protectionist policies limit the freedom of the consumers and reduces competitiveness of local farmers, this study proposes more emphasis on intensification to improve production and adopt open policy that promotes consumer freedom and improved quality of rice produced. Also the institutional policies should target effective delivery of inputs such as seeds, fertilizers, insecticides, irrigation, and farm tools at individual farmer levels.

5.3.2 Policy recommendations

From the conclusions, this study recommends the following:

i. The MINAGRI, Local Government Authorities, agronomists and cooperative leaders should encourage smallholder farmers resembled in cooperative to adopt high yielding rice seeds varieties and technology in order to improve rice productivity and ensure food security and hunger eradication.

ii. The Government of Rwanda and Development Partners should improve capacity of smallholder farmers by increasing their knowledge and skills related to agricultural intensification and transforming agriculture from subsistence to commercial farming in order to increase income for smallholder farmers in the country.

iii. Smallholder farmers in partnership with the Government of Rwanda and other stakeholders should strive to improve productivity by not only increasing their capital and labor but also by reducing cost of inputs and by mechanization of agriculture; this will allow them to produce more at a lower cost and to reach the level of self-sufficiency and generation of surplus for supplying to the market and for export.

5.3.3 Recommendation for Further Studies

The study also suggests the following recommendations for further studies:

i. To examine contribution of human capital development among farmers in terms of capacity building, participation in projects, management skills and marketing skills in production improvement.

ii. To assess challenges facing farmers in accessing capital in terms of bank loans, machineries, ICTs and ways to alleviate these challenges.

iii. To explore research advancement in terms of seeds varieties innovations to assess suitable varieties for given type of land and effects of these varieties in terms of land sustainability and consumers' health.

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APPENDINCES

Appendix 1 : Structured Questionnaire

1. Identification: Names …………………………………………………………

Sex: male ☐

Female ☐

Age: Under 25 years ☐

25 years and beyond ☐

Level of education: Read and write only ☐

Vocational training ☐

Secondary school ☐

University or high institution ☐

Farm size: less or equal 0.5 ha ☐

Between 0.5 – 1 ha ☐

Between 1 ha – 2 ha ☐

2. Do you agree that the adoption of rice in Kirehe District derived from the factors below?(1= disagree very much; 2=disagree ; 3=not sure; 4=agree; 5= agree very much)

Factor	**1**	**2**	**3**	**4**	**5**
Shift from poor produce					
Food insecurity					
Lack of employment					
Marshlands exploitation opportunities					
Farm credit schemes					
Regroup into cooperatives					

3. Do you agree that the productivity of rice in Kirehe District derives from the factors below?

(1= disagree very much; 2=disagree ; 3=not sure; 4=agree; 5= agree very much)

Factor	**1**	**2**	**3**	**4**	**5**
Chemicals inputs					
Seeds varieties					
Labor (hours worked)					
Size of land					
Climate					
Utilities					
Personal management skills					
Extension services					
Access to farm credit					

APPENDIX 2

INTERVIEW SURVEY GUIDE

1. Identification: Names ……………………………………………………………

Sex: male ☐

Female ☐

Age: Under 25 years ☐

25 years and beyond ☐

Level of education: Read and write only ☐

Vocational training ☐

Secondary school ☐

University or high institution ☐

Farm size: less or equal 0.5 ha ☐

Between 0.5 – 1 ha ☐

Between 1 ha – 2 ha ☐

2. Do you agree that the adoption of rice in Kirehe District derived from the factors below?

(1= disagree very much; 2=disagree ; 3=not sure; 4=agree; 5= agree very much)

Factor	**1**	**2**	**3**	**4**	**5**
Shift from poor produce					
Food insecurity					
Lack of employment					
Marshlands exploitation opportunities					
Farm credit schemes					
Regroup into cooperatives					

3. Do you agree that the productivity of rice in Kirehe District derives from the factors below?

(1= disagree very much; 2=disagree ; 3=not sure; 4=agree; 5= agree very much)

Factor	**1**	**2**	**3**	**4**	**5**
Chemicals inputs					
Seeds varieties					
Labor (hours worked)					
Size of land					
Climate					
Utilities					
Personal management skills					
Extension services					
Access to farm credit					

APPENDIX 3

KIREHE DISTRICT

Kirehe is one of the 30 districts that make up the Republic of Rwanda. It is also one of the seven districts that compose Eastern Province (MINALOC, 2007).

Map 5. 1: Map of Rwanda showing the location of Kirehe District

Source: (Bockel & Touchemoulin, 2011)

APPENDIX 4

RICE FARMERS IN FIELD

Smallholder rice farmers preparing rice fields

Source: (Sygenta Foundation , 2012)