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TECHNOLOGY TRANSFER IN RICE CROP IN MOZAMBIQUE: FROM RESEARCH TO FARMERS

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A Dissertation carried out on the PhD in Tropical Knowledge and Management under the supervision of Professor Doctor Fernando Brito Soares and cosupervison of Professor Doctor Alexis Ndayiragije

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ABSTRACT

Adoption and diffusion of agricultural inputs are the stimuli for boosting yields and improve food security and nutrition in households in Mozambique. This study focuses on finding out the rice technology transfer setbacks, investigating rates of adoption and reasons for the low adoption in farmers and proposing measures for effective dissemination. Face-face interviews and semi - structure questionnaires have been undertaken on the research, extension and farmers levels. Further, econometric functions for empirical analysis were carried out to perform the results. But the process of technology transfer is constrained by many factors. The nonparametric test χ^2 and binary logistic regression model coefficient β showed that traditional technologies are yet predominant and that the socioeconomic factors determine decision choice on rice innovation. Finally, adopters are running in a decreasing production level as was illustrated by Cobb – Douglas Production Function. These results suggest that adoption of rice varieties and other production factors will be increased if the highlighted socioeconomic characteristics are improved and an effective scheme of agricultural factors dissemination is created and properly implemented.

Key-words: rice technology, determinants of adoption, empiric studies, rice dissemination, adoption, the effect on productivity

OUTLINE OF THE WORK

The remainder of this work is organized in the following chapters:

(1) General Introduction

(2) Technology transfer from research to farmers in Mozambique: current status, constraints and opportunities.

(3) Factors affecting adoption of newly developed rice technologies transferred from research to farmers in Mozambique.

(4) Estimation of return to scale in farmers adopting modern rice technologies in Nicoadala District, Zambezia – Mozambique.

(5) General discussion, conclusion and possible solutions.

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FIGURES

TABLES

ACRONYMS

BPES	Balance of Economic and social Plan
CIAT	International Center for Tropical Agriculture
DF	Demonstration Field
DFDTT	Documentation Training and Technology Transfer
DNEA	National Directorate of Agricultural Extension
DPA	Agriculture Provincial Directorate
FAO	Food Agricultural Organization
FAOSTAT	Food Agricultural Organization Statistic
FFS`s	Farmer Field Schools
FSF	Farmer Seed Fair
IIAM	Agricultural Research Institute of Mozambique
INE	National Statistical Institute
IRRI	International Rice Research Institute
MASA	Ministry of Agriculture and Food Security
MIA	Agrarian Investment of Mozambique
MINAG	Ministry of Agriculture
PAPA	Plan of Action for Food Production
PARP	Action Plan for Poverty Reduction
PEDSA	Strategic Plan for Agricultural Sector Development

PES	Economic and Social Plan
PITTA	Integrated Technology Transfer Programme
PVS	Participatory Variety Selection
R&D	Research and Development
SDAE	Economical Activities District Service
SEMOC	Seed of Mozambique
T & V	Training and Visits
TIA	Agricultural Survey
UPLB	University of the Philippines
VT	Vitrine Technology

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CHAPTER I

GENERAL INTRODUCTION

CHAPTER I

1. General Introduction

1. 1. Technology transfer

The use of innovations in agriculture has generally drawn more attention of development economists because the majority of the population in developing countries relies on agriculture for their livelihood. The introduction of new technologies would, potentially, increase the agricultural output and consequently provide opportunities for higher household income. In many cases the introduction of newly developed technologies did not reach the expected potential adoption (Feder et al., 1985), requiring, therefore, a clear understanding of the principles governing the process technology transfer. Rogers, (2003) views technology transfer as a multi-step process of communication which includes a diversity of senders and receivers of advice or materials. In the development process technology transfer may be defined as the passing of technology from one country to another (Loevinsohn et al., 2017). Rogers, (1983) has also used the term diffusion to define technology transfer. To him diffusion of innovation is the process by which an innovation is communicated through channels over time among the members of a social system. In addition Rogers, (2003) has also defined diffusion as a special type of communication, in which the advices are sent with new suggestions or ideas to introduce or to improve a given innovation.

Communication is very important for a genuine technology transfer and hereby we try to clarify it in different perspectives based on earlier related studies. Baiyegunhib et al., (2019) discuss communication as a process in which participants create and share information with one another in order to meet a consensus. The previous statement by Feder et al.,(1947) reported that communication may be viewed as a two-way process of convergence, rather than as a one-way in which one person seeks to transfer a message to another. However transferring technologies comprises four main elements (Rogers, 2003; Seifried et al., 2017): innovation, communication channels, time, and the social system.

Smit and Smitherst, (1992) have verified that rapid adoption of soil improvement technology was very dependent on putting together the four requisites aforementioned (innovation, communication channels, time, and the social system). Prior experiences show that uniform and immediate acceptability of technologies are quite rare, as reported in the study by Manda, et al., (2016), and suggestions from many authors (Conroy, 2017; Hounkonnou et al., 2012; Sanyang et al., 2012; Schut et al., 2014) indicate that policy-makers should have full consideration of the above mentioned four master guidelines when running technology transfer.

An innovation is an idea, practice, or object that is understood as new by a person or other unit of adoption (Affholder et al., 2010). The reaction of a person who receives an innovation determines how the technology is perceived. However it becomes innovation as long as the idea or the object disseminated seems new to the person (Grisley 1994). The social system is considered by Danso-abbeam et al., (2017 and 2018) as a set of interrelated units that are committed to jointly fulfil a common objective.

In technology diffusion time is divided in three different branches: (1) the innovation-diffusion process, (2) innovativeness, and (3) the innovation's rate of adoption. The innovation decision process is the most important since it is considered as the process by which the targeted person passes from first acknowledgement of the technology to forming a position towards it. This means that the individual is in the stance to accept or reject the innovation, to inforce the new idea, and to confirm final the decision (Danso-abbeam et al., 2017; Kunzekweguta et al., 2017).

Whereas communication channels may be perceived as the means by which a message gets from a source to a receiver (Kunzekweguta et al., 2017; Manda et al., 2016). Some examples of channels are the Voucher System and Seed Fairs, the Participatory Variety Selection (PVS), and the Farmer–First–and-Last (FFL) model. The Voucher System and Seed Fairs is a program which includes a combination of seed vouchers providers and seed fairs attendants as well as many invited seed dealers exposing their seed (Klerkx et al., 2012). According to Burman et al., (2017) the Participatory Variety Selection (PVS) refers to a participatory scheme adopted for conducting on-station and on-farm experiments. While the Farmer – First – and - Last (FFL) is an approach that starts with a systematic process in which scientists learn and understand the resources needs and problems of Resource Poor Farmers (RPF) families. Research and learning are carried out at the farmers' fields where problems were previously identified (Chambers,1985).

1.2. Review of models of the adoption behavior in individual firms

The knowledge on agricultural innovation is extensive and slightly difficult to sum up. Basically, earlier clarifications about adoption of agricultural technology are made from empirical studies, and usually concentrate on factors such as uncertainty, risk, institutional constraints, human capital, input availability, and infrastructure (Dobbs and Foster, 1972; Feder et al., 1985; Kohli, 1998). More recently the empirical analysis tends to focus on social networks and learning, including extension contacts, and demographic factors among others.

Most of the studies of the adoption behavior of individual households use statistical tests that enable to identify rates of adoption and determinants affecting the adoption decision (Feder et al., 2014). One simple way to characterize the procedure is to consider that the individual has to decide to choose between two innovations: for example improved rice technology and its complementary inputs. The models who follow this logic tend to investigate how much land is allocated to the newer agricultural technology and what are the ratios of input per land using improved inputs, under different circumstances.

One interesting example is reported in Lockheed et al., (1980) who uses a stochastic production function and considers risk aversion to analyze the association of uncertainty and imperfect advice on adoption of chemical fertilizer, where only variable expenses are involved in adoption. Results on his study showed that risk aversion was correlated with use of less land and less fertilizer in the production of the new crop and it was more likely that the adoption would grow as the information related to modern production increased. Information development was due to extension efforts, and this result is in line with a recent study by Just and Pope, (2013). The probability of adoption by a farmer or individual increases with a better physical environment of the farm. For example, the availability of water or better land raises the predicted income from new production and then the likelihood that the final user will accept the newly developed technology (Dalton and Guei, 2003).

Another useful argument was provided by Tversky and Kahneman, (1992) who reported that uncertainty is correlated with the new technology (for example high yielding variety) only if technology requires the application of agrochemicals (complementary innovation). In order to know whether the level of fertilizer use is independent from degree of risk Feder et al., (2014) used a constant returns-to-scale function .

1.3. Factors affecting adoption

1.3.1. Farm size

Farm size is one of the determinants on which the studies related to adoption have been focused on. This factor, depending on the characteristics of the technology and institutional setting can display different effects on the level (or rate) of adoption. The positive effect of farm size to adoption depends on such determinants as fixed adoption costs, human capital, credit constraints, labor requirements, risk preferences and tenure arrangements, among others (Hans, 1978). One obstacle to the adoption of new innovation by farmers is associated with fixed costs attached to the implementation. Studies refer that a decreasing tendency to adopt and a lower level of acceptance on the use of innovation by farmers is caused by large fixed costs. Weil, (1978) also clarified that in Africa, great number of adopters of new technologies were those cultivating larger areas of land rather than small farmers. Similarly, in Asia the same researchers have found that inadequate farm size constrained an efficient utilization of irrigation equipment, more specifically pumps. Evidence provided by Hans, (1978) indicate that capital may be more available if farmers are capable of enlarge farms.

A good example was that of Thailand's farmers. Although the government had established a tractor service (for hiring tractors) to overcome the low crop production there were no farmers hiring this mechanization technology due to their limited financial capacity, with the end result of production remaining low. In the Philippines the situation was similar. Dobbs and Foster, (1972) results indicated that in some areas of the Philippines, governmental tractor hire stations have been created, but quite often these programs were abandoned due to not only to poor maintenance but also to the small adhesion of farmers. The study by Weil, (1978) further indicates that the negative relation between adoption of new technology and farm size may be attributed by credit constraints.

1.3.2. Human capital

Human capital is another important factor for the introduction of new agricultural technology (Just and Pope, 2013). Various studies indicated that education is at the basis of creation of potential human capital. Barbara, (1978) examining the contribution of different factors in adoption in India found that education plays a strong role in determining rates of adoption of new technology in agriculture. Furthermore, some indirect support for this assertion is presented by Lockheed et al., (1980) who showed a significant relationship between education and farm output.

1.3.3. Labor Availability

Availability of labor is a fundamental variable determining farmers' decisions regarding the adoption of improved agricultural practices insofar as many agricultural innovations can be labor saving or labor intensive (Lockheed et al., 1980). For instance ox cultivation technology is labor saving and its acceptance by the farmer may be driven by lack of labor (Helleiner, 1980). On the other hand, improved varieties will often require huge labor utilization and limited labor availability may prevent adoption. Moreover, innovation may increase the seasonal requirement of labor which can make adoption less attractive (Dixon and Gibbon, 2002).

Hicks and Johnson, (1974) have found that higher rural labor supply leads to increase adoption of labor-intensive rice varieties in Taiwan while shortage of family labor determines weak adoption of varieties in India (Barbara, 1978). Moreover, there are plenty of studies which agree that one of the greatest challenges in farming systems in African countries is the labor scarcity. Norman's research has reported that seasonal peak labor shortage in Nigeria may be overcome if neighboring farms have peaks of labor demand in different points in time, the problem may be alleviated with migration. According to Norman, (1978) the importance of promoting mechanization is to alleviate labor shortages. For example, ox power and tractor power can lead to increased production by making possible more timely farming operations and, simultaneously, the smaller labor demand may reduce costs.

1.3.4. Credit Constraint

Most empirical studies have reported that differential access to capital is often crucial because it may generate different rates of adoption of improved technologies in particular, those considered as indivisible technologies (Bhalla, 1980). This includes tractors or other related machinery especially those which require a larger amount of investment. These implications have been confirmed by descriptive and empirical work on the role of credit (Michael, 1980). However, access to capital in the form of either accumulated savings or capital markets is crucial in financing the adoption of the majority of agricultural innovations (Spenser and Byerlee, 1980). On the other hand the lack of investment capacity prevents small farmers from quick adoption of new innovation (Bhalla, 1980).

1.3.5. Market distance

Market distance is very important for the farmers, not only because it affects transaction costs but can also be responsible for outdated market information, namely prices. It is then not surprising that the adoption of agricultural new technologies be sensitive to the increase in market distance (Rosca et al., 2016). Impact of market distance on cereal crop production was also recognized by other authors. For example Manda et al., (2016) have found that maize technological package was more largely adopted when the household was much closer to market. This result was also confirmed by the findings of Seifried et al., (2017) who went further saying the technology adoption was pulled by the market distance. In the case of other inputs the empirical analysis may show a negative association of market distance with improved adoption. It was reported in the research by (Bekele, 1980) that distance to the stock center was negatively and significantly linked with the use of chemical fertilizer. A similar negative effect was reported by (Nkonya and Norman, 1997). However, the advantage on reducing the distance to the markets is of course the reduction in transport costs.

1.4. The potential of rice growing in Mozambique

Agriculture is an important sector for the economic development in Mozambique, and considered as the base of development of the country. The Strategic Plan for Development reports that for the last 10 years, the sectoral contribution for GDP, was about 23,3 percent (MINAG, 2015; PARP, 2011).

The country has a population of 27.216.276 millions of inhabitants with the annual growth rate of 2,3 % (FAOSTAT, 2017), and its majority (80%) depends on the agricultural activity of farmers whose exploitations have around 1.1 ha/household (TIA, 2007). As stated by the National Strategy for Rice Development of 2015 (Republica de Moçambique, 2015), about 70% of the Mozambican population live in rural areas and has agriculture as their main income generation source. More than 97% of 5 million hectares of agricultural land are currently cultivated, the major food crops being maize, cassava and rice (PEDSA, 2010).

Rice can contribute overwhelmingly for the satisfaction of the demographic growth in Mozambique. The National Statistical Institute (INE, 2012) predicts that until 2035 (last year of implementation of the National Strategy for Rice), the population will rise to 41.5 million, and estimates that the 900,000 ha available for rice cultivation may provide food security for future generations. The good climatic and hydrological conditions, besides ensuring guaranty self-sufficiency, may even allow the participation in the external market.

1.4.1. Hydrological conditions

Hydrological conditions comprise the hydrographic basins, along the 2,400 km of coastline. According to (PAPA, 2008) there are 13 hydrographic basins in Mozambique: Maputo, Umbeluzi, Incomáti, Limpopo, Rio Save, Búzi, Zambeze, Licungo, Ligonha, Lúrio, Messalo and Rovuma. Cunguara et al., (2013) refer that currently there are 27 dams measuring about 10 or more meters high. The dam of Cahora-Bassa in the Zambeze River is the biggest one in Southern Africa.

In the country there are unexploited fluvial systems such as the fluvial system of Zambeze and Limpopo. These unexploited systems provide an opportunity to enhance the Agricultural sector. The irrigation systems are only used at 14% of its potential and cover 3.3 million hectares, according to Cunguara et al., (2013).

1.4.2. Rice Ecosystem

In what concerns the rice ecosystems, there are 3 ecosystems in the country: the irrigated, the upland rain fed and the low land rain fed. Basically, the irrigation systems in Mozambique, only covers 3 % of the area. The widest irrigation infrastructure is located in the district of Chokwé, Gaza province, in the south of Mozambique, covering 30,000 hectares. Generally, the irrigated areas are those preferred by commercial farmers because they give a possibility of using modern agricultural mechanization and higher yields. In the Chôkwé irrigation system yields vary between 3 - 5 tons/ha in 2014 (Mather and Boughton, 2008).

In upland, rice is usually cultivated on land without leveling. In other words, cultivation takes place even in sloping fields and the crop is rarely flooded (Machado, 2014 and Zandamela, 2012). Moreover, the upland rice ecosystem represents 7% of the existing rice production area in Mozambique and is located in Nampula and Cabo Delgado. The rainfed ecosystem, is characterized by leveled or slightly sloping areas without continuous flooding where the crop is established through direct seeding or transplantation by the farmers. This ecosystem is found to be the most important system in Mozambique and it accounts for 90% of the total area in the country. Zambezia, Sofala, Nampula and Cabo Delgado the most important regions for the rainfed ecosystem and where traditional rice varieties are the widely used.

1.5. Potential locations for rice production in Mozambique

The main locations with potential for rice production in Mozambique are shown in table 1.

Table 1. Potential locations for rice production in Mozambique

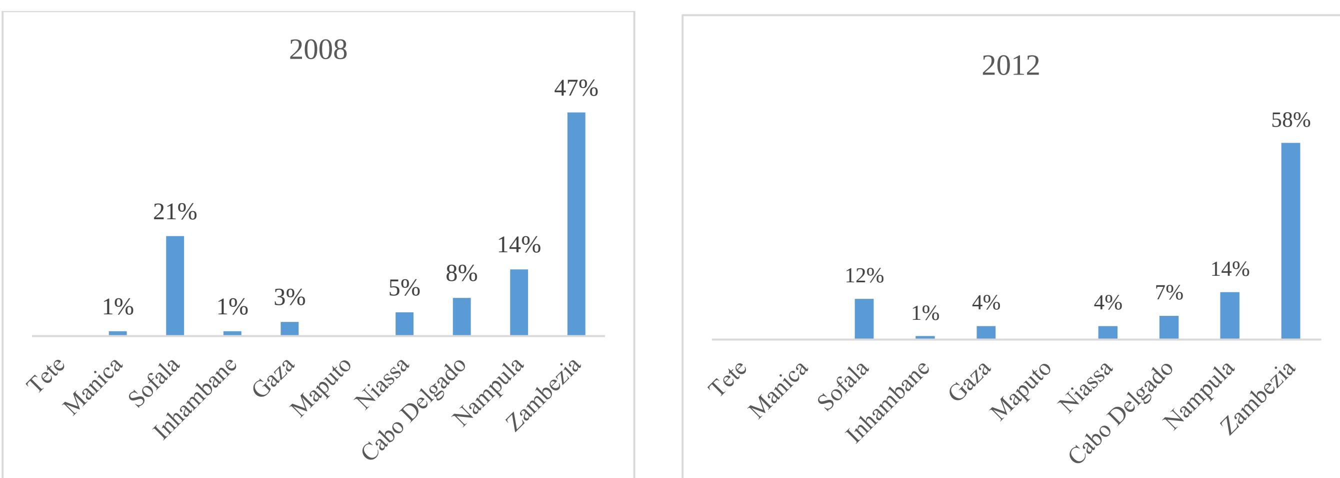
Center	**North**	**South**
Zambezia province	**Nampula province**	**Maputo province**
Nicoadala	Moma	Matutuine
Morrumbala	Angoche	Manhiça
Chinde		
Mopeia	**Cabo delgado province**	**Gaza province**
Namacurra	Muidumbe (N´guri)	Chòkwé
Maganja da Costa	Balama (Chipembe)	Xai-xai
Inhassunge		Bilene
	Niassa province	Mandlakaze
Sofala province	Mecanhela	
Dondo	Mandimba	
Buzi		
Beira		

Source**:** Action Plan for Food Production (PAPA 2008-2011)

1.5.1. Distribution of rice production by province

The distribution of rice production in Mozambique depends on the variability of the climate and agro-ecological conditions (FAO, 2014). In Southern Mozambique, the climate is semi-arid under significant irregular rainfall ranging from about 350 mm to 900 mm per year, but this rainfall is inadequate due to poor soil water retention conditions. In the Center and North, there are very favorable opportunities for the crop cultivation. Rainfall variation is from 1000 mm to 2900 mm and the soils are suitable for the rice crop (FAO, 2014). This explains why the rice production is more concentrate in the Center and Northern than in Southern regions as shown in Figure 1 (Zandamela, 2011)

Figure 1. Rice production distribution (percentage / province) in 2008 to 2012



Source: Data sourced from TIA (2008).

1.6. Rice as a crop priority for research of the government

There are three reasons that make rice a priority crop in agricultural sector. The first is because rice is becoming the most preferred food staple in Africa. Rice consumption must have risen from 86 000 tons in 1990 to 519 000 tons in 2010 at an annual growth rate of 8.6%. Such growth scenario has been considered the faster growth rate among cereals. Maize consumption rose 5.5%, while wheat and sorghum have risen 7.4% and 4,7% respectively (Kajisa and Payongyon, 2008).

The second reason is the fact that national rice production is stagnated due to the low adoption of improved technologies by farmers. This fact has rapidly made imports rise, according to various authors (Cunguara and Darnhofer, 2011; Mather et al., 2008). To provide effective measures to deal with the present situation, the Mozambique Government had launched an action plan in 2011 (PAPA, 2008) in which several measures for the intensification of rice production are suggested, namely the farms size.

Although new varieties and agricultural practices have been developed, there is still no scientific information that can support policy makers decisions on measures to reverse the situation of poor adoption of rice innovation.

1.7. Rice consumption

In Mozambique domestic households spend on average 6% of their food costs on rice buying, making rice the fifth most important item in terms of budget expenditure. The share of rice expenditure varies from province to province (Uaiene et al., 2009). For example the Provinces where households spend the highest share in rice food purchasing include Zambezia, Sofala, and

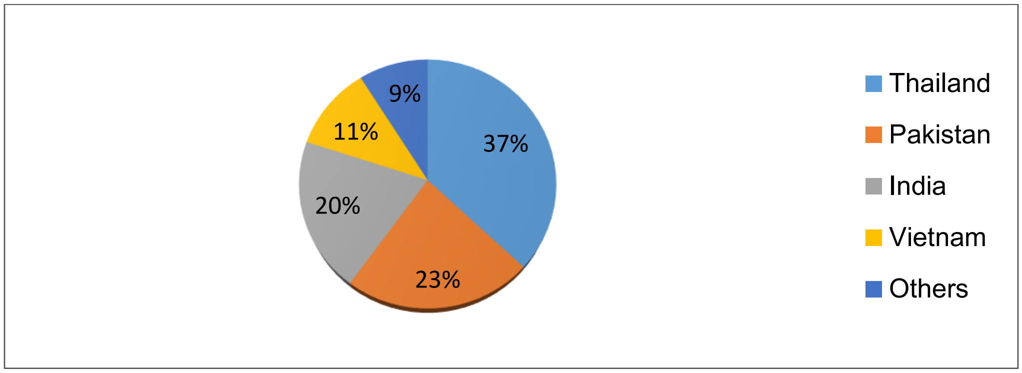
Maputo (Zandamela et al., 2011), reaching 9 % of total food expenditure. Tete is the province with the lower percentage: around 1% Households from other provinces allocate 4% of expenditures to milled rice

According to USDA, (2016), Mozambique was self-sufficient in rice from 1960 to 1974 in terms of rice intake and output. From 1975 on the domestic rice intake has exceeded domestic production, by a large margin. In the period between 1975 and 1991 there was little fluctuation in the rural domestic family consumption around 95,000 tons of rice. But afterwards, the consumption grew decisively from 133,000 tons in the year 1992 to about 600,000 tons in 2013 (FAO, 2014). According to Low (2014) this dramatically increase in consumption was mainly attributed to people living in urban areas where households consume larger quantities or rice than other cereals like wheat or maize (Zandamela, 2011).

1.8. Imports

According to the rice food balance during the period of 2011 and 2012, about 53% of the rice consumed in Mozambique was imported mainly from Asia, and namely, from Thailand, Pakistan, India, Vietnam, and others. About 60% of total imports during the period of 2005 to 2012, came from Thailand and Pakistan as can be seen in Figure 2. In Mozambique rice imports is mainly operated by high-level businessmen through three main entrance ports of Maputo, Beira, and Nacala (Howard et al., 2001; Walker et al., 2006; FAO, 2014; Xavier et al., 2010).

Figure 2. Rice exporting countries to Mozambique in the period between 2005 - 2012



Source: FAOSTAT, (2017)

Similar dependence on imports also occurs in other African countries. For instance in Ghana the domestic rice production has been consistently less than its consumption needs. Demand for milled rice has outstripped supply due to population increase, and improved standards of livings. Ghana imports come from 44 different countries but mainly from the USA, Thailand, and Vietnam and most of the imports (73.2%) are private companies, while the Government responds for the remaining percentage (Blench et al., 2003).

1.9. Main strategies for Rice Development in Mozambique

1.9.1. Policies

The government of Mozambique has proposed many policies to ensure the effectiveness of the rice value chain. For example, the Action Plan for Food and Production was designed in 2008 and had recommended two measures to overcome the situation of low productivity in the rice chain. The first measure was to consider rice research as a source of scientific basis to design robust measures. The second, encouraging farmers to use new rice technologies. However, these measures have not yet been materialized (PAPA, 2008).

1.9.2. Research

Rice research, as the first priority policy to tackle the problem of poor productivity, has always included, the development of high-yielding rice varieties and the improvement of the seed production system, in order to get the amount of certified seed to meet farmers' need. In 2006 the Mozambican Government established a partnership with the International Rice Research Institute (IRRI) to reinforce research in the rice sector. The partnership with the international organization was necessary for technical capacity enhancement and assistance and to alleviate the limited of financial resources (Chaves and Zandamela, 2000).

Among the various research weaknesses, it is worth mentioning as being the more relevant: a) the absence of an information management system that allows greater dynamism to the availability and sharing of information and scientific knowledge; b) a lack of staff, both in quantity and in quality, for specific areas of agricultural research; c) difficulties in the management of the research support services (laboratories) namely the lack of technical assistance for the maintenance of the equipment; d) the insufficient quality control of the results produced by this important research support services.

1.10. Framework and objectives of the study

Agriculture has been seen as the main source of income for 90% of Africa's rural population for many years (EUCORD, 2012; UNECA-SA 2009). On the other hand, strengthening agricultural income, especially for smallholders, remains a vital focus for agricultural policy makers in sub-

Saharan Africa, where production capacity is very limited, and its population growing. On the other hand Africa population has been predicted to grow from 1.01 billion in 2009 to more than 2 billion in 2050 (AfDB, 2014). This enormous population growth has risen a question on how agricultural production can meet consumer demand, as reported by the African Development Bank Group (AfDB, 2014).

Therefore rice, maize and cassava were widely considered as priority crops for investment in Africa owing to their potential effects on food security, poverty alleviation, income generation and ability to benefit Southern African countries (South Africa, Swaziland, Zimbabwe, among others) especially in terms of exchange of scientific and technological information (CCARDESA 2014).

In Mozambique, agriculture is the most important economic sector, accounting for more than 40% of gross domestic product (GDP) and remaining the most important sector for developing rural communities (USDA, 2016).

The Government of Mozambique has selected rice crop as key to fight farmers hunger, malnutrition and food insecurity. This choice has many motivations. The long tradition of rice cultivation (for example rice has been cultivated for more than 500 years in Mozambique), and the historical leadership with regard to production at the level of the Southern Africa (for example in the 1970's the country ranked in one of the top position with an annual average production 57. 000 tons).

The establishment of a research program to continuously promote the improvement of quality varieties and agricultural practices affordable to farmers is crucial for reducing the widening gap between production and consumption. Recent figures estimate that the consumption need is about 728,000 tons from which 500,000 comes from outside countries (ADZ, 2014). According to

Cunguara and Darnhofer, (2011) the existence of more than 900,000 ha of potential area for rice production could be enough to meet national demand.

It is important to highlight that on one hand, despite the technological advances on rice research programme, rice productivity remains stuck at 0.7 to 1.2 t/ha. On the other hand there are public extension services availability in Mozambique. The public extension services were created in 1987 and assumes the role of disseminating technological advices to farmers. Nevertheless farmers do not adopt the improved varieties and complementary technologies. The question therefore arising is: Why do farmers not adopt the modern rice varieties and complementary technologies?

Bozeman, (2000) assessing the impact of technology transfer on alternative uses of the resources found that adoption was related to limited agricultural policies, needing little modification on the technology transfer process. Dandedjrohoun, et al., (2017) noted that the limited diffusion of new rice varieties in Africa (NERICA) was responsible for low adoption. Feder et al., (1985) have previously agreed that the introduction of modern agricultural technologies has obtained only partial success in terms of observed rates of adoption. Furthermore , the same authors point out that the following agricultural factors are also responsible for that failure: lack of credit; limited access to information; risk aversion; inadequate farm size; inadequate incentives associated with farm tenure arrangements; insufficient human capital; absence of equipment to relieve labor shortages (thus preventing timeliness of operations); chaotic supply of complementary inputs(such as seed, chemicals, and water); and inappropriate transportation infrastructure were the main constraints for the rapid adoption of innovation.

In this context the present study focuses on finding out the main reasons why farmers do not adopt the improved rice technologies and on the proposition of measures for an effective technology transfer of improved rice technologies in Mozambique. More specifically**:**

(1) To understand the current situation of technology transfer, finding out constraints and opportunities to conduct effectively the process of technology transfer from research to farmers.

(2) To determine the factors affecting the decision of choice of improved rice technologies in rice growers in Mozambique.

(3) To estimate the return to scale in farmers adopting modern rice technologies in Nicoadala District, Zambezia – Mozambique

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Explanatory Note

The importance of conducting this study arises from the limited of rice yields among farmers, despite the rice value chain efforts on developing new rice varieties are being made in Mozambique.

In such a way, the questions therefore are: whether new technologies disseminated to farmers' farms are really being used by farmers and what factors really affect the adoption of the newly agricultural technologies and why? Do rice technologies have impact on farmers? In order to effectively answer to these questions different analysis will be applied.

Feder et al., (1985) have already stated that for solving technology transfer bottlenecks empiric analysis is required. Thus, this research was carried out mainly based on face-face interviews, questionnaires at different levels: Research – Extension agents – Farmers. It is important to highlight, that the study comprise three publishable (3) papers: (a) Technology transfer in rice crop in Mozambique: current status, constraints and opportunities. (b) Factors affecting the adoption of improved rice technologies in rice growers in rice Nicoadalas farmers, Zambezia and (c) Estimation of return to scale of rice technologies transferred from research to farmers in Mozambique.

CHAPTER II

TECHNOLOGY TRANSFER FROM RESEARCH TO FARMERS IN MOZAMBIQUE: CURRENT STATUS, OPPORTUNITIES AND CONSTRAINTS

Technology transfer from research to farmers in Mozambique: current status, opportunities and constraints

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Abstract

Rice is a staple food and an important commodity that meets nutritional and food security needs of consumers in sub-Saharan Africa. In this region, rice consumption needs are growing faster than for any other cereal, and since production cannot match the consumption needs, imports are increasing**.** The low yields of rice production and the low adoption of improved rice varieties in Mozambique poses major challenges to production expansion despite research entities efforts to promote high yielding technologies. The objective of this study is to understand current situation and identify opportunities and constraints along the pathway of high yielding rice varieties from rice breeding to farmers. Information discussed in this study comes from the rice production strategy documents and from interviews with seventeen key informants (researchers and extension agents) from the rice research and technology transfer institutions in Mozambique. The technology transfer in Mozambique has not been efficient due to extended several reasons, even if most of the high yielding varieties have a promising potential. The main constraints are: a) the inefficient seed certification caused by poor field inspection and limited means of transportation, thus limiting availability of improved seeds which perpetuates the informal seed system; b) the extension services have a limited capacity to reach farmers and limited funding to support the dissemination of new technologies; and c) the weak economic conditions of the farmers is also an important obstacle for the adoption of improved varieties and inputs. Therefore, the intervention of the National Authority Services should aim at promoting the training of improved rice seed producers in order to bring higher amounts and better quality seeds to the market. It is also suggested that technology transfer agencies are set up closer to the farmers namely by creating mobile work brigades committed to monitoring the technical production system transferred to the field, insofar as extension services alone cannot reach many farmers through direct contacts.

Keywords: high yielding varieties, extension agencies, seed production system, technology transfer, dissemination.

1. Introduction

Rice is a staple food and an important commodity required for nutritional and food security needs of consumers in sub-Saharan Africa. In Mozambique rice consumption needs are growing faster than that in any other cereal (EUCORD, 2012). The growth in demand of this cereal is driven by urbanization, since urban households are more market-dependent and consume more rice than maize. Historically, Mozambique was self-sufficient in rice from 1960 to 1974. From 1975 to 1991 rice consumption exceeded domestic production since, on average, annual production amounted to 95,000 tons compared with only 40,000 tons of domestic production. Furthermore, from 1992 household consumption rose sharply from an average of 133,000 ton to 600,000 tons in 2013, while the estimated production increased from 20,000 tons to 100,000 tons. Nowadays consumption needs are estimated 728,000 tons and the fulfillment of these needs relies on imports from the Asian countries of Thailand, Pakistan and Vietnam (IIAM, 2018).

The literature refers that the potential area for rice production in Mozambique is estimated at 900,000 hectares (ha), but only 33.3%, approximately 300,000 ha, are currently under rice, of which 97% in the Central (Zambezia and Sofala) and Northern (Nampula and Cabo Delgado) provinces. However, most farmers (around 90%) cultivate, on average, only 0.5 to 2 ha of land with low rice yields in the range of 0.7 to 1.2 tons per hectare (ton/ha) in rainfed lowland ecosystems (IIAM, 2018 and MINAG, 2006). In addition only 8.7 % of farmers plant improved rice varieties (MINAG, 2007, 2015). A wide range factors may be contributing to the current scenario but the unawareness of the current technology transfer program and its effects is the principal one. The diagnosis of bottlenecks and opportunities in the main steps of technology transfer, namely the varietal release system, the certification of seed use and its diffusion would help the policy–makers to suggest vigorous measures to promote the agricultural innovation among Mozambican farmers.

With regard the varietal release, official release is essential to assure both the entity seed growers and the final users (farmers) that seed has been developed satisfying useful criteria including novelty, distinctness, uniformity and stability. This will certainly contribute to the scale-up of the rice productivity and adoption of high yielding varieties (Orton 2020). In some African countries (Rwanda, Congo, Niger, Liberia, Guinea-Bissau and others) where varietal release system do not operate due to disruption of agricultural institutions, the adoption remains very low (Sanni et al., 2013; Singh et al., 2019). On the other hand it is not surprising that dissemination of new seed varieties in many development countries has been poor (Manzanilla et al., 2016) due to the lack of effective seed production system which jeopardize the methods used to transfer agricultural innovation (Defourny et al., 2019; Flavell, 2017; Kassie et al., 2015; Kiptot et al., 2006). In the case of Mozambique the informal seed production system accounts for 98% of the seed used and the formal system for the remaining 2%.This has led to fostering farmer-to-farmer exchange traditional varieties and to a decreased productivity (MINAG, 2010 and Zandamela, 2008).

According to various authors (Balasubramanian et al., 2007; Corales et al., 2019; Molnar and Jolly, 1988; Singh et al., 2019), improving the access of final users to new agricultural technologies necessarily requires the identification of constraints in the technology transfer program. Nabbumba and Bahiigwa, 2003) believe that if agricultural technologies are effectively developed and transferred to farmers, production and productivity can increase. The objective of this study is to understand the current situation and identify opportunities and constraints along the pathway of modern rice varieties from the rice breeding to farmers with emphasis in the following issues:

improved technologies and varietal release system; dissemination of improved seeds; methods of technology transfer, and the use of improved rice varieties and agricultural practices by farmers.

2. Methodology

Information discussed in this study comes from documents on rice cultivation guidelines in Mozambique and from interviews with seventeen key informants, researchers and extension workers engaged in rice research and rice technology transfer in Mozambique.

2.1. Interview

2.1.1. Elaboration of the interview guide

An interview guide was designed, pre-tested and adapted to meet the study objectives under the qualitative and exploratory study context. Semi-structured open-opinion questions were designed in clear terms to assure respondents freedom to provide a more detailed information. The questions were also designed to allow respondents the possibility of modifying any word within a sentence. Additionally, questions were put in sequence so as to activate the respondent's memory clues (Atkinson and Flint, 2015). The principal questions that oriented the interviews with key informants were: a) who are the actors of technology transfer? b) which technologies were introduced and transferred to farmers? c) which extension models were used by the rice research and extension actors to disseminate rice technologies and innovation advices? d) which were the bottlenecks that the technology transfer process did face to?

2.1.2. Reaching the target population

The number of key informants aforementioned (researchers and extension agents) were contacted using snowball sampling. Snowball sampling is viewed as a research technique usually used in sociology, psychology and management studies and it is recommended in case the sampling population cannot be strictly delimited (Atkinson and Flint, 2015). Additionally, Atkinson and Flint, (2004) considered it as a technique for finding research subjects where, one subject gives the researcher the name of another subject, who in turn indicates the name of a third, and so on. The respondents in this research were thus met by asking a previous participant to suggest someone else resourceful to answer the questions (Atkinson and Flint, 2004).

3. Results and Discussion

3.1. The Improved technologies and varietal release system

In this section we broadly describe and consider the improved rice varieties as the most important technology due to its importance in the rice value chain. This does not exclude the importance of other rice technologies that are also being promoted in Mozambique, namely the application to fertilizers (nitrogen - N, phosphorus - P and potassium - K), the use of pesticides, land preparation, sowing, mechanization, irrigation, weed management as well as post-harvest techniques. The improved rice varieties were introduced in Mozambique under the objectives of the rice research programme, in order to: a) develop, test and adopt the high yielding varieties for both rainfed and irrigated lowland ecosystems tolerant to biotic (pests and diseases) and abiotic (drought and salinity) stresses; b) produce basic seed in sufficient quantities to meet demand within the value chain; and c) perform genetic seed purification (GoM 2015). This rice research program is currently undertaken mainly by the Agricultural Research Institute of Mozambique (IIAM) who works in partnership with the International Rice Research Institute (IRRI) and other national institutions, such as the National Directorate of Agrarian Extension (DNEA) and the National Farmers Union (GoM 2013, 2015). The Agricultural Research Institute of Mozambique delivers the import license of improved rice lines to Mozambique and provides also rice research resources such as land and other means for collaboration activities. While the Internationl Rice Research Institute accomplishes this to facilitate the implementation of collaborative programmes (technical assistance among others) it also helps IIAM to create links with other CGIAR members, namely the AfricaRice, International Institute of Tropical Agriculture (ITTA), the International Center for Tropical Agriculture (CIAT) and IRRI, which is the headquarter for the introduction of rice varieties in Mozambique (GoM 2013, 2015).

The first group of improved varieties introduced in Mozambique was developed by IRRI, the University of the Philippines (UPLB) and the International Institute for Tropical Agriculture (IITA) in the 1960s and 1970s and released in Mozambique in 1980s and 1990s for the irrigated lowland ecosystem (Kajisa and Payongayong 2011) (Table 2). These varieties belong to the indica (needle) group and in terms of organoleptic characteristics, the grain is long and thin and not susceptible to retrogradation due to its low content of amylopectin (Khush and Virk, 2005). They have a yield ranging from 5 - 6.2 ton/ha in irrigated conditions as referred by Kajisa and Payongayong, (2011) and Khush and Virk, (2005).

Another group of new rice varieties was developed by IRRI, IIAM, MIA (an agrarian investment company in Mozambique that closed down in 2013) and Wanbao (a Chinese company) and were released in Mozambique in 2011 and 2012 (Table 2 below). Those varieties have a growth cycle that varies between 105 - 139 days and the nature of their preferred ecosystem is the irrigated lowlands, although some varieties are also used in the rainfed low land ecosystems. In terms of preference, high yield, short growth cycle, medium long grain, intermediate amylose content, non-sticky after cooking, and plant height are the most preferred characteristics of rice by the farmers (Kajisa and Payongyong, 2008). However, a characterization of rice genotypes in Mozambique suggests that local genotypes can be used in breeding programs to acquire some preferred characteristics (medium to long grain) are Chupa, Nené, Chencherica, Mucandara Redondo, Paula, Mocuba, Nunkile and Faya (Abade et al., 2016). This program would allow the creation of varieties with the high yielding traits if corrected. Whereas in terms of potential yield it is in the range of 6.0 ton/ha - 10.2 ton/ha and an industrial yield that ranges from 70-74% of non-broken milled rice (Table 2). According to interviewees, the development of these varieties was aimed at improving the undesirable characteristics of local varieties, especially for the high yield and short growth cycle (MINAG 2015).

The list of improved varieties introduced in Mozambique analyzed in this research (Table 2) shows a higher yield potential from 5 ton/ha to 10.2 ton/ha) compared with some varieties from Southwest Asian countries like Iran where yields range from 4 ton/ha to 7 ton/ha (Ashoori et al., 2018). Additionally, their growth cycles (short to medium) are similar to what has been reported for some rice varieties in Ghana (Ansah et al., 2017). Regarding the shorter growth cycle studies conducted by Ansah et al., (2017) and Burman et al., (2017) report on the advantage associated with such characteristic as to allow more than one harvest in the same growing season.

Relevant justifications that may support the fact that most of the varieties are more adequate to the irrigated ecosystem (Table 2) are: increase the production due to existence of large scale farms with areas ranging from 10 to 100 ha, and the likelihood that these farmers use improved technologies to increase yields in irrigated ecosystems cultivation (Burman et al., 2017). Additionally, another study (Estudillo and Otsuka, 2001 and Suzuki et al., 2014), explained that irrigated areas in Asia, were a huge priority where newly developed varieties were grown during the implementation of the green revolution in 1960s. The idea was always to start the green revolution experiment on the irrigated lands and then broaden its scope to other ecologies (Ashoori et al., 2018; Dawson et al., 2016; Estudillo and Otsuka, 2001). In contrast, Mozambique currently has only 3% of irrigated land. A larger part of this irrigated land has been affected by soil salinization (Martins, 2015; Rickman and Zandamela, 2011). The salinization of the land has negative effects on crop yield if measures for its mitigation are not implemented.

A study conducted by Balasubramanian et al., (2007) states that ecological characteristics can determine the type of varieties to be developed. This argument is also supported by Singh et al., (2012) who suggested the urgent development of high-yielding varieties for rainfed lowland ecosystems in the Eastern and Southern African (ESA) countries with larger areas of these ecologies as it is the case of Mozambique (90 % of area), Tanzania (70% area) and Uganda (approximately 100% area). Kenya has 90% irrigated area and 50% use of improved varieties in that ecosystem. In Uganda, where almost the entire ecosystem is rainfed, has all 10 improved varieties adapted to that ecosystem (Haneishi, 2014 and Singh et al., 2012).

Mozambique has a larger diversity of traditional rice varieties, distributed almost by all suitable lands for cultivation, and most of these varieties are in the province of Zambezia (INE, 2012). The main traditional varieties in the rice chain are: Chupa, Muiamuriangana, Agulha, Chibiça, Mamima and Nené (Kajisa and Payongayong, 2011). However, according to IIAM newsletter (nº 11 of 2010), a program for the crossing of some local genotypes with genotypes from CIAT and Africarice is under way. It started in 2009 at Muirrua Rice Research Station and has the following combinations, ZM30-68 X ZM30-81. The genotype ZM 30-68 comes from the cross between: Nené (traditional) X FL28-10 (imported from CIAT - Colombia) and genotype ZM 30-81 results from Chupa (local) X FL28-10 (imported from CIAT - Colombia). It should also be noted that the varieties have not yet been released but the demand for varieties release has already been submitted. To launch these breeding activities, Mozambique possesses some technical capacity but technical support for strengthening the human resource potential is still needed.

Table 2. Improved rice varieties (developed in the 1960s and 1970s and introduced in Mozambique in 1980s and 1990s) and those improved in the years 2011 and 2012.

Variety	Year of release	Origin	Growth cycle	Ecosystem	Characteristic	Industrial yield	Yield
C4-63	1980	Introduction by UPLB	125	IR, RL	indicates	n/d	5 - 6 t/ha
IR 52	1980	Introduction by IRRI	116	IR, RL	indicates	70,2%	5,8 t/ha
IR 64	1990	Introduction by IRRI	117	IR, RL	indicates	69,8%	5,9 t/ha
ITA 212	1990	Introduction by IITA	130	IR	indicates	70,0%	5 – 6 t/ha
ITA 312	1990	Introduction by IITA	142	IR	indicates	n/d	5 – 6t/ha
Limpopo	1980	Selected by SEMOC	125	IR	Aromatic/indicates	77,8%	6,2t/ha
Macassane	2011 - 2012	Introduction by IRRI	133	IR	Non aromatic	73%	7.8t/kg
M'ziva		Developed by IRRI	129	RL	Less aromatic	70%	6,0t/ha
Farox		Developed by MIA	118	IR, RL	n/d	n/d	n/d
BRS Alvorada		Developed by MIA	139	IR, RL	n/d	73%	n/d
Tio Taka		Developed by MIA	134	IR, RL	nd	70%	n/d
Vasomat		Developed by MIA	134	IR, RL	Non aromatic	n/d	n/d
Tumbeta		Developed by MIA	105	IR	Non aromatic	73%	10,0 t/ha
Simao		Developed by Wanbao	133	IR	Non aromatic	74%	10,2 t/ha
Huwa		Developed by IIAM	127	IR	Non aromatic	70%	10,0 t/ha

Source: IIAM, (2018); Kajisa & Payongayong, (2011); Khush & Virk, (2005); MINAG, (2015); Singh et al., (2012). **Note**: irrigated – IR, rainfed lowland –RL, long grain paddy rice – indica, no data – n

In what concerns the rice variety release system, the procedure that is adopted is as follows. The breeder conducts on-station agronomic experiments of the improved rice lines according to this sequence: observation yield trial (OBT); preliminary yield trial (PYT); advanced yield trial (AYT); and participatory variety selection (PVS). To evaluate the adaptability to local conditions the following measures are collected: plant height, grain type, disease tolerance, lodging tolerance, grain quality and yield potential. After the results of agronomic experiments with the new varietal lines, the breeder submits a detailed report, including a name proposal for the new variety, to a sub-committee chaired by the National Director of Agriculture and Forestry (DINAS) for registration. Lastly, the breeder defends the report in a meeting with the sub-committee, which decides the release of the new variety into the markets if all agronomic and marketing quality requirements are met (IIAM, 2018). This variety release mechanism carried out in Mozambique has been efficient and complies with the international varietal release regulations. According the survey in the study by Sanni et al., (2013), Mozambique is among 18 countries (Ghana, Burkina Faso, Egypt, Kenya and others) where varietal release operates efficiently.

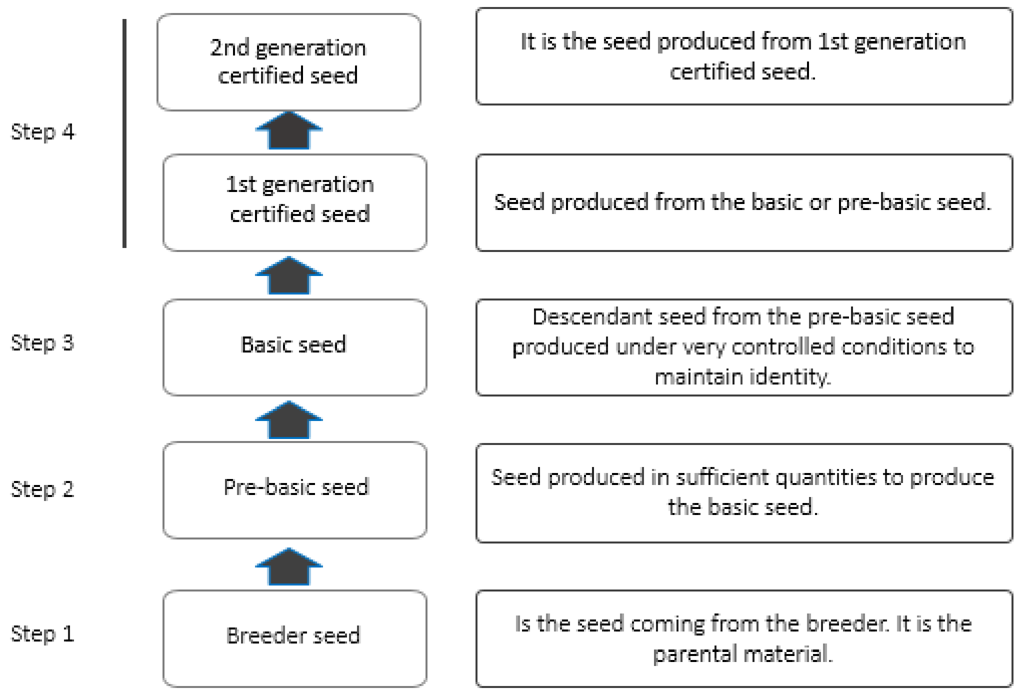
3.2. Dissemination of improved seed

Before the seed coming from the breeder is disseminated it has to be certified. The process of seed certification in Mozambique is usually conducted by the Unity of Basic Seed (USEBA). According to Mozambican seed regulation (GoM, 2013) the certified seed has to be registered on the official list of varieties belonging to any of the following classes: pre-basic, basic, and 1st and 2nd generation certified classes, which comply with a set rules and seed regulations. A certified seed falls into one of the following two categories: The first (1^{st}) generation certified or the second (2^{nd})

generation certified seed (Figure 3). The 1st generation certified seed is produced from the basic or pre-basic seed under the supervision and control by the official certification body (National Seed Authority). The 2nd generation certified seed is produced from 1st generation certified seed under the control of the official certification body (GoM, 2013).

It is important to highlight that the entire certification process is integrated in the Formal Seed Production System but accounts only for 2% of the seed used by farmers. According to the Integrated Development Report for the Seed Sector (DISS, 2017), the main constraints affecting the seed production system are the lack inspection during seed production, due to limited means of transport (linked to the limited funds) and the very few number of seed inspectors available to ensure excellence in quality control. In addition, AGRA-SSTP, (2016) reports that there are a few companies engaged in seed production, but they only produce a small quantity of the certified seed that reaches farmers. For instance, in 2016 only three 3 varieties of rice seeds were available to farmers. Lastly, seed quality management like storage and cleaning (most farmers clean seeds manually) is very poor, not contributing to stronger demand of high quality rice seed (AGRA-SSTP, 2016).

Figure 3. Roadmap of seed production by the Basic Seed Unit (USEBA

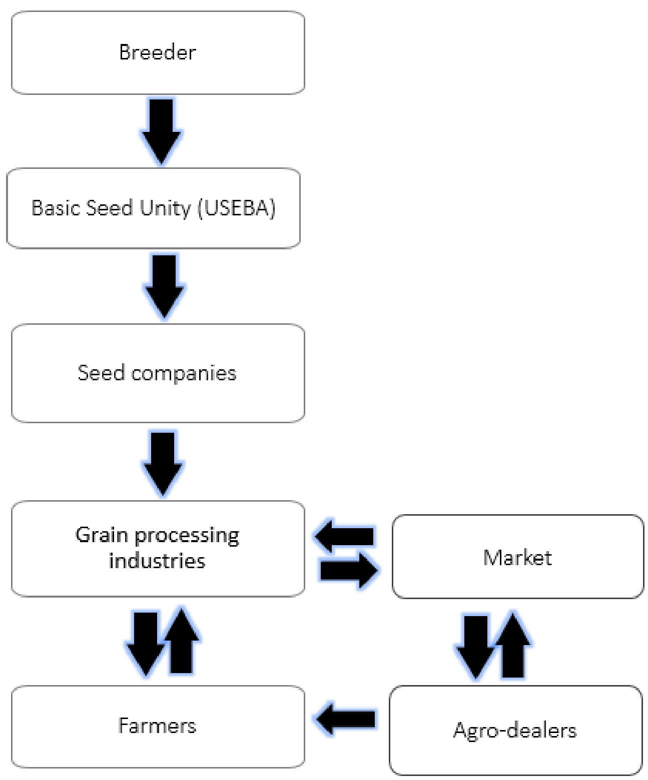


Source: GoM (2013)

In the process of dissemination of seed, farmers acquire certified seeds and additional technological advices from agricultural extension and research services. In Mozambique various extension methods (Training and Visits, Participatory Variety Selection, Vitrine Technology, Integrated Technology Transfer Program, Farmer Seed Fair, Demonstration Field and Farmer Field Schools) were developed to promote technological innovation in the rice sector but have not had the expected impact on rice farmers. Currently, however, farmers gain access to certified seed by purchasing directly from commercial seed companies or from certified seed producing farmers and agro-dealers who also work as commercial seed producers (GoM, 2007).

To improve farmers' access to certified seed, researchers in the rice program came up with the idea (a suggestion described in the IIAM 17º Newsletter), that instead of farmers acquiring improved seed through certified seed producing companies, farmers could acquire rice seed through the rice grain processing industries (Figure 4). With such a model, farmers can receive a better recommendation from the industry regarding the varieties to cultivate (IIAM, 2010) and also be assured of the possibility to acquire high quality seed due to the greater capacity of industry to effectively clean seeds (DISS, 2017). However, the financial structures necessary to acquire the equipment to achieve a regular operation of the industries need to be strengthened (DISS, 2017).

Figure 3. Proposal of improved varieties' path from the breeder to farmers



Source: IIAM (2010) and Interviewees

To sum up, there is a poor network of efficient dissemination capable of supplying enough quantities of improved seeds to the market. In light of this limitation farmers may be motivated to use saved seeds for subsequent agricultural campaigns, thus, boosting the development of the informal seed production system (Ashoori et al., 2018).

Additionally, other authors (Ashoori et al., 2018; Taylor and Bhasme, 2018) argue that the availability of improved seed to farmers should be followed by technical advice (training and awareness of advantages on using new seeds) in order to assure the rapid adoption by farmers. A study by Janaiah and Debdutt, (2017) reported that, in Nepal certified seed is successfully allocated to private concessionaire companies for further distribution to farmers. The experience in Nepal, leads us to state that in Mozambique appropriate policies are needed to motivate private companies in their active involvement in seed production and dissemination. In the case of Mozambique there are conditions for the private sector to play an important role in the diffusion of improved rice seed varieties.

3.3. Methods of Technology Transfer

In Mozambique, agricultural extension has taken various forms regarding extension methods implementation (including frequency and beneficiaries). Before independence in 1975 (1965 to 1974), agricultural extension was only undertaken by Unstructured Field Visits (UFV) targeted at large-scale farmers engaged in market oriented crop production (MINAG, 2007). According to respondents and the Mozambique Extension Master Plan (MINAG, 2016) the main methods of rice technologies transfer were Training and Visits (T and V), Participatory Variety Selection (PVS), Vitrine Technology (VT), Integrated Technology Transfer Program (PITTA), Farmer Seed Fair (FSF), Demonstration Field (DF) and Farmer Field Schools (FFS`s).

Due to limited financial resources, most of these methods do not work nowadays (MINAG, 2015). The most widely used is the Participatory Variety Selection (PVS), which involves on-station new variety pre-release, addressed to small and medium-scale farmers. According to Matarage, (2012) the PVS may be playing an important role in the dissemination of rice technologies from farmer to farmer although currently, it is frequently conducted on-station, specially in the Zambezia province, in central Mozambique. On the other hand Matarage highlights that limited financial resources is the principal factor through which PVS occurs less frequently. Similar observation was made in the study by Rahman et al., (2015) in Myanmar. There, farmers have expected to see PVS experiments under environments representing their farming conditions. If PVS experiments are carried out directly on farmer's field they will provide an opportunity for greater number of farmers to take part in the process, thus developing new, comprehensive and realistic extension methods with more affordable operation costs.

The decline of Unstructured Field Visits (UFV) during the period of 1965 to 1974 was probably associated with the emergence of rice crop research and the institutionalization of IIAM in 1965. Whereas the failure of Training and Visit method, introduced in 1988, may be due to its constant amendments resulting from its "top down" approach (MINAG, 2007). Most methods of technology transfer have not been used since the independence period, declared in 1975 (Bias and Donovan, 2003). An additional factor was the resignation of contracts that occurred with a larger share of researchers from the Ministry of Agriculture (MINAG 2012).

On the other hand, the Farmer Field Schools (FFS's) were introduced in 1990 with the financial support of the World Vision, an International Agency for Christian Humanitarian Support (Alage and Carmo, 2014) (Table 3). However, in the period between 2007 and 2012 many of the methods became more relevant to rice farming in Mozambique, probably due to the agreement established between IRRI and the Government of Mozambique in 2006. Unfortunately the agreement did not have a more positive impact on rice cultivation because it was not used effectively (MINAG, 2015).

The extension methods were adopted to help increase the agricultural productivity through the diffusion of adequate technological messages to farmers. However, most of the methods continue to be short of reaching the entire farmers' demand for assistance. For instance, the coverage level of extension services was under 13% of farmers assisted between 2003 and 2007, and in 2008 only 8.3% of farmers had access to rural extension (MINAG, 2015).

Table 3. Extension methods for Technology Transfer provided by extension agents and researchers.

Period	Method of Technology Transfer								
	UFV	**T&V**	**PVS**	**VT**	**PITTA**	**FSF**	**DF**	**Media**	**FFS**
1965 - 1974	+	–	–	–	–	–	–	–	–
1975 – 1990	-	+	–	–	–	–	–	–	+
1991 – 2006	-	+/-	**n/d**	**n/d**	**n/d**	**n/d**	**n/d**	**n/d**	**n/d**
2007 - 2012	-	+	+	+	+	+	+	+	+
2013 - Present	-	+/-	+	-	+/-	-	+/-	-	+/-

Source: MINAG (2015) interviewees

Note: +: used most frequently; - / +: less used; - :not used; n/d: no data

3.4. The use of improved rice varieties and agricultural practices by farmers.

Various document reveal the failure in the use of these technologies by farmers (ADVZ, 2015). For instance, from the point of view of the national rice production program meeting report (MINAG, 2015), estimations indicate that only 2.8%, 6.3%, 4.2% and 4.3% of farmers use fertilizers, pesticides, mechanization and irrigation, respectively. It has also been documented that the growing practices involved in land preparation (tillage, harrowing, leveling and bunding) have been carried out with huge limitations. For example 77 % of farmers do not bund the fields and the leveling with the use of agricultural machinery is almost non-existent (ADVZ, 2015). Other similar situations of poor use by farmers are the improved post-harvest practices that aim at maximizing rice yields and quality, through grain cleaning, drying and storage techniques (DISS, 2017).

This significantly low use of agricultural inputs and good farming practices in the rice sector is due to the high costs involved (Ashoori et al., 2018) and the lack of a developed credit system (Seck et al., 2010). Nevertheless, Seck et al. (2010) argue that some land preparation practices, leveling and bunding contribute significantly to yield if well conducted by farmers (Ashoori et al., 2018). In their view the combination of these practices can increase yield by 40% and reduce weed biomass by 25%.

Suzuki et al., (2014) studied the accessibility of farming techniques, including inputs, in Northern Ghana, concluding that their use was dependent on the coverage capacity of extension and transport costs for improved seeds and fertilizers.

It has been pointed out by the Ministry of Agriculture (MINAG, 2011), that the Mozambican extension services cover only 5% of farmers. Several documents including the audit report on agriculture refers that these services are not linked to research (Cunguara et al., 2013 and MINAG, 2010), meaning that research results are not sufficiently or effectively transmitted to farmers.

4. Conclusions and policy implications

The discussion in this research leads us to state that the greater number of high yield improved varieties introduced in Mozambique through the operational varietal release system and the advice availability of National and International rice research institutions may give a larger opportunity to update and run a technology transfer program. Nevertheless, many limitations were detected mainly in the patterns of the improved seed dissemination, models of technology transfer and in the adoption of new agricultural practices by farmers. More specifically:

1. The shortage of certified seed production caused by poor field inspection and limited means of transportation leads to unavailability of enough quantities of new seed for farmer's, thus perpetuating the informal seed system.
2. Extension services have a poor coverage capacity and a great share of the methods of technology transfer do not adequately and efficiently disseminate research messages to famers, given the limited funding to support its operation.
3. There is a low adoption rate of improved varieties and other farm inputs due to poor economic conditions of farmers as well as to a lack of knowledge to adopt cultivation practices that are supposed to help increase productivity

Based on these findings, it is recommended that government intervention in the seed production system should promote training for seed producers, namely on inspection matters (from selecting cultivation areas to seed certification). In this manner the National Authority Services could provide huge amounts of better-quality seeds to the market.

It is also suggested that technology transfer agencies be set up closer to the farms, consisting of mobile work brigades committed to monitoring the technical production system transferred to farmers and to disseminate marketing rules, since extension services alone cannot reach many farmers through direct contacts.

Finally, it is recommended that the knowledge of factors involved in the use of modern agricultural technologies be promoted in order to achieve a better technology transfer program. An increased rate of adoption and higher productivity would then improve the welfare of the rice farmers.

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CHAPTER III

FACTORS AFFECTING ADOPTION OF NEWLY DEVELOPED RICE TECHNOLOGIES TRANSFERRED FROM RESEARCH TO FARMERS IN MOZAMBIQUE

Factors affecting adoption of newly developed rice technologies transferred from research to farmers in Mozambique

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Abstract

One of the huge challenges in Mozambique's rice value chain is to increase rice production at affordable price and thus contribute to reduce poverty, hunger and malnutrition of the Mozambican population. With this concern national research institutions in partnership with international ones, have been establishing programs aimed at developing and introducing high potential better-quality varieties using modern agricultural practices, with good nutritious characteristics and adapted to Mozambique's main ecosystems, rainfed or irrigated. However, it is recognized that the newly developed and introduced technologies are not being properly used by farmers. Therefore, characterizing rice growers, to estimate adoption rates and determine the main factors that are significant in explaining the adoption of improved rice technologies are the scope of this study. A pretested questionnaire containing structured questions was used to survey randomly 100 households in four administrative localities including Nicoadala, Namacata, Munhonha and Nhafuba from Nicoadala's districts in Mozambique. Statistical Package for Social Science was used for data analusis using the Binary logistic regression model to identify the mainl factors which significantly contribute to use or not of a particular improved rice technology. Results revealed that male are the decision-maker agent on the rice cultivation in the majority of households.

Farmers, although in the economically active age, have a low level of schooling, lack of experience and unwariness on advantages of using the newly technologies. In addition the result obtained shows that only 34% of rice farmers adopted improved rice varieties , 22% used fertilizer, 29% used pesticides, 30% performed land preparation, 23% adopted line sowing, 26% used mechanization, 24% adopted weed management, 12% irrigated the crop, and 49% adopted post-harvest practices. Famers' socioeconomic and demographic factors such as gender, age, level of education, farm size, knowledge, experience, distance to market access, extension visits, number of visits by extension agents, membership to association, credit and farm size are affecting adoption and decisions on adopting improved rice technologies. Thus, political decision-makers should develop and promote programs aiming at improving these socioeconomic factors as to have increased adoption among rural rice farmers.

Keywords*:* improved rice seed, households, agricultural technologies, socioeconomic and extension services.

1. Introduction

The use of Improved agricultural technologies (such as improved seeds, fertilizers and others) in Mozambique was suggested by the Government through the Green revolution strategic plan document (GoM, 2007) and the Strategic Plan for Agricultural Development, 2010 to 2019 (PARPA, 2009). Such documents aim at reducing hunger and ensure food security by improving the major crops (maize, rice and cassava). However, potential yields of these selected crops are still very low. For instance, rice ranges on average from 0.7 to 1.2 tons per hectare in rainfed lowland conditions (IIAM, 2018).

According to the document of strategic plan for rice crop development in Mozambique (MINAG, 2011), the poor use of improved rice technologies such as improved seeds, application of fertilizers, application of pesticides, land preparation, sowing, mechanization, irrigation, pest and disease control, weed management and post- harvest techniques by farmers, are the main reasons for the low yields of rice cultivation. In the sample study only 8.7 percent of farmers use the improved seeds and on top of that, few adopt other farming inputs such as chemical fertilizers (only 2.8 percent of farmers), pesticides (only 6.3 percent of farmers) and among others.

Feder and Zilberman (1947) and Uaiene et al., (2009) argued that to explain comprehensively the reasons behind the low technology adoption and propose changes on the technology transfer process, the comprehension of socioeconomic factors associated to decisions is very important. According to Handio and Yuansheng, (2018) studies analyzing the determinants of rice adoption, were made only by a few rice-growing African countries in particular Benin (Dandedjrohoun et al., 2012), Nigeria (Tiamiyu et al., 2009) Ethiopia (Asmelash, 2012) and Kenia (Okello et al., 2016).

On the assumption that factors associated with the adoption of improved rice varieties especially for rainfed and irrigated ecosystems in Mozambique need to be urgently identified, this study focused on inputs and farming practices used in the most suitable areas for rice cultivation in Mozambique. In particular this work aims at: (1) to describe farmer's demographic and socioeconomic characteristics; and (2) figure out the main factors that are significant in explaining the use of the improved rice technologies.

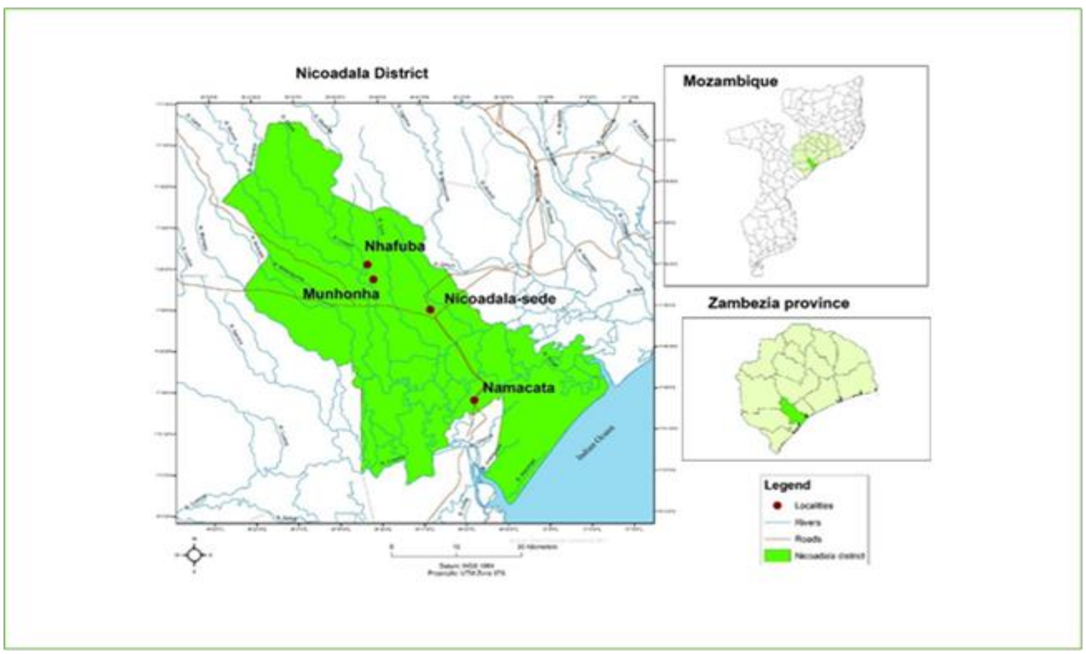
2. Methodology

2.1. Survey site

Survey was carried out between January to June, 2019 in Nicoadala district where the rice production takes place in four administrative localities: Nicoadala, Namacata, Munhonha and Nhafubua**.** Nicoadala district with an area of 6, 285 Km^2 is about 6% of the territory of Zambezia and is located in the South part of the Province. This district borders Morrumbala and Namacurra districts to the North, Quelimane to the South, Mopeia to the West, Namacurra district and Indian Ocean by the East. The population of Nicoadala is about 234, 475 people, with a population density of 31.6/Km^2.

The geographic position of the four study areas can be seen in Figure 5.

Figure5. Location of the study area



Source: Data georeferenced during the survey.

2.2. Sampling design

A pretested questionnaire composed of 4 sections in a random survey of 100 households (25 each) in the administrative localities. The first part of the tool (questionnaire) encompassed structured questions (dummy, categorical and nominal variables) for demographic information collection. While the second section comprised dummy questions for adoption determinants estimation. The pretest was submitted to rice experts from Mozambique public institutions (the directorate of agriculture of the Zambezia province and agricultural research station of Muirrua) and then modified based on the experts suggestions.

2.3. Data analysis

2.3.1. Descriptive analyses

2.3.1.1 Percentages

Statistical Package for Social Science (SPSS) was used for data analysis where percentage values were considered for demographic and socioeconomic information such as, gender, age, marital status, household size, level of educational, farm size, knowledge on the advantages on using the new rice technologies, experience, extension visit, number of visits by extension per month, membership to association, government support (credit), number of family member studying and distance to market.

2.3.1.2 Non parametric test

Rates of adoption were estimated following different steps. We used Kolmogorov-Smirnov test to detect hypotheses of data distribution. As Kolmogorov-Smirnov test shown highly significance ($P<0,01$) indicating that the data did not have a normal distribution we then used a nonparametric test based on Chi-square (χ^2) to measure dissimilarity of percentages between the adopter and non-adopter groups (Imbens, 2011).

2.3.2. Binary Logistic regression model

To analyze the principal factors which significantly contribute to the use or not a particular improved rice technology, binary logistic (logit) regression model was used since the questions on the use of technology can only have two possibilities of answers (Yes in case the technology is used and otherwise No). Logit regression model leads to calculate the probability of adoption of a newly developed technology conditional on the explanatory variables included in the model (Onyeneke and State, 2017). Analytical expression of this model can take the following form:

$$Q_i = \beta_0 + \beta_i X_i \qquad Equation\ 1$$

$$L_i = (P_i/[1 - P_i]) = \beta_0 + \beta_i X_i \qquad Equation\ 2$$

Where: Q_i denotes adoption of rice technology; 1 adopt, otherwise 0; β_0 is the intercept or constant and β_i is the vector of coefficients or the vector of covariates X_i; L_i denotes logit and $P_i/1 - P_i$ the odds ratio of probability of occurrence of events; P_i denotes the predicted probability that the event occurs to an individual with a given set of characteristics; and $1 - P_i$ is the predicted probability that the event does not occur (Greene, 1997; Onyeneke and State, 2017). The dependent variables Y in table 4 are: use of improved varieties, use of fertilizer, pesticide, land preparation, sowing, mechanization, irrigation, weed management and post-harvest practices. The explanatory variables X in table 5 are: gender, age, marital status, household size, level of educational, farm size, rice farming experience, knowledge of the advantages of using the new rice technologies and number of extension visit among others.

Table 4. Description of dependent varieties

	Dependent variables	
y1	Use of improved rice variety	1 if adoption, otherwise 0
y2	Use of fertilizers	1 if adoption, otherwise 0
y3	Use of pesticide	1 if adoption, otherwise 0
y4	Land preparation (leveling and bunding)	1 if adoption, otherwise 0
y5	Line sowing of paddy cultivation	1 if adoption, otherwise 0
y6	Use of Mechanization	1 if adoption, otherwise 0
y7	Weed management	1 if adoption, otherwise 0
y8	Use of irrigation	1 if adoption, otherwise 0
y9	Postharvest practices	1 if adoption, otherwise 0

Source: data from survey, 2019

Table 5. Description of the explanatory variables included in the technology adoption model

	Independent Variable	
X1	Gender	(1 if male 0 if not)
X2	Age	(21-30; 31 - 40; 41- 50; 51- 60; 61 - 70; >70)
X3	Marital status	(married, single, divorced, widowed)
X4	Number of family members	(1-5; 6-10; 11-15; 16-20)
X5	Level of schooling	(1 if no education at; 2 if primary school; 3 if professional; 4 if secondary school; 5 if university degree)
X6	Farm size in hectare	(< 0.5 ha;0.6 - 0.8 ha; 0.9 -1.2ha; 1.3-1.6ha; 1.7-2.0ha;> 2.0 ha)
X7	Knowledge on new variety advantages	(1 knowledge; 0 if no knowledge)
X8	Years of experience	(< 6-10; 11-15;16-20; >20)
X9	Extension visit	(1 if yes 0 if no visit)
X10	Number visited by extension/week	(every day; 15 days; 7 days; once)
X11	Membership to association	(1 if yes 0 if not)
X12	Government support (credit)	(1 if yes 0 if not)
X13	Farm ownership	(1 if yes 0 if not)
x14	Number of family member studying	(1-5; 6-10; 11- 15; 16-20)
x15	Distance to Market	(<5Km; 6-10Km;11-15Km; >15km)

Source: Data from survey, 2019;

2.3.2.1. Important tests in regression model

Main tests considered in this study include, p-value, which reflects to hypothesis whether a coefficient or the explanatory variable is equal to zero (β_i= 0) or different (β_i≠0) to; coefficient (β_0) or the intercept of the function, to understand whether an explanatory variable is relevant inside the equation; odds ratio (which sees if the odds obtained for explicative variables proves to be significant) and, Hosmer, Lameshow Chi^2 and the pseudo R^2 Nagelkerke (analyses whether data is adequate to the model applied).

3. Results and discussion

3.1. Characteristics of rice growers in Mozambique

Table 6. presents the characteristics of surveyed farmers at the study site (Nicoadala district, Mozambique). According to data analyzed in this study, the majority of farmers surveyed are Male (58%). On the one hand this finding clearly suggests that the rice production activity in the cultivation area is headed by Male. On the other hand, it may mean male are the decision-makers on the rice cultivation in most households. This is in line with findings by Onyeneke and State, (2017) who, studying the decisive-factor for the new technology adoption in Nigeria found that male were the deciders on the choice of rice improved technologies.

However the National Rice Production Strategy document (MINAG, 2011) contradicts this view by reporting that female are the driving force of rice cultivation activities, including the adoption of new technologies.

Results also show the majority (36%) of the households surveyed are in the age group 41 to 50 years old. This age category corresponds to the majority of the economically active population in

Mozambique (BPES, 2010) and it is also consistent with what was stated in the Social Economic Plan Document which referred, agricultural activities in Mozambique are mostly practiced by economically active age farmers. Similarly, Bekele, (2005) showed that in Ethiopia rice production was mostly practiced by farmers in a similar age group.

Table 6. Socioeconomic characteristics of household respondents

Socioeconomic characteristic	Percentage (n=100)
Gender (gender of household head)	
Male	58
Female	42
Age	
21-30	9
31 – 40	19
41- 50	36
51 - 60	10
61 – 70	17
more than 70	9
Marital status	
Married	66
Single	26
Divorced	3
Widowed	5
household size	
1-5	2
6-10	92
11-15	4
16-20	2
Level of education	
No education ;	24
Primary school;	53
Professional;	13
Secondary school;	4
University	5
Farm size in hectare	
less than 0.5	38
0.6 - 0.8	26
0.9 -1.2	14
1.3-1.6	8
1.7-2.0	7
greater than 2.0	7
Knowledge	
Knowledge	29
No Knowledge	69
Experience (years)	

less than 5	3
6-10	10
11-15	30
16-20	48
greater than 20	9

Source: author’s own computation based on data from survey, 2019

Table 6a. Socioeconomic characteristics of household respondents (continuing)

Socioeconomic characteristic	Percentage (n=100)
Extension visit	
Visit	64
No visit	36
Number of visits by extension/month	
Every days	1
15 days	4
7 days	59
Once	36
Membership to association	
Member	45
No member	55
Government support (credit)	
Support	9
No support	91
Land ownership	
Owner	27
No owner	73
Number of family members studying	
1-.5	81
6-.10	5
11-.15	0
16-20	0
None	14
Distance to Market (km)	
less than 5	15
6 -.10	17
11-.15	48
greater than 15	20

Source: author’s own computation based on data from survey, 2019**.**

Whit respect to marital status, the results indicate that the majority of farmers are married (66%). Married farmers represent a good strength in agriculture because that enlarges the labor force in farming activities and also allows for an exchange of suggestions and ideas among the whole family (husband, spouse and sons) especially in the decision of adopting the agricultural technologies (Onyeneke and State, 2017; Simtowe, 2012).

As far as household size is concerned, analysis revealed that 92% of farmers belong to the category of 6 to 10 members (Table 6a). According to Abubakar et al., (2016) household size is very important in the rice crop cultivation due to the fact that it is an labor intensive crop production.

The education level of household respondents is very low. Results show 53% of farmers having only completed elementary school followed by 24% of the farmers with no schooling at all. The lowest percentage corresponds to those with secondary school level. It is clear that, these farmers are still in need to increase their education even though, apparently, they may have acquired the ability to use modern technologies from the experience acquired over time.

However, this result in level of education is in contrast with findings from Agbamu and Ju, (2005); Amazaand Tashikalm, (2003); Kolawole et al., (2003) and Onyeneke and State, (2017) which have found farmers with relatively high level of education. In sum, the adoption of improved technologies can be achieved in case farmers' literacy levels also increase.

In the survey the majority of the farmers cultivated less than 0.5 hectares of rice. This result was not expected and contradicts the findings of Guilherme et al., (2019) that in Mozambique the majority of farmers are in the dimension bracket 0.5 to 1-2 hectares. Furthermore, the finding in farm size(<0.5) is in accordance within the strategic plan for rice production in Mozambique which consider most farmers inside the rice sector to be cultivating on areas ranging from 0.25 to 5 ha (MINAG, 2015). Moreover, the result conforms to the data found by Cunguara and Darnhofer, (2011); Loevinsohn and Sumberg, (2013) who pointed out that the Mozambican small scale rice farmers not only need to enlarge their cultivation areas as well as to adopt new farming practices in order to be able to increase production levels.

Furthermore, by investigating whether farmers were aware of the benefits of growing the use of improved varieties and other improved farming practices the results reveal that within the total number of farmers interviewed, 69% were unaware of the new agricultural technologies. As for farmers' experience on growing rice crop the results show that 48% are clustered in interval ranging from 16 to 20 years of experience. This implies that although they got some experience in rice production, the numbers are smaller than the average encountered by Onyenekeand State, (2017) which was 27. 2 years of farming experience.

When asked if they had been visited by an extension agent during the previous agricultural season (2017/2018) the majority of farmers (64%) answered "yes" (Table 6a). Furthermore, when inquired about the frequency of visits by extension agents the majority (59%) reported it was seven days each month.

This lack of extension service coverage of rice growers, contrasts with that could be expected from the Master Plan for Extension document. On the one hand the document could have recommended that extension agents should live inside the villages as to facilitate interaction with farmers. On the other hand, taking into account that the extension agents act as a link between researchers and end users of technology, farmers should be informed about the existence and the benefits of effective use of new technologies (Bonabana-Wabbi , 2002). The access to extension services by farmers has been considered to be a landmark in technology adoption, as Bonabana-Wabbi, (2002) reported.

Concerning the Membership to association parameter, data analysis shows, that the majority (55%) of farmers are not members of any association, which is in net contrast with Tiamiyu et al.,(2009) view, who reported that it is important for farmers to take part into their associations. However, one who is a member of an agricultural association is expected to get ability or skills to assist others and provide them with suggestions for purchasing inputs or even the route where to get credit (Simtowe, 2012; Asfaw et al., 2010).

Regarding the access to credit, the majority (91%) of farmers does not get to access to any kind of credit. In what concerns the land ownership, the descriptive data analysis revealed that 73% of household respondents cultivate rice in areas which do not belong to them. However, various areas are borrowed from their neighbors and family members. Regarding the number of family members studying, a sizeable portion (81%) of the households indicated that there are between 1 to 5 members. In terms of the distance between home and local acquisition and selling markets it is between 11 – 15 kilometers.

3.2. Rate of adoption to improved rice technologies

Adoption of rice technologies is presented in table 7. The nonparametric test shows that percentage differences between the groups of adopters and non-adopters were highly significant for all variables except for post-harvest operations.

The table reveals that 34% of the farmers adopted improved rice varieties, a rate that was considered low in the study by Meijer et al., (2015), and that the majority of farmers (66%) still crop traditional rice varieties under rainfed low land ecosystem. Moreover, it also suggests that farmers are unwilling to use newly developed varieties probably because of the lack of knowledge, the poor seed dissemination system and perhaps because they identify greater risks involved on the improved rice varieties farming (Bizimana et al., 2019; Cunguara and Darnhofer, 2011).These indicators hampering the wide adoption, were also identified as important for Eastern and Southern African countries, including Mozambique, Tanzania and Uganda, by other researchers (Nhamo et al., 2014). Numbers in the table also show that 29% of farmers have adopted pesticides, and about 30% of them adopted land preparation operations, whereas 49% adopted post-harvest technologies. Furthermore, fertilizer and irrigation exhibited the lowest rates of adoption: 12% and 22% of the households, respectively.

Table 7. Distribution of rice farmers according to adoption of rice production technologies.

		Rate of adoption (%); N = 100			
N	Rice technology	No adopter (%)	Adopter (%)	Test χ^2	P-Value
1	Improved rice varieties	66	34	10.240	0.001***
2	Use of fertilizer (NPK)	78	22	31.360	0.000***
3	Use of pesticide	71	29	17.640	0.000***
4	Land preparation (leveling and bunding construction)	70	30	16.000	0.000***
5	Line sowing of paddy cropping	77	23	29.160	0.000***
6	Mechanization	74	26	23.040	0.000***
7	Weed management	76	24	57.760	0.000***
8	Use of irrigation	88	12	27.040	0.000***
9	Post-harvest practices	51	49	0.040	0.841^{ns}

Source: author's own computation based on data survey, 2019. **Note**: adoption rate were estimated in percentage through dummy variables composed by 1 (the household adopting technologies) and 0 (those not adopting technologies). For technical relevance, percentages values were run a nonparametric statistics. The P-value corresponds to the Chi-square (χ^2) test towards the following significance levels: * significant at 0.1, ** significant at 0.05, and *** significant at 0.01

3.3. Factors affecting adoption of improved rice technologies in Mozambique

For factors affecting the adoption of improved rice technologies the Binary Logistic regression model was applied for categorical dependent variables classified into adopter and non-adopter for each technology, namely: use of improved rice varieties, use of fertilizers, use of pesticides, land preparation, line sowing of paddy cultivation, mechanization, weed management, use of irrigation and post-harvest practices.

Model and data validation tests were made. For this particular purpose, in the Hosmer and Lameshow test, analysis revealed the higher likelihood than the confidence level (P> 0.05) for all dependent variables. The Negelker-R^2 test was always higher than the Cox and Snell-R^2) test and lastly, the Omnibus test shown a significant likelihood for P<0.05 (table 8); this evidence suggests that both the data and model used are adequate to explain the factors determining adoption of rice production technologies among farmers in the region studied (Table 8).

Table 8. Data and model Validation testes including, Hosmer and Lameshow, Negelkerke and Omnibus testes

Model fit index		use of improved rice varieties	use of fertilizers	use of pesticides	land preparation	. line sowing of paddy cultivation	Mechanization	weed management	use of irrigation	Post-harvest practices.
Hosmer and Lemeshow Test	Chi 2	10.970	22.452	19.050	13.669	7.265	14.386	13.674	13.674	4.216
	P-value	0.203	0.064	0.065	0.091	0.508	0.072	0.091	0.091	0.837
Model summary	R-square Nagelkerke	0,128	0.423	0.419	0.331	0.259	0.457	0.315	0.390	0.219
	Cox & Snell R^2 square	0,067	0.290	0.292	0.207	0.168	0.307	0.212	0.197	0.164
Omnibus test	P-value	0,045	0.004	0.004	0.009	0.054	0.002	0.048	0.023	0.006

Source: author's computation based on data from survey 2019**.**

Concerning the marginal effects of socioeconomic factors affecting technology adoption (Table 9), gender variable (male) has a positive and significant effect on the following variables: use of improved rice varieties (P<0.05), weed management (P <0.05) and post-harvest management (P<0.05). The gender of the household head is a dummy variable that takes the value of 1 in case the head of the household is male and 0 if female. Since we noted that male category was dominant in terms of demographic information in this research (see table 6) we chose the male category as reference during the logistic regression analysis process.

These findings indicate that the increase of the male variable increases the likelihood of adopting improved rice varieties by a positive coefficient (β) by 0.431 (43.1%), weed management by 1.359 (134, 9%) and post-harvest practices by 0.989 (98.9%).

On the other hand, results representing the individuals in the male category shown the odds ratio of adopting improved rice varieties, weed management and post-harvest practices respectively, by 5,642; 3,891; and 2,688 times higher than the individuals in the female category (Table 10) making it different from early results study by Sumberg, (2005) who found lesser numbers.

In addition, the findings regarding the gender variable are completely different from those found in Nepal in the study by Himire et al., (2015) which encountered for this explanatory variable (gender) a non-statistically significant likelihood result to adopt the improved rice varieties and other agricultural practices.

In that case, where the explanatory variable (gender) is not associated with any agricultural technologies included in a model, Himire et al., (2015) and Ly et al., (2016) try to defend that it occurs due to the fact that decisions in choosing improved agricultural technologies are made in accordance with the opposite gender. We would rather state that men are the driver factor for the use of agricultural inputs in Mozambique, especially in the research area.

Table 9. Coefficients(β) from binary logistic regression function for determinants of adoption.

variable	Use of improved rice varieties	Use of fertilizers	Use of pesticide	Land preparation	Line sowing of paddy cultivation	Mechanization	Weed management	Use of irrigation	Post-harvest practices
Gender	0.431(0.011)***	-0.140(0.827)	-0.056(0.929)	0.259(0.704)	0.453(0.458)	-0.270(0.694)	1.359(0.038)**	-1.583(0.133)	0.989(0.045)**
Marital status	-0.518(0.234)	-0.165(0.715)	-0.228(0.576)	-0.284(0.497)	0.606(0.192)	0.096(0.839)	-0.092(0.834)	0.899(0.206)	0.186(0.568)
Age	0.279(0.296)	0.230(0.305)	0.398(0.08)*	-0.122(0.806)	0.341(0.147)	0.179(0.471)	0.326(0.141)	0.008(0.982)	0.166(0.335)
household size	1.081(0.352)	0.031(0.961)	-0.113(0.86)	-0.165(0.183)	1.119(0.117)	0.699(0.343)	-0.701(0.234)	0.759(0.445)	0.623(0.220)
Level of schooling	0.686(0.044)**	-0.368(0.264)	-0.522(0.122)	0.467(0.0 83)	0.670(0.07)**	0.266(0.494)	0.003(0.991)	-0.017(0.974)	0.317(0.221)
Number of family members studying	-0.239(.0.341)	0.054(0.835)	-0.237(0.302)	0.269(0.228)	-0.193(0.333)	-0.18(0.432)	0.028(0.915)	1.173(0.168)	0.156(0.400)
Farm size (hectare)	-0.393(0.036)**	-0.578(0.016)**	-0.37(0.106)	-0.216(0.331)	-0.441(0.054)**	-0.444(0.076)**	-0.251(0.229)	-0.641(0.085)*	0.025(-0.089)*
Land ownership	0.385(0.596)	-0.144(0.693)	-0.058(0.872)	-0.364(0.356)	-0.279(0.356)	-0.175(0.648)	0.207(0.562)	-0.697(0.197)	-0.076(0.784)
Knowledge	1.222(0.008)***	0.634(0.275)	0.237(0.705)	0.303(0.623)	0.627(0.623)	0.847(0.334)	0.217(0.71)	-0.754(0.373)	0.37(0.455)
experience (years)	0.764(0.022)**	0.167(0.491)	0.282(0.234)	0.186(0.972)	0.446(0.077)**	0.268(0.014)***	0.1(.0.657)	-0.153(0.634)	-0.126(0.475)
Distance to Market (km)	0.027(0.931)	-0.307(0.149)	-0.337(0.108)	-0.007(0.972)	-0.31(0.136)	-0.583(0.014)***	-0.127(0.529)	-0.549(0.102)	0.295(0.051)**
Extension visit	-0.177(0.788)	0.390(.0.261)	0.313(0.358)	0.924(0.015)**	0.175(0.617)	1.102(0.004)***	0.502(0.135)	0.847(0.033)**	0.601(0.041)**
Number of visit by extension /month	1.38(0.017)**	0.259(0.353)	0.14(0.613)	0.038(0.897)	-0.124(0.661)	-0.095(0.76)	0.243(0.339)	0.562(0.156)	-0.193(0.345)
Membership to association	-0.187(0.772)	1.710(0.134)	2.297(0.053)**	0.705(.0.552)	-0.289(0.783)	1.408(0.209)	1.431(0.194)	0.715(0.559)	-0.5(0.619)
Government support (credit)	1.344(0.256)	0.242(0.434)	0.758(0.357)	1.713(0.087)**	-1.395(0.191)	-0.228(0.080)**	0.56(0.515)	-18.817(0.999)	0.251(0.743)
Constant	11.934(0.025)	-2.696(0.434)	-4.397(0.214)	-0.97(0.787)	-0.283(0.932)	-2.583(-0.492)	-6.043(0.088)	4.067(0.999)	-4.547(0.135)
Pseudo R^2 Nagelkerke	0.423	0.423	0.419	0.212	0.259	0.457	0.315	0.39	0.219
Likelihood chi^2	77.971	79.803	83.352	101.595	83.865	73.229	85.800	47.371	118.240
Chi^2 Omnibus	40.367	33.59	33.909	15.665	17.972	35.876	23.306	21.461	17.576

Source: author's computation based on data from survey, 2019.

Note:

Values out of the parenthesis are coefficients of the model. Values in parenthesis are the sig or P-Value.
*Significant at 10% probability level (P < 0, 10)
** Significant at 5% level (P < 0, 05)
*** Significant at 1% level (P < 0, 01)
R^2 = R - square
Chi^2 – Chi - square

Table 10. Odds ratio of the variables in the equation

Variable	Use of improved rice varieties	Use of fertilizers	Use of pesticide	Land preparation	Line sowing of paddy cultivation	Mechanization	Weed management	Use of irrigation	Post-harvest practices
	OR	OR	OR	OR	OR	OR	OR	OR	OR
Gender	5.642	0.869	0.946	1.296	1.573	0.763	3.891	0.205	2.688
Marital status	0.725	0.848	0.796	0.753	1.832	1.1	0.912	2.457	1.205
Age	1.573	1.259	1.488	0.885	1.406	1.196	1.386	1.008	1.18
household size	0.987	1.031	0.893	0.848	3.061	2.012	0.496	2.135	1.865
Level of schooling	0.762	0.692	0.593	0.627	1.954	1.304	1.003	0.983	1.373
Number of family member studying	0.727	1.056	0.789	0.764	0.824	0.836	1.029	3.23	1.168
Farm size in hectare	0.718	0.561	0.69	0.806	0.643	0.642	0.778	0.527	1.025
Land ownership	1.123	0.866	0.944	0.695	0.756	0.84	1.23	0.498	0.927
Knowledge	5.563	1.886	1.267	1.353	1.873	2.333	1.242	0.471	1.447
Experience (years)	1.349	1.182	1.326	0.83	1.561	1.307	1.105	0.858	0.882
Distance to Market (km)	1.169	0.736	0.714	0.993	0.733	0.558	0.881	0.577	1.343
Extension visit	1.043	1.476	1.367	2.52	1.191	3.01	1.652	2.332	1.824
Times visited by extension /month	1.066	1.296	1.151	1.039	0.883	0.909	1.275	1.755	0.825
Membership to association	3.007	5.528	9.944	2.023	0.749	4.087	4.181	2.044	0.606
Government support (credit)	1.074	1.274	2.134	5.546	0.248	0.797	1.751	2.055	1.285

Source: from survey 2019, Mozambique.

Note:
OR = Odds ratio

The age variable has a positive and significant effect (P < 0.10) for the use of pesticides, meaning that with the increase of a unit in farmers' age, the likelihood farmers adopt pesticides is improved by 0.398 (39.8%). In addition, coefficients found for the age are consistent with those of Rasyid et al., (2016) In a similar model these authors found that the variable age of farmers revealed a positive effect on technical effectiveness especially to pesticides, fertilizers among other agricultural technologies. It all implies that new practices aimed at improving rice crop production levels are increasingly adopted as rice farmer's age increases.

Moreover, these results confirm the view of some authors (Uaiene et al., 2009) who, analyzing elder individuals (household's heads) found an upward trend in adopting new agricultural technologies, such as agricultural mechanization, even though such observations were made for a different crop (tobacco). However, this view is associated with the belief that farmers who have gained experience throughout the years have higher ability in adopting better decisions.

Regarding the level of education variable, it showed statistically positive and significant results when crossed with the following dependent variables: the use of improved varieties; land preparation; and line sowing of paddy cultivation. Significance levels of these 3 regressions were of 5% (P <0.05), 10% (P<0.10), and 10% (P<0.10) respectively, and all coefficients (β) are positive: β = 0.686, β = 0.467 and β = 0.670 respectively:

Thus, results for each of these variables suggest that increasing the level of schooling by 1%, increases the likelihood that farmers will adopt the improved technologies by 0.689 (68.6%) especially for the improved varieties; 0.467 (46, 7%) for land preparation; and by 0, 670 (67,0%) for line sowing of paddy cultivation. In addition, these positive coefficients (β) coming from regressions between the level of schooling and rice technologies are on line with those found in

North Sindh, Pakistan, in the study conducted by Handio and Yuansheng (2018) who similarly found a positive association. Same findings were obtained in the study by Himire et al., (2015) in Nepal who concluded that a farmer has the ability to quickly accept advices and opinions provided by researchers and extension agents as the level of education increases.

However, although there is a significant number of authors reporting findings with similar positive coefficients, it may be important to note that there is a small number of authors who found negative associations, such as Khanna, (2001) and Loevinsohn, (2013).

Farm size had significant relations with 6 dependent variables: the use of improved varieties (P <0.1); use of fertilizer (P <0.1); line sowing of paddy cultivation (P<0.05); mechanization (P <0.05); use of irrigation (P <0.10); and postharvest practices (P<0.10). In terms of their effect, the variables in the equation presented negative coefficients suggesting that with a 1% increase in farmers' area there was less likelihood of adopting the improved varieties and farming practices respectively by; -0.393 (-39.3%); -0.441 (-44.1%); -0.444 (-44.4%); -0.641 (-64.1%); and -0.025 (-2.5%).

Negative influences in farm size when crossed with the rice technologies may be explained in accordance to Lavison, (2013) who claimed that it was due to the negative influence from other relevant unknown factors that affect the use of improved technologies (Jamal et al., 2014). On the other hand, the lack of economic power of farmers to maintain labor in larger cultivation areas may limit adoption of newly developed agricultural technologies (Lavison, 2013).

Other authors like Bonabana-Wabbi, (2002); Buah et al., (2011); Landini and Brites, (2017) and Lowenberg-DeBoer, (2000) found similar results. And Yaron's et al., (2017) point out cases where there is no possibility for farmers to increase areas, and they prefer to adopt land saving technologies (zero grazing, home green technology) and other labor-intensive operations as an alternative to increase productivity.

However, results showing negative effects in the farm size contrast with those found by Ahmed et al., (2015); Kasenge et al., (2017) and Uaiene et al., (2009) that have shown a positive association. The importance of this association is explained by the fact that there are technologies that cannot be used on small farms such as irrigation, mechanization and others. It is therefore extremely important for farmers to extend their land for the new technology adoption process in order get the appropriate return from technology investments. In sum, while cultivating small parcels the use of animal power for plowing instead of mechanization is the most advisable choice (Cunguara et al., 2011).

According to results the coefficient (β) in the knowledge variable was of 1.222 (122.2%) positive and significant (P <0.001). This means that farmers who are aware of the benefit to using improved varieties are naturally more willing to adopt. The binary logistic regression model analysis showed significant associations in the following variables: use of improved rice varieties (P<0.05); line sowing of paddy cultivation (P<0.10); and mechanization (P <0.5). It means that the increase in years of experience of farmer increases the likelihood of farmers to adopt technologies, specifically the use of improved seed by 0.764 (76.4%), line sowing of paddy cultivation by 0.446 (44.6%) and mechanization by 0.268 (26.8%).

In addition, farming experience of farmers, increases the likelihood for perceiving the performance of agricultural practices. Furthermore, positive effects in the experience variable on the adoption of the rice technologies may be explained by the fact that, probably farmers with a considerable number of years of experience influence other farmer's adoption. This would confirm the view of

Handio and Yuansheng, (2018) that highly experienced farmers are leaders in the adoption of new technologies.

In what concerns the distance to market, the result was statistically significant for mechanization ($P<0.05$) and post-harvest ($P<0.05$) variables. However, the association for the mechanization variable is negative: $\beta = - 0.583$ (-58,3 %). One possible explanation for this negative effect may be, that those farmers who are further away from the market are less likely to adopt improved rice technologies due to increased transaction cost, as referred by Hagos, (2015); Handio and Yuansheng, (2018) and Simtowe, (2010). Shorter distance to the market, where generally farmer purchase inputs, agricultural implements and sell commodities is likely to decrease transaction costs thereby influencing early adoption (Abubakar et al., 2016).

Regarding the extension visits, results showed almost half (four out of nine) of dependent variables included in the model were statistically significant at the confidence levels of 0.01 and 0.05. It suggests that a unit increase in the number of the contacts between extension services and farmers, will lead to increase the likelihood of farmers adoption by 0.920 (92,0 %) in land preparation; 1,102. (110.2%) in mechanization; 84.7% in irrigation; and 60.1% in post-harvest practices.

Association between these variables was already expected given that the importance of direct contact between extension agents and farmers necessarily conveys vital information to farmers and facilitates the exchange of learning from each other. This interaction will lead these farmers to their own choice of a particular technology, as the theory of diffusion and innovation of technology highlights (Uaiene et al., 2009).

As to the number of visits per month from the extension services to the farmer's firms, analysis showed a positive and significant effect ($P <0.05$) only in adoption of improved varieties, meaning that the likelihood that farmers will adopt improved rice seeds increases with the increase of the number of visits per month.

It is important to highlight that this explanatory variable (number of visits by extension services to farmers) was included in this analysis to understand whether the frequency of extension agents' monthly visits to farmers would have any positive effect mainly on the adoption of the improved rice varieties. In addition we wanted to test the orientation stated in the Master Plan of Extension document (MINAG, 2007) which recommends that in order to improve technical extension assistance to farmers, extension agents should reside in the communities where farmers live. Apparently this instruction is not yet been followed as shown in the study from Cunguara et al., (2011)

Thus, positive effects between extension and technology adoption is due to exposing farmers to information based upon innovation and diffusion theory, ending up to stimulating the adoption (Uaiene et al., 2009; Buah et al., 2015).

The membership to association variable was positively and significantly associated ($P < 0.05$) only with the use of pesticides variable. This weak effect of the explanatory variable when crossed with the large majority of dependent variables may be explained by the fact that there are unobservable factors involved in the relationship, as pointed out by Benin by Dandedjrohoun et al., (2012) when investigating the factors determining diffusion and adoption of improved technologies of rice.

Government support (through credit) variable revealed importance in land preparation and mechanization technologies. It showed statistically significant differences ($P < 0, 10$) and was positively ($\beta = 1,713$) associated with land preparation. But credit was not positively ($\beta = - 0,228$) associated with mechanization even though presented statistically significant results ($P < 0, 10$). If the increase of a unit of credit is likely to lead farmers to adopt land preparation technologies by 171.3 %, it may also reveal that credit is not the only factor that drives farmers to use mechanization, since a lot of training is probably needed. However the lack of effects of association between credit with the new technologies included in the model presupposes that farmers are affected by the need to purchase required inputs for a good rice cultivation (Chandio et al., 2017; Handio and Yuansheng, 2018).

4. Conclusions and policy implications

Rice production chain in Mozambique is characterized by poor use of improved technologies even though research institutions have introduced improved high yielding technologies (mainly improved seeds) adapted to local ecosystems in order to tackle hunger and increase productivity. Given the concern, this study brings the socioeconomic factors which, under the conditions of Mozambique, may contribute to the adoption of improved technologies by farmers.

According to the results of the study one can conclude that the modern rice technologies, including improved rice varieties, use of fertilizer, pesticide, land preparation, line sowing of paddy cultivation, mechanization, weed management, use of irrigation and post-harvest practices are not properly adopted by farmers.

Among the socioeconomic and demographic factors affecting the adoption of improved rice technologies are: gender, age, level of schooling, farm size, knowledge, experience, distance to market access, extension visit, number of visits by extension agents, membership to association and government support (credit).

Thus, creating programs aiming at improving the levels of adoption can be viewed as a high priority in the decision-makers plan. Efforts to design programs for improving the farmer's educational level should be made. The dissemination of improved seeds should be addressed to male farmers because they have the decisive role in the decision making process in rural areas, even though female are considered to be the most active workers in rice farms. Farmers who get such improved seed should be in the active age group and have considerable years of experience in rice crop cultivation and good knowledge on new rice characteristics, inputs and advantages on using the technologies.

This study also points to the need of increasing farmers' land size since the adoption of several modern technologies (mechanization, irrigation, fertilizer and pesticide) that require larger areas to obtain adequate return on the investment made. Land size has a statistically significant negative effect in adoption.

However, it is also necessary to strengthen the extension service access especially in terms of the frequency of their visits to farmers' fields to ensure that these farmers are getting the ability and skills to work with new seeds and the required agricultural practices.

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CHAPTER IV

ESTIMATION OF RETURN TO SCALE IN FARMERS ADOPTING MODERN RICE TECHNOLOGIES IN NICOADALA DISTRICT, ZAMBEZIA - MOZAMBIQUE

Estimation of return to scale in farmers adopting modern rice technologies in Nicoadala district, Zambezia – Mozambique

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Abstract

Use of rice technologies in extended areas of sub-Saharan Africa can increase productivity in agriculture and thus raise farmer's household income and reduce poverty. In Mozambique rice technologies were introduced to farmers by the Government and partners research entities. But the scenario of poor productivity in rice crop with special regard to rainfed regions still remains. The first hurdle to be overcome is the adoption of modern rice technologies that has been discussed in previous studies. There have not been new policies for catalyzing adoption beyond the previous existing methods of transfer (Guilherme *et al.*, 2019. Technology transfer from research to farmers in Mozambique: current status, opportunities and constraints). Furthermore, policymakers have no new evidence about rice technology effects and much less attention is given to assess the effectiveness of rice inputs used by farmers. The existing literature provides limited guidance, although some efforts have been made in other staple food crops such as maize. The interest of this research is to estimate the return to scale coefficient in rural rice adopters so as to understand if the newly developed technologies has an increasing, constant or decreasing return to scale. Data of the research came from a survey of 60 household head's through a pretested questionnaire conducted during the period of January to June, 2019 in Nicoadala district, Mozambique. A logarithmic linear regression Cobb-Douglas production function model was used to estimate individual elasticities and then the level of returns to scale. According to the results returns to scale are decreasing implying that, in the surveyed households, the combination of all inputs included in production process is not positively effective in output. Based on the findings of the study it is needed that the government and other development partners keep working in close collaboration towards full implementation and enforcement of effective strategies to enhance the rate of adoption of seed and other inputs, with special attention to fertilization, pesticides, labor and mechanization.

Keywords: Elasticity, Cobb-Douglas production function, returns to scale, effectiveness

1. Introduction

Paddy rice is an important cereal crop consumed by most of the people and its production provides livelihood security for more than 2 billion people worldwide (Handio and Yuansheng 2018). In Mozambique rice ranks third, after cassava and maize, in daily caloric intake per capita. Daily average caloric intake by households from these three crops are about 680, 480, 170 Kcal/capita/day during the period 2000 - 2015. Growing rice is concentrated in the Central (Zambezia and Sofala) and Northern (Nampula and Cabo Delgado) regions. These regions together account to nearly 85 percent of total rice produced. Historically rice demand exceeds domestic production, creating a large national rice deficit with imports averaging 500 000 tons and production only 228 000 tons. One important explanation factor is that most farmers (around 90%) exploit on average an area of 0.5 to 2 hectares with low yields (ranging from 0.7 to 1.2 t/ha in rainfed lowland ecosystems. This is far below the potential yield of 5 to 10.2 t/ha if farmers were adopting the improved technologies.

National estimation indicates that only 8.7, 2.8, 6.3, 4.2 and 4.3 percent of farmers are using improved varieties, fertilizers, pesticides, mechanization and irrigation, respectively (MINAG, 2015; Guilherme et al., 2019). However, in the Zambezia province, and more specifically in the Nicoadala district, the recent study Guilherme et al., (2019) showed that besides the low adoption rates of improved rice varieties, the absence of other adequate improved technologies is also responsible for the low productivity levels. There are only 34, 22, 29, 30, 23, 26, 24, 12, and 49 percent of the rice growers adopting improved rice varieties, fertilizer, pesticide, land preparation, line sowing of paddy cultivation, mechanization, weed management, irrigation and post-harvest practices, respectively. Additionally, socioeconomic characteristics such as gender, age, level of education, farm size, knowledge, experience, distance to market access, extension visits, number of visits by extension agents, membership to association, credit and farm size are the factors that most affect the adoption.

The importance of adopting improved technologies is stressed by several authors in order to boost production, meet the growing demand, improving family farmer nutrition and achieve reduction of imports. This procedure can create employments and raise living standards ensuring sustainable economic development for the most deprived households (Chen and Martin, 2004; Loevinsohn et al., 2013; Ragasa et al., 2015 and Simtowe, 2012). In addition, with adoption of modern technologies, input elasticities are expected to improve, rice productivity and eradicate food insecurity. To revert the situation it is important that Mozambican police-makers play a positive role in helping farmers to adopt the existing modern technologies. The policies should ideally be designed using evidence on the effectiveness of adequate input used by farmers (Cunguara and Darnhofer, 2011; Fox, 2002; Izekor, 2017; Whitfield et al., 2015).

In recent times, the constant return-to-scale from a production function has been used by agricultural economists for obtaining the economic optimum output (Liu et al., 2019; Mutyebere et al., 2018; Reynès, 2018; Wu et al., 2019). Mutyebere et al., (2018) studies in Uganda have shown that a correct combination of agricultural inputs results in increasing return-to-scale coefficients for adopters. The elasticity of all inputs studied was higher further suggesting that the adoption of inputs was a key requisite for achieving good results. In Mozambique no studies have reported yet any estimated level of returns. The question therefore arising is whether the adopters achieve a good return from improved technologies employed on the production process. Thus, the scope of this paper is to estimate the stage of returns-to-scale in paddy rice through elasticity analysis with a Cobb - Douglas production function so as to understand the effectiveness of technologies used by farmers.

2. Methodology

2.1. Location of study area

The survey was carried out in 4 administrative areas of the Nicoadala district: Nicoadala, Namacata, Munhonha and Nhafubua. Nicoadala accounts for an area of 6,285 km^2, which is about 6% of the territory of Zambezia province. The district borders Morrumbala and Namacurra districts to the North, Quelimane district to the South, Mopeia to the West and the Indian Ocean to the East. Nicoadala population is about 234, 475 people, with a population density of 31.6 inhabitants/Km^2.

2.2. Survey

2.2.1. Source of data and measures

A pretested structured questionnaire was administrated during the period between January and June 2019 to collect primary data from a total of 60 rice farmers (15 farmers each locality) adopting rice technologies. The adopters were purposively selected to have a more homogeneous sample for a better evaluation of the input/output relations. In the choice of households we had the help of experts from governmental institutions such as the Agricultural Research Station of Muirrua and the Directorate of Economic Activities of Nicoadala. The information collected regarded the following variables: i) seed rate; ii) family labor; iii) mechanization; iv) fertilizer v) pesticides and vi) output.

The Variables were collected based on farmers' interviews (Kajisa, 2014). The output, fertilizer, pesticide and seed were measured in kilogram per hectare (Kg/ha). While family labor and mechanization were measured as men per hectare (Men/ha) and hours spent per hectare (H/ha), respectively. For the output variable, each bag (common container used by farmers) of 50 kg of harvested paddy rice was converted to 38 kg of husked rice, according to Kajisa, (2014). The seed rate variable refers to the amount of improved seed used. As to the labor variable, it includes the number of persons manpower employed in all operations of rice cultivation and mechanization was computed as the amount of hours spent during tractor work for land preparation (Coelli et al., 2002; Hendren, 2013; Madau, 2010; Theil, 1971 and Wakili and Isa, 2015).

Additional variables which could have been considered are the post-harvest practices, irrigation and line sowing. They were not selected due to several reasons. For example post-harvest practices were difficult to recall for a large number of the respondents, whereas irrigation was not included because it was used only by a small share of farmers and large number of irrigation schemes are under rebuilding.

2.2.2. Data analysis and the specification of Cobb-Douglas production function

The Cobb-Douglas production function was used to compute individual elasticities which is assessed by the degree of responsiveness of the output to a unit percentage of change in input (Berndt and Khaled, 1979; Majumder et al., 2009; Mutyebere et al., 2018). The function is widely used in economics and socioeconomic studies and its general form is expressed as follows:

$$Q = f(L, K) = \beta_0 L^{\beta_1} K^{\beta_2} \qquad \text{(Equation 1)}$$

Where: Q denotes rice output, L total quantity of labor, K expresses capital. The parameters β_1 and β_2 are the coefficients of labor and capital and β_0 is the efficiency coefficient. Cobb-Douglas function can display any degree of returns to scale depending on the values of β_1 and β_2.

Let us suppose that all inputs were increased by a factor of γ. Then

$$f(\gamma L, \gamma K) = \beta_0 (\gamma L)^{\beta_1} (\gamma K)^{\beta_2} = \beta_0 \gamma^{\beta_1 + \beta_2} L^{\beta_1} K^{\beta_2} = \gamma^{\beta_1 + \beta_2} f(L, K) . \qquad \text{(Equation 2)}$$

Thus if $\beta_1 + \beta_2 = 1$ the function expresses constant returns to scale, since production also increases by a factor of γ. In the case $\beta_1 + \beta_2 > 1$ the function exhibits rising returns to scale, whereas if $\beta_1 + \beta_2 < 1$, it denotes decreasing returns to scale (Bernard et al., 2008; Gechert et al., 2019)

Importantly to highlight that the constant β_1 is the elasticity of output with respect to capital input, and β_2 is the elasticity of output with respect to labor input (Bernard et al., 2008; Gechert et al., 2019; Nichols, 2006).

The function is usually estimated in its logarithmic form:

$$\ln(Q) = \ln(\beta_0) + \beta_1 * \ln(L) + \beta_2 * \ln(K) \qquad \text{(Equation 3)}$$

Our model can then be expressed as:

$$\ln(Y) = \ln\beta_0 + \beta_1 \ln(X_1) + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 \qquad \text{(Equation 4)}$$

where:

Y = Total paddy output (kg/ha)

β_0 = Estimation of productivity;

β_1 to β_5 are the coefficients.

X_1 = Total rate of improved seed used in planting (Kg/ha)

X_2 = Family labor used during rice cultivation (Men/ha)

X_3 = Quantity of fertilizer (Kg/ha)

X_4 = Quantity of pesticide (Kg/ha)

X_5 = Hours in mechanization (Hours/ha)

The coefficients $\beta_1, \beta_2, \beta_3, \beta_4$ and β_5 in the production function are the direct input elasticities. Furthermore, the summation of these individual elasticities is interpreted as the elasticity of production εp (Abdulai and Eberlin, 2001) e.g. the degree of responsiveness of the output to a unit change in input. The elasticity of production estimates the level of returns to scale farmers are getting (Izekor, 2017; Nirmala et. al., 2014) as shown in Table 11.

Table 11. Stages of return

Scale decision	Description	Acronym
$(\varepsilon p) = 1$	Denotes constant returns to scale	CRS
$(\varepsilon p) > 1$	Denotes increasing returns to scale	IRS
$(\varepsilon p) < 1$	Denotes decreasing returns to scale	DRS

Source: Nirmala et al., (2014) Note: (εp) = elasticity of production.

3. Results and Discussion

3.1. Productivity Analysis

This section examines the effectiveness of the agricultural inputs as one of the most relevant drivers for the adoption of new agricultural technologies. Output (the dependent variable) and inputs (explanatory variables) were the main tools to the examination of technological effects (Battese, 1995; Conroy, 2017). For that purpose, 5 factors of production were introduced into the analysis.

3.1.1 Robustness check in the linear regression analysis

3.1.1.1. F – Value

The F-Value for the regression equation was 48.50 high significance ($P < 0.01$) at the 1% level. That means that all explanatory variables included in the production function were vital in any attempt of measuring and explaining the variation of production returns of the farmers (Battese, 1995; George et al.,1996; Majumder et al., 2019)

3.1.1.2. Value of R^2

We also checked the R^2 statistic that took the value of 0.83 indicating that the level of explanation of the independent variables is 83%.The high R^2 denotes that not many predictors were omitted in the explanation in the output variation. The values of robustness found in this study concur with those obtained by Cunguara and Darnhofer, (2011) and Majumder et al., (2019).

3.1.2. Summary statistics of Variables Used for productivity analysis

Figures in Table 12 indicate that the mean output obtained by the farmers was achieved by: using on average 41.17 Kg/ha of improved rice seed; 9.55 Men/ha of family labor; 712.50 Kg/ha of fertilizer; 8.92 Kg/ha of pesticide and in the case of mechanization it was 14.12 hours/ha. The minimum value output (680 Kg/ha) and its maximum (3,500 Kg/ha) reveals that farmers did not reach the expected potential yield of improved varieties available in the country ranges between 5 t/ha (C4-63 variety) and 10.2 t/ha (Simao variety).

Table 12. Summary Statistics of parameters in the estimation of Cobb-Douglas production function

Variable	Unit	Min	Max	μ	σ
Output	kg/ha	680.00	3,500.00	928.67	472.30
Seed	kg/ha	5.00	60.00	41.17	11.49
Family labor	(man/ha)	4.00	120.00	9.55	20.15
Fertilizer	kg/ha	250.00	800.00	612.50	328.59
Pesticide	kg/ha	6.00	13.00	8.92	2.00
Mechanization	hours/ha	4.09	21.03	14.12	53.77

Source: author's own calculation based on data survey, 2019**. Note:** μ = mean; σ = standard deviation

3.1.3. Economic interpretation and partial elasticity of output

The elasticity coefficients for seed, family labor, fertilize, pesticide and mechanization are shown in table 13. Out of the five variables in the model, four were statistically significant, namely, family labor ($P < 0.01$), fertilizer ($P < 0.1$), pesticide ($P < 0.1$) and mechanization ($P < 0.1$). The largest elasticity regards family labor (0.336), followed by mechanization (0.224). The only negative elasticity was observed for fertilizer (- 0.018).

Table 13. Statistics for the parameters of the effects of the inputs in Cobb-Douglas production function.

Variable	Parameter	Coefficient	Standard Error	T-value	P-value
Intercept	β_0	5.864	0.520	11.272	***
LnSeed (Kg/ha)	β_1	0.001	0.066	0.008	ns
LnFamily labor (man/ha)	β_2	0.336	0.044	7.592	***
LnFertilizer (Kg/ha)	β_3	- 0.018	0.052	- 0.347	*
LnPesticide (Kg/ha)	β_4	0.102	0.126	6.813	*
LnMechanization in Lnhours/ha	β_5	0.224	0.131	7.530	*

Source: author's own calculation based on data survey, 2019**. Note**: *** $p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$ level of significance; ns = non-significant;

3.1.3.1. Seed

The β_1 regression coefficient for seed was positive but not significant (table 13). A positive value on the elasticity would have implied that the seed has tendency to be important in rising productivity. However, its no significance indicates that the effect of improved rice seed is not determinant for productivity. This finding is in contrast to that found by Chandio et al., (2019) who estimated elasticities for maize and found negative and statistically significant value. Most studies have reported the importance of improved seeds since it promotes higher yields (Wongnaa and Awunyo-vitor, 2019). However, it is worth mentioning that the expected significance may not occur if other technical requirements (time of plantation, correct rate of seed per hectare, among others) are not followed. Other authors have speculated that the lower output elasticity, or even non significance, in new seed use can be caused by two reasons. On the one hand the shortage of improved seeds supply at the time of seeding leads farmers to mix the improved with the poor seed (Buah et al. 2011). On the other hand the lack of appropriate technical advice from the extension agents (AGRA-SSTP, 2016; Buah et al., 2011; Cunguara and Darnhofer, 2011; Janaiah and Debdutt, 2017 and Stoop et al., 2009) can also have a decisive negative effect.

3.1.3.2. Labor

Regression coefficient $\beta_{2,}$ for family labor employed rice cropping was positive, meaning an elasticity value of 0.336, and was statistically significant (P<0.001) at 1% level of confidence (table 13). This coefficient indicates that considering all other factors constant, one percent (1%) increase of family labor would increase output return by 0.336 percent. This result may not be consistent with that found by Malaiarasan, (2015) who reported negative coefficient with respect to labor, and also with an earlier study by Sidhu and Baanante, (1981) who estimating the farm level input demand in India and got values close to those of Malaiarasan, (2015). However, recent findings Ali et al., (2019) and Wakili and Isa, (2015) report positive and highly significant coefficients for labor, whose values also show a low elasticity.

3.1.3.3. Fertilizer

Coefficient $\beta_{3,}$ has not shown a positive elasticity (-0.018) in this study, revealing that a 1% increase of chemical fertilizer, leads to an output decrease of 0.018 % (table 13). It is therefore in contrast with that found by Rehman et al., (2019) which got a positive elasticity in their study, concluding that fertilizer is one of vital inputs to achieve higher productivity and fast rates of agricultural returns. Furthermore, other authors (Diagne et al., 2015 and Sanni et al., 2013) discussing fertilizer contribution for rice have as well stated that it is practically impossible to achieve a quick return on new seed of rice without any application fertilizer (Diagne et al. 2015; Sanni et al. 2013). For example, nutrient wise 1 kg of fertilizer produces almost 8 kg in cereals crops including rice, wheat and maize (Farooq et al., 2011; Mutyebere et al., 2018; Nhamo et al, 2014 and Rehman et al., 2019). Behind the response in fertilizer in our surveyed area, may be one reason: farmers do not use correct rates of fertilizer applying excessive amounts of it, probably due to lack of knowledge and poor monitoring by the extension agents (Cunguara and Darnhofer, (2011). It is clear from the literature that farmers need constant monitoring on their technological adoptions. According to Mozambique agricultural guidelines, fertilization rates for rice in the surveyed area should be 200kg NPK/ha for basal dressing, incorporated before sowing, and 90KgN/ha of nitrogen for top dressing which is applied in two stages: first 45 Kg/ha for rice tillering stage and 45 kg/ha for panicle initiation (IIAM, 2018; MINAG, 2006).

3.1.3.4. Pesticides

Results shown that pesticides have a positive and statistically significant impact (0.102) in the output (P<0.1) at the 10% level of confidence. It implies that keeping all other factors constant, one percent (1%) increase in pesticides would increase productivity return by 0.102 percent (table 13). This positive effect means that application of agrochemicals in the form of pesticide and herbicide have an important role in protecting rice crop from the infestation of pests and weeds. This result is in line with Temel et al., (2009) who found that the agrochemicals influence positively the productivity. Similar results were also shown in the study of Kwarteng and Towler, (1994).

3.1.3.5. Mechanization

The parameter β_5 is positive (0.224) and statistically significant ($p < 0.05$) at the 5% level. The response to an increase in mechanization by 1% is a 0.224% increase in output (table 13). This finding is consistent with a previous study by George et al., (1996) for wheat farmers in Pakistan but differs from achievements by Temel et al., (2009) whose findings in agricultural machinery use had a non-significant effect in rice output. In Mozambique tractors are the dominant tool in mechanization technology. Thus positive and statistically β_5 means that the increased availability of tractors in Nicoadala district will mean a decreased demand for traditional implements such as hoe, which are used by farmers in additional operations (i.e. tillage, harrowing, levelling and bund construction).

3.1.4. Returns to scale in rice production

The elasticities of output based on different inputs are functions of the level of inputs employed in the production function. According to Umanath and Rajasekar, (2013) the summation of the output elasticities denotes the estimation of returns to scale in production. In this study that sum was estimated as 0.645 (table 14). This value indicates that rice production has decreasing returns to scale. In other words, if the households increase all agricultural inputs by 1%, rice production will only increase by 0.65%, meaning that the technologies employed in the Nicoadala district do not demonstrate efficacy (Bernard et al., 2008; Nicholson, 2006; Nirmala et al., 2014; Wongnaa and Awunyo-vitor, 2019). This finding is in line with a plenty of researches which concluded that sizeable number of farmers cultivate under decreasing returns to scale. The explanation is that they are generally adversely affected by several bottlenecks, namely credit markets, bad road infrastructures, inadequate knowledge and the very limited use of improved agricultural technologies. (Cisilino and Amadeu, 2007; Coelli et al., 2002; Latruffe et al., 2005; Madau, 2010; Umanath and Rajasekar, 2013).

Table 14. Summation elasticities in Cobb-Douglas production function

Variable	Parameter	Coefficient	Standard Error
LnSeed (Kg/ha)	β_1	0.001	0.066
LnHuman labor (men/ha)	β_2	0.336	0.044
LnFertilizer (Kg/ha)	β_3	- 0.018	0.052
LnPesticide (Kg/ha)	β_4	0.102	0.126
LnMechanization in hours/ha	β_5	0.224	0.131
$\sum_{i=1}^{5} lnXi$		0.645	
εp		$(\varepsilon p) < 1$	

Note: $\in p$ = Elasticity of production or the estimated level of return.

4. Conclusion and policy implications

This study was intended to investigate the effects from farmer adoption of rice technologies in rainfed low land ecosystems using a Cobb-Douglas production function econometric approach. The result obtained for (εp) shows decreasing returns to scale, implying that the farmers are operating on the level three (3). Moreover, the combination of all inputs is not effective in rice productivity among the farmers. Several previous studies refer that the low effect of technologies on the productivity may be explained by the fact that they are operating under a lack of knowledge about the correct use of inputs. The values found for the β coefficients may help clarifying the situation. For example, the negative elasticity for fertilizer use can only be explained by an excessive application input. In addition, the very low elasticity in seed use is very likely due to the application of a mix traditional and improved seed leading to implication that traditional operations of rice farming are still predominant among rice farmers in Nicoadala district.

Based on the findings of the present research the government and other development partners should work together towards a full implementation and enforcement of effective strategies including:

(i) Promote technical knowledge on new seed and complementary operations to ensure their correct use;

(ii) Provide funding for the adoption of improvements, and;

(iii) Call the attention of rice growers to the new output market opportunities that can be expected from the implementation of the above actions.

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CHAPTER V

GENERAL DISCUSSION, CONCLUSION AND POSSIBLE SOLUTIONS

1. Foreword

The technology transfer process in general continues to be an important determination tool for the full adoption of agricultural technologies as well as their complementary useful messages for farmers. However, such a process has not yet been capable to influence the adoption of new technologies to a large number of rice farmers in Mozambique, thus requiring more effective policies to fight low adoption. This thesis aims at understanding what is behind the situation of low adoption and why farmers do not choose improved technologies. To that, several measures were considered by identifying the current opportunities and setbacks to run Technology Transfer; determining de factors affecting adoption of the rice innovations and, lastly, assessing the impact of the newly improved rice inputs on Mozambican farmers. This chapter contemplates a general discussion, conclusion and possible solutions.

2. Discussion

2.1. Main entities on technology transfer and first initial condition to run the process

Findings on today's situation of the technology transfer process has shown that greater number of institutions engaged in technology transfer in Mozambique are public such as the Mozambican Agricultural Research Institute (IIAM), the National Directorate of Agrarian Extension (DNEA) and the National Farmers Union, all working in partnership with International Rice Research Institute (IRRI). It is important to point out that there were also other international organizations (ITTA and CIAT) that promoted the early introduction of new varieties in Mozambique. We learned from various sources that currently, the CIAT and ITTA organizations do not concentrate on research support in rice crop but in other crops, namely beans and sesame (Renkow and

Byerlee, 2010). Some setbacks, with both national and international institutions, in fulfilling agreements or the enforcement and implementation of programs, do not exclude the necessity of more rice research partnerships between the Government of Mozambique and international organizations, for two reasons. First, because Mozambique has a growing increase in the consumption of rice. Secondly because there is a rapid change of farmers crop mix preferences due to climate change (Africarice, 2012; Kajisa, 2014). On the strategic side, the collaboration between the Mozambican Agricultural Research Institutions with the International Rice Research Institute (IRRI) represents a high opportunity for effective implementation of technology transfer programs since IRRI is able to exchange the rice genetic material with the world's largest genetic material preserver (Africarice) as well as for developing new rice varieties (Africarice, 2012; Leeuwis et al., 2014) (Leeuwis et al., 2014) (Africarice 2012). Another opportunity relies on the fact that there is a functional varietal release system that is strengthened thanks to the varietal release committee regular meetings. Hence, altogether these conditions lead to the generation of varieties with high yield potential. The yield potential refers to maximum yield which can be achieved by a cultivar when cropped in environments to which it is adapted, with all favorable conditions, such as water, nutrients and effective control of pests, diseases, weeds, lodging, and other stress factors (Peng and Khushg, 2016).

The major part of the rice varieties included in the process of technology transfer in Mozambique possess desirable traits for farmers (high yield, short growth cycle, medium long-grain, intermediate amylose content, non-sticky after cooking, and plant height). The introduction of the modern varieties in Mozambique requires the farmers’ understanding and interest. Taking these conditions into account is one of the basic strategies to have farmers stimulated for adoption. Additionally, the agronomic characteristics were crucial for the first IRRI improved variety (IR

36) to be widely accepted by the farmers and cultivated on about eleven million hectares in the 1980,s in Asian countries, such as Indonesia, India and the Philippines (Peng and Khushg, 2016).

2.2. Seed Certification constraints

For effectiveness and efficiency in the transfer of technologies, a process of certification of better seed quality is required. Nevertheless, seed certification is constrained by several setbacks, such as inefficient inspection on seed production, insufficient number of private companies engaged on seed multiplication, and poor seed storage and cleaning. The consequences generated by these bottlenecks are serious and dramatic for normal running of technology transfer, as they translate into a shortage of certified seed for farmers. The poor supervision during the multiplication phases in particular, was also detected in Northern Ghana (Ibrahim, 2019) and to tackle the problem, capacity building among researchers was promoted by the Government. On the other hand, identification of the very experienced private seed growers, who had the ability to work under minimum supervision of senior experts was carried to minimize the financial costs of regular government training (Ibrahim, 2019).

Seed quality is critical for stimulating the adoption of modern varieties (Mondal et al., 2020). Paudel et. al., (2015), discussing the grain quality for rainfed central Queensland concluded that several physical characteristics like shape, size, translucency and chalkiness of the grain cooking qualities, volume expansion ratio, cooking time and digestibility, as well as chemical traits like amylose content, gel consistency and protein-fat content, were required to meet farmers preferences.

2.3. Seed access constraints and inefficiency in extension services

As far as the seed access is concerned, this study recognizes the diffusion of seed as one of the huge challenges ahead and verified that farmers gain access to certified seed by purchasing directly from commercial agents, namely seed certified producing farmers and dealers. However, this diffusion model as a problem: the seed flow from seed producers to final users does not ensure the seed quality due to the limited storage capacity of dealers. Moreover, this inefficient operation is also affected by the inefficiency of extension services. Those services are training and visits (T & V), participatory variety selection (PVS), vitrine technology (VT), integrated technology transfer program (PITTA), farmer seed fair (FSF), demonstration field (DF) and farmer field schools (FF`s).

From the discussion, it results that with the exception of the participatory variety selection (PVS), the services are not working properly, and limited financial resources are viewed as a common constraint. Some authors (Kaur and Probhjot, 2018; Sumberg, 2005) point out that problems in the communication of useful advice may lead to failure in the technology transfer process. Thus, a careful analysis of the entire process is needed before engaging in a process of technology transfer.

The ineffectiveness in the Training and Visits (T & V) approach was due to its "top-down extension" characteristic, meaning that it was not participatory, too much bureaucracy was involved in the release of the advice, not to mention that in most cases there were overlapping activities. This same problem was also present in Indonesia (Cahyano and Agunga, 2016) where the approach has been criticized and abandoned. Additionally, the same authors also pointed that the greatest crisis on Training and Visit is that we use only one brain (the extension agent) while farmer's brain remains dormant. Although, in contrast, the model had previously successfully worked in Turkey and India (Taylor and Bhasme, 2018). Where the Training and Visit model consisted on training groups of contact farmers who in turn broadcast the same information in their localities.

The Vitrine of Technology often focused on establishing station experiments closer to roads or at the main entrance of an Agricultural Research Station. It was also designed for exposing as much as possible the newly developed technologies on a platform to any farmer who occasionally crosses by the road where it has been installed. VT failed because many farmers were not close to roads and so could not get the message. Another disadvantage of such exposure is the fact that a farmer passing by a vitrine can only view the crop details information that includes the type of variety, potential yield, technical requirements for cultivation, among others, but not able to get the full knowledge of process (Fatunbi, 2016).

The Integrated Program of Technology Transfer (PITTA) consists in each extension worker conducting a 1 ha demonstration plot inside the farmer's estate to show and stimulate the adoption of new practices. It had poor results due not only to limited means of transportation but also to the lack of knowledge of farmers goals. In other countries where it was run, extension workers, researchers and farmers established 4 plots of about 3.5 ha (total land size) within 4 leaders' farms of a given village, As a result 24 farmers, out of the 40 involved, replicated the new practices in the following agricultural campaign (Ibrahim, 2019). Since this approach enables the farmers to view and compare their achievements with those from the extension workers it can probably be one of the most effective and productive approaches. The same applies to the Farmer Field School and the On-farm trial methodology.

The Farmer Field School (also called the School without a wall) was not running as expected in particular on the study area due to limited financial resources and lack of involvement of the very skilled farmers, contrary to what happened in India as shown by Kaur and Prabhjot, (2018). The Farmer Field School program in India has the same structure as that of the Mozambique rice sector which consists on a group-based learning process involving between 20 to 30 farmers who meet one morning every week for an entire agricultural campaign (the crop growing season).The program includes also a periodically evaluation of framers. Yamazaki & Resosudarmo, (2008) have reported the farmer field schools (FFS) impact on providing knowledge to farmers. Which is also reported in various countries by many authors like Praneetvatakul et al., (2006) for Thailand, Godtland et al., (2003) for Peru, and Quizon & Bank, (2002) for the Philippines.

The Demonstration Field (DF) consists in setting up farms adopting modern rice technologies, side to side with local farms, aiming at comparing the performance of the new technology with the framers traditional one. The demonstration field approach has similarities with the On-farm trial model (Kijima 2012; Tanaka et al. 2017) which focuses on taking experiments to farmer’s environment (Moyo and Salawu 2018). On-farm mechanism was considered as one of the best participatory approaches that gave important contributions to improve production efficiency and farm profitability in Austria (Aendekerk et al. 2016)

Farmer Seed Fair (FSF) was focused on conducting a market or exposition of newly developed seeds and its complementary technologies (agricultural practices) and where farmers could purchase seed and interact with researchers, extension agents and other stakeholders. The seed fair used to be organized on specific days and at specific locations. Difficulties with this approach are seed price fixing, organization costs and resources needed to pick-up farmers from villages to the event location (Buah et al. 2011). On the other hand, advantages to be recognized on seed fairs in rural rice production regions are reported by other authors (Conroy, 2017; Emmanuel et al., 2016) as follow: (a) promote the strengthen of the share of useful advice as well as the communication among the households; (b) promotes the exchange of seed to overcome the limited access of modern seed after in critical circumstances, as for example natural disasters;

2.4. Improved technologies and the rates of adoption

In the analysis of which technologies and complementary factors are adopted by to farmers, the study has elected the following: improved varieties, fertilizer and pesticide, land preparation, line sowing of paddy cultivation, mechanization, weed management, use of irrigation and post-harvest practices. This set of agricultural practices follows the line of a prior study by Feder's et al., (1947) that explained that, in developing countries, it is advisable that the transfer of innovations to farmers takes the form of packages. In this manner farmers are free to adopt the full technological package or a subset of it (Carlino and Inman, 2015).

Several findings indicated that the success of technology transfer to farmers is not overwhelming, with the adoption ranging from 12% to 34 %. This means that traditional or local varieties are still popular special in the largest ecosystem (rainfed), where the bulk of rice cultivation occurs in Mozambique. This traditional popularity is catalyzed by the farmer to farmer communication centered in the poor seed system. This is consistent with findings by Ragasa et al., (2015) in Ghana who observed that the low adoption of modern technologies had perpetuated the use of local technologies consequently leading to negative effects on household well-being.

Ragasa et al., (2015) have also investigated the rate of adoption of the main recommended agronomic rice varieties and practices among farmers in Ghana and found that only a few number of farmers had planted modern varieties. Further the authors concluded that the limited plantation with newer varieties was explained by limited amount of certified seed available.

2.5. Status of the determinants affecting the decision of adoption

According to results of this study socio-economic and demographic factors including gender, age, level of schooling, farm size, knowledge, experience, distance to market access, extension visits, number of visits by extension agents, membership to association and government support (credit) have influenced adoption of rice varieties and complementary practices.

2.5.1. Gender

Analyzes on gender factor has shown that male has a positive and significant effect on the adoption of modern technologies. This results from the fact that men, as head of the households, are the decision-makers on the rice cultivation in most rice farms of the Nicoadala district. It also means that the presence of men as a household head in rural areas implies that women are not considered as legitimate receivers of rural institutional services (Bjornlund et al., 2017; Tsige et al., 2020). Although, Seebens and Sauer, (2007) stated that if men and women possessed equitable control over farm management production would have scaled up significantly. But inequality between men and women has also identified in various parts of sub-Saharan Africa (Bindraban et al., 2009; Giller et al., 2009; Thierfelder et al., 2017). In rural Ethiopian households, men has exclusive decision power over credit, water, fertilizer and other agricultural technologies including market linkage, as reported by Tsige, (2019) and Tsige et al., (2020). In sum, it is most likely that the prevailing power of man in Africa comes from customary laws which view men as the main owners. In addition, land inheritance rights are guided by patriarchal principles in most parts of Sub-Saharian Africa (Fisher and Carr, 2015; Pretty et al., 2011; Tsige, 2019; Tsige et al., 2020;).

2.5.2. Age

According to analysis on the age factor, the majority of farmers belong to the economically active group (41 to 50 years old). Additionally, this age group has shown a positive and significant influence in the adoption of the modern rice technologies. The one plausible reason for this is that experience plays an important role in rice cultivation (Bannor et al., 2020). In fact, the older the rice farmers are, the better they appreciate the importance and usage of using modern rice technologies in Nicoadala. On the other hand it cannot be ignored the existence of studies that found a rather negative effect of age in adoption (Chandio and Yuansheng 2018) mainly in elderly age groups.

2.5.3. Level of schooling

The level of schooling in the households is drastically low and the majority (53%) of the rice growers have only completed primary school, followed by farmers who have not gone to school at all. Additionally, other analyses revealed that the level of education has statistically positive association with the adoption of the modern rice technologies included in this study. These findings mean that completion of at least lower primary school implies a much higher propensity to adopt newly developed technologies than zero level of schooling, as Uaiene et al., (2009) also refer. Previous evaluations by Yamazaki and Resosudarmo, (2008) show that more educated farmers tend typically to be much able to accept useful technological and capable to address their production bottlenecks. In addition to this, Uaiene et al., (2009) state that high educated farmers possess the ability to perceive, interpret, accept and implement faster than their non-educated counterparts. These same conclusions are present in a recent research by Baiyegunhi et al., (2019).

2.5.4. Farm size

Farm size is important in technology adoption decisions mainly in yield-enhancing innovations. According to our analysis the majority of farmers in the researched area cultivate less than 0.5 hectares. This result has surprised us since the previous findings (in *Rice technology transfer from research to farmers in Mozambique: current status, opportunities and constraints*) reported that most farmers were in the dimension bracket of 0.5 to 1.2 hectares although both results are in line with the document of the strategic plan for rice production in Mozambique which considers most farmers inside the rice sector do plant on areas ranging from 0,25 to 5ha (MINAG, 2015). These discrepancies may be derived from samples where the studies where carried being different. Moreover, according to the econometric analysis used in this study, the small farm size showed a negative influence on the use of new technologies, which implies that most of the improved technologies do not look adequate in small areas (Dandedjrohounet al., 2017). This result is not consistent with that of many African empirical studies on adoption that have exhibited statistical positive association with farm size (Chandio et al., 2019; Saiful-islam et al., 2015). Farmers with larger farms do not fear risk experimenting agricultural innovation and, Kunzekweguta et al., (2017) assessing the constraints of adoption of conservation agricultural practices in Zimbabwe concluded that larger farms make adoption more profitable. It should also be noted that the farmer can allocate a larger parcel to modern varieties as long as he has enough land to allocate to other crops. Thus, farmers possessing more area get a comparative advantage to adopt improved rice varieties (Burman et al., 2017; Manda et al., 2016). Overall, the size of the area is the fundamental measure of the household wealth and can, therefore, influence the farmer decision-making process

(Manda et al., 2016); the same authors have found that households who possess larger areas are more likely to adopt improved varieties than those with smaller dimension.

2.5.5. Knowledge

Our analysis has shown that most farmers are unaware of the new agricultural technologies. Furthermore, investigating whether knowledge is associated with the modern agricultural technologies, results shown a significant and positively association with improved rice technologies. The lack of knowledge in the household relies on poor agricultural extension approaches. According to Porteous, (2020), technical guidance and reliable information on a given innovation is a driver for rapid adoption. There is plenty of literatures providing evidence of the importance of knowledge for the households (Buah et al., 2011; Chambers, 1985; Feder et al., 1947; Porteous, 2020; Poussin et al. 2006). (Buah et al., 2011; Chambers and Studies, 1994; Sahin and Roger, 2006; Seifried et al., 2017)

Farming experience increases the probability of uptake of planting depth; improved nursery, and timely transplanting.

2.5.6. Experience

The farmers in the Nicoadala district are sufficiently experienced in plating rice. Such socioeconomic characteristics may lead them to adopt rice technologies. Therefore, as expected the experience variable had both significant and positive effect on the use of rice technologies. Similarly, in Conroy, (2017) study only farmers who had high experience in maize cultivation were found increasing steadily the use of the new technology. The ability gained overtime will facilitate them to evaluate and recognize better varieties and complementary agricultural practices

(Conroy, 2017; Taylor and Bhasme, 2018). Nevertheless, these positive findings differ to that of other authors (Amengor et al. 2018) who found a negative correlation between users of improved seed and farmers level of experience, further suggesting that the less experienced farmers are open to new ideas and more willing to try modern agricultural practices than those who have high experience. Highly experienced farmers are likely to have more information and knowledge about rice production management practices. The result show that a unit increase in the number of years spent in rice farming increased the likelihood of adopting ideal planting depth by 0.058 (5.8%), improved nursery by 0.991 (99.1%), and timely transplanting by 0.014 (1.4%).

2.5.7. Distance to market:

It was not surprising that the results on distance to market showed a negative coefficient, implying that the longer the distance from the household to the place where they usually access agricultural inputs (seeds and other important factors such as machinery, fertilizer, pesticide among others), the lesser the likelihood of using the newly developed rice innovations. This finding contradicts those shown by Salasya et al., (2007) who got the unexpected result of a positive coefficient that the longer the distance from household to the nearest market, the higher the probability of adopting improved maize varieties in Western Kenya. However the most expectable situation is that farmers who are nearest to the main markets are more likely to obtain a modern technology due to better access to suppliers and lower transaction costs (Ali et al., 2019). However an earlier research by Nkonya et al., (1997) reported that the crop grower may travel greater distances to purchase inputs in case he can get a better price that may reduce the total the cost.

2.5.8. Extension visits

In what concerns the extension visits, results from the analysis showed that most of the farmers had been visited by the extension agent during the previous agricultural season (2017/2018). Further results from the binary logistic function revealed that the extension visit was statistically significant and had a positive influence on the adoption of new technologies, which is in line with previous assessments by Knowler and Bradshaw, (2007). Other studies revealing positive effects between extension and farmers adoption are Uaiene et al., (2009) and Silva, (2016). It is then apparent that the adoption of improved varieties is heavily dependent on the extension agent contacts as they represent fundamental drivers by which households receive advice on new agricultural practices (Tetteh et al., 2020).

2.5.9. Number of visits by extension agents

The number of visits per month is relatively limited in Mozambique with an average frequency of seven days per month. Based on the econometric function results, the number of visits showed a positive and significant effect on the dependent variables meaning that it is important for the adoption of rice technologies. It is important to note that the Extension Plan Master (MINAG, 2007) recommended that, to promote efficiency of the extension agents should permanently live closer to households (within the communities or villages). Unfortunately this recommendation did not materialized neither in our research area nor almost everywhere in the country. Our results are consistent with the findings by Tetteh et al., (2020) in Ghana, where due to an inadequate number of extension agents the number of visits is on average 3 for the cropping season. Manda et al., 2016) studying on impact of adoption on sustainable agricultural practices on maize in

Zambia, agreed that adoption in rural areas also depends on the frequency of contacts by the extension agents.

2.5.10. Membership to association

In what concerns membership to association, the analysis showed that only 45% of the farmers were members of one association. This result is lower than that reported by Tiamiyu et al., (2009) who found a larger percentage of farmers were affiliated in associations, and further argued that a rapid path for farmers to get the advice from extension agents and researchers was to take part in an association. However, in our study, the membership to association parameter revealed a small impact insofar as it had only positive and significant association with only one dependent variable (use of pesticide). We did not have access to the number of the existing association in the area of research but a considerable fraction of farmers interviewed complained that most of the existing associations in the Nicoadala district were not yet legalized, therefore raising concerns for most of the households. Hence, this may probably be the reason why they are not joining the associations. It is important to highlight that nowadays, farmers' associations are recognized as cost-effective means to disseminate information technology to rural households. Various authors have demonstrated that the associations enable the aggregation of seminars, workshops and lead farmer-to-farmer knowledge exchange and market management (Boubacar et al., 2016). Other researchers who agree with this are (Abdallah and Abdul-rahaman, 2016; Danso-abbeam et al. 2018; Uaiene et al., 2009).

2.5.11. Government support (credit)

Most of the farmers (91%) do not have access to any kind of credit. We can speculate that this situation is due to the fact that a greater number of farmers are cultivating rice in small plots of borrowed land. In addition, our coefficient for credit use reveled significantly negatively association with adoption of new technologies. Furthermore, it has also revealed that credit is not the unique agricultural deterrent for farmers to use mechanization since a lot of training is another requirement for the use of traction. This result contradicts the findings by Kajisa, (2014). His empirical assessment in constraints on rice sector development in Mozambique revealed significant and positive importance of credit on the use of new technologies, hence implying that lack of credit could be the principal agricultural factor hampering the access to irrigation and threshers in the irrigated low lands in Chokwe area. Another good example highlighting the importance of credit may be found in a recent study by Chandio et al., (2016) in Pakistan.

2.6. Impact of modern rice technologies on adopters

In order to gather evidence that will help policy makers to formulate effective recommendations for technology transfer, the impact of new rice technologies was also assessed. Final results revealed that both partial technologies and the combination of the modern inputs adopted by farmers may not be effective. Cobb-Douglas function regression coefficients β showed discrepant values in individual elasticities. For example, the β regression coefficient for seed was positive and positive β coefficients were also found for family labor, pesticide and mechanization, while for fertilizer that value was negative. However, the sum of these values is less than one, hence suggesting that the crop cultivation using the modern technology shows decreasing returns to scale. Furthermore, the output is negatively influenced by the limited knowledge on crop management and prevalence of traditional operations in rice farming in Nicoadala district. Similar results were also obtained in the study by Bernard et al., (2008); Nirmala et al., (2014) and Wongnaa and Awunyo-vitor, (2019).

3. Conclusion

Overall, there are plenty of reasons hindering the use of rice technologies by farmers in Mozambique. Technology transfer is conditioned by many setbacks, such as constraints on certification in seed multiplication and an insufficient number of private actors committed to seed multiplication, thus hampering the timely availability of seeds needed by users. Moreover, the seed access to farmers has an inefficient distribution circuit, insofar as the seed producers and the agro-dealers involved in the process do not have the appropriate stocking conditions to guarantee the quality of the seeds. Furthermore, rice farmers do not benefit of new seeds and complementary technologies due to both limited coverage of extension services and weak unsatisfactory extension approaches. Other crucial bottlenecks related to the limited adoption of new technologies by the rice households can be attributed to the poor prevailing socioeconomic conditions, mainly the level of schooling, farm size, knowledge, experience, distance to market, extension visits, number of visits by extension workers, membership to associations and limited credit.

4. Possible solutions

4.1. Government / Minister of Agriculture and Rural Development

Based on the results discussed it is clear that the weak coverage of agricultural extension services is one of the highest constraints for the process of technology transfer. This limitation is largely explained by the lack of financial funds. Hence, from the present study may emerge a few possible solutions:

1. To enhance the impact on the action of technology transfer the Government of Mozambique should provide financial support targeted to a rice research programme specially for:

   a) Transportation means to facilitate mobility of: (i) Inspectors of seed multiplication process, since inspection is a fundamental requisite at all stages ranging from the selection of growing areas to seed certification. (ii) Extension agents during the implementation of the agricultural extension approaches.

   b) Increasing the number of extension agents to ensure effective coverage of rice farmers.

2. Funds should also be allocated for the acquisition of improved seeds and complementary technologies to alleviate farmer's costs. Farmers cannot adopt technologies if they do not have the needed purchasing power. Therefore, the implementation of a credit system, including insurance to prevent potential losses, would be a good measure to positively influence adoption among the farmers.

4.2. Research and development

The difficulties identified in transferring research results to the farm level may suggest:

1. Since the Participatory Variety Selection (PVS) is the unique frequently used approach and usually conducted on-station conditions given the high costs involved in picking-up farmers from their villages, researchers should as well carry out on-farm pre-release experiments in order to get a greater number of farmers covered.

2. To ameliorate the seed distribution conditions researchers should promote training for rice seed producers, mainly on inspection matters, selecting cultivation areas and seed certification.

The lack of technical knowledge of farmers requires a vast programme of training promotion on input management: fertilization, labor management, mechanization, application of pesticide and others.

4.3. Agricultural extension services

On the extension services front some proposals can also be put forward

1. Implementation of a different mechanism technology transfer relying on agencies (public, private and partners stakeholders) closer to the farms, and consisting of mobile work brigades committed to monitoring the technical production system transferred to the farmer and to disseminate market rules.
2. The connection between extension agents and researchers should be strengthened for a better training of the extension agents and their permanent linkage with the Agricultural Research Institute of Mozambique.
3. When disseminating technology and knowledge it is very crucial to take into account the socioeconomic factors that influence adoption, namely:

a) Gender – Male plays a fundamental role in influencing behavior choosing the innovation.

b) Age - Make sure that the household receiving advice is of the economic active age-group.

c) Level of schooling, knowledge and experience – recognition that households who have an acceptable level of education, knowledge and experience are early adopters.

d) Farm size – a farmer who has a large cultivation area will more likely to adopt rice innovation.

e) Distance to market and membership to associations - farmers having better access to the marketplace and belong to an association are more likely to become influenced to accept adoption.

f) Credit - Farmers who benefit from credit are in better conditions to adopt improved rice technologies.

4.4. Further studies

As a result of the experience and knowledge acquired during the conduction of this study some general guidelines for future research are suggested below that.

a) Research on other factors influencing the use of improved technologies - The research on the factors influencing the adoption of rice technologies presented in this study was mainly focused on analyzing socioeconomic characteristics. Therefore, future research efforts should contemplate environmental issues like soil erosion, fertility and climate change. These items are becoming more and more important in other studies such as Fuglie, (2017) and Smit & Smitherst, (1992).

b) Perception of farmers on modern technologies - Determining how farmers perceive the messages and the advice resulting from agricultural extension models will help to understand the efficiency and robustness of the approaches. A Likert Scale will be useful for approaching these issues.

c) **Investigate farmers degree of risk aversion associated with new technologies** – risk analysis is important to understand the use of modern technologies. For this purpose it will be necessary to consider dummy variables and a list of potential risk factors, that include: a) risks of agricultural natural disasters (flood and drought); b) difficulty on weeding; c) production variability; d) lack of market opportunities ; e) Lack of availability of seed; f) regularity of input supply (fertilizer, pesticide); g) variability of prices; h) labor demand; i) investment in mechanization; j) maintenance of irrigation systems.

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