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Estimation of NERICA adoption rates and impact on productivity and poverty of the small-scale rice farmers in T he Gambia

BY

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Declaration

I hereby declare that this thesis has been composed entirely by myself and that it has not been previously submitted for the award of any other degree or qualification. All sources of information have been duly acknowledged.

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Abstract

The study uses a country-wide data from a stratified sample of 600 rice farmers to assess NERICA adoption rates and the causal effect of NERICA adoption on rice yields and income. It reveals that the observed sample adoption rate does not consistently estimate the true population adoption rate even if the sample is randomly selected. Consequently, it uses the counterfactual outcomes framework to estimate the true population adoption rate which corresponds to what is defined in the modern policy evaluation literature as the *average treatment effect* (*ATE*). The *ATE* estimate shows that the NERICA adoption rate could have been 83% instead of the observed 40% sample estimate provided exposure to NERICA was complete in 2006 or before. This shows an adoption gap of 43%, which represents a very high unmet demand for NERICA in The Gambia. Moreover, the results of the causal effects of NERICA adoption on rice yields and income based on observed sample estimates show significant differences between NERICA adopters and non-adopters. However, since the observed estimates could be attributed to differences in socio-demographic and environmental characteristics of adopters and non-adopters, they may not have any causal interpretation of NERICA adoption on the variables of interest. Indeed, the importance of some socio-demographic and environmental characteristics variable in explaining the differences in rice yields and income between NERICA adopters and non-adopters was confirmed by the data analysis. Hence, the study uses the counterfactual outcome framework to control for such differences. The results of the framework based on ATE estimates show in general significant estimates of NERICA adoption on rice yields and income. However, since adoption is a choice variable, the ATE estimates cannot be given a causal interpretation. Therefore, the study proceeds with the LATE estimates, the impact parameter which has a causal interpretation under this circumstance. The LATE estimates show that NERICA adoption significantly increases average rice yields and daily income of small-scale rice farmers by 146 kg/ha and D10.16 respectively.

Keywords:

Counterfactual**,** Heterogeneity, Impact, NERICA, Causal effects, Potential outcomes, The Gambia

Dedication

This work is specially dedicated to my late grandmothers JANKEY KRUBALLY and JAWARANDING JAMBA who were very eager to see me complete my study successfully. Unfortunately they passed away during my study programme, which made my grief for their loss unbearable.

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Chapter One:

Introduction

This chapter presents background information on rice productivity and poverty. It examines the problem of low rice production and poverty and provides justification for research to combat the problem. It also presents the study objectives, research questions and how the thesis is organized.

1.1 Background

The demand for rice in West Africa has far outpaced the production level. As a result, rice imports keep growing at an alarming rate. It is reported that rice imports in West Africa has grown at an annual average rate of 8% since 1997 (WARDA, 2002). It is in this regard that the West African governments tightened their belts, for the past three decades, to wage war against the low productivity of rice by devoting a significant amount of resources to increase rice production nationally. Despite the endeavours made by West African governments to increase rice production; productivity still fails to keep pace with demand. The low productivity has been attributed to the prevalence of rainfed rice growing systems, which has consequently resulted in a low yield achieved by West African rice farmers (Matlon et al., 1996). In West Africa, the rainfed rice growing systems (upland and lowland) accounts for 74% of the area planted to rice, producing about 55% of the total rice produced (Lançon et al., 2001) and this partly explains why West African farmers are experiencing low productivity.

Current efforts to increase production and productivity have been centered on the development of new rice varieties. In the past the development of new varieties was based on the use of improved genetic materials through the use of traditional breeding methods. However, in recent years emphasis has been placed on wide-crossing. A good example of the recent approach is the interspecific hybridization programme used by WARDA to breed a range of new rice varieties, which have been given the name New Rice for Africa (NERICA). The NERICA varieties are the result of crosses between two different rice species (*Oriza sativa* and *Oriza glaberrima). Oryza sativa* is originally from Asia and was introduced to Africa about 450 years ago. *Oriza glaberrima*, a less well known rice specie, is originally from Africa and was domesticated in the Niger River Delta over 3,500 years ago (Viguier, 1939; Carpenter, 1978). These rice species both have distinct and complementary advantages and disadvantages for use in African farming systems. The Asian rice (*O. sativa*) is known for having good yields, absence of lodging and grain shattering and high fertilizer returns. These characteristics are lacking in the African rice species (*O. glaberrima*). On the other hand, the *O. glaberrima* exhibits resistance to drought, weed competition, blast and virus diseases, soil iron toxicity and acidity (Jones *et al.* 1997a and 1997b; Dingkuhn *et al.* 1998; Audebert *et al.*, 1998; Johnson *et al.,* 1998; Dingkuhn *et al.* 1999), which are also lacking in the Asian rice species (*O. sativa).* Therefore, the idea to combine the desirable characteristics of both species into one rice varieties was a brilliant endeavour by the Africa Rice Center (WARDA).

The successful breeding efforts by WARDA to cross-breed landraces of *O. sativa* and *O. glaberrima* into what is now referred to as NERICA is an excellent opportunity for the farmers in West Africa to increase rice production and productivity. The NERICA varieties combine desirable traits from both parents, which make them superior. A comparison of performance of NERICA progenies with that of their *sativa* and *glaberrima* parents and other *sativa* checks under selected stresses in upland rice ecologies revealed that the mean yield of NERICA under low input condition is significantly higher than that of both parents. Under drought and soil acidity conditions, the mean yield of NERICA is also found to be significantly higher than that of both parents (Diagne, 2006b). Moreover, NERICA have a shorter growth cycle (90-110 days approx) when compared to local varieties. This means that it is possible to harvest NERICA while the local varieties are still struggling to reach maturity; thereby producing food during the hungry season. Furthermore, the short duration NERICA will allow farmers, who live in regions where the climatic conditions are subjected to variations, to adjust their agricultural calendar to climatic variation (Jones and Wopereis-Pura, 2001). Since NERICA mature earlier than the local varieties, one could be right to say that they have a comparative advantage over the local varieties with respect to the demand for labour. The comparative advantage of NERICA adoption with respect to demand for labour, combine with the yield advantage it has over the local varieties can result in an increased income for farmers that adopt NERICA; thereby creating an incentive for poor farmers to fight against poverty.

1.1.1 NERICA and Poverty Reduction

Poverty is a major problem confronting the developing world (World Bank, 2008). A person or family is identified as being poor if its resources fall below the minimum standard

of living used to indicate its wellbeing, commonly known as the poverty threshold. The Food and Agriculture Organization has reported that about 850 million people round the world have been going hungry each year for the last five years (20022007). In Africa more than one-third of the population endures food insecurity in the form of undernourishment and malnutrition (Union Africane, 2005). Just recently, rising food prices have worsen the food insecurity situation of many countries in sub-Saharan
Africa, which led to food riots in 2008 in countries such as Burkina-faso, Cameroon and Senegal. Nevertheless, there is still hope to combat poverty in Africa. The Department for International Development (2003) estimated that a 1% increase in agricultural productivity reduces the percentage of poor people living on less than 1 dollar a day by between 0.6 and 2% and that no economic activity generates the same benefit for the poor. This is an indication that rice productivity increase through NERICA adoption can reduce poverty significantly in Africa. Datt and Ravallion (1996), also affirm that agricultural growth is essential for fostering economic development and feeding growing populations in most less developed countries. However, since area expansion and irrigation have become a minimal source of output growth at a large scale, agricultural growth will depend more and more on yield-increasing technological change. For these reasons, NERICA have been developed and initially disseminated in seven pilot countries in West Africa: Benin, Gambia, Ghana, Guinea, Mali, Nigeria and Sierra Leone. The NERICA varieties are believed to impact positively on rice productivity and poverty in the selected pilot countries.

The Gambia, being one of the selected pilot countries, there is high hopes for increased rice production with the introduction of NERICA. In The Gambia, rice is the most important staple food crop and source of calories in terms of consumption. Its production is one of the main agricultural activities and an important source of income for a large number of women farmers. Currently 75% of the total population of approximately 1.5 million depends on agriculture for their livelihood (World Bank, 2005). Of the faming population, only 40% are male. Women are the predominant farmers; in fact by 1993, 67% of the female population was engaged in agricultural production (1993 National Census). Female farmers are those largely involved in rice production. The women cultivate rice in five principal ecologies (Carney, 1998). These ecologies are locally called *Tendako* (upland), *Bantafaro* (hydromorphic), *Leofaro* (out edge of tidal zone), *Wamifaro* (middle range of tidal zone[1]) and *Bafaro* (High tidal zone). Traditionally, women carry out rice-growing activities during the wet season using hand cultivation, which still remains the predominant system of production. Despite the hard work of women, poverty is still a serious issue ravaging the female population. Compared to men, women have a higher incidence and severity of poverty. Traditionally, women do not own or control land but they bear a heavy burden of labour.

Since a good proportion of women in The Gambia are rice farmers, rice production can contribute significantly to poverty alleviation. With regard to the low production of rice in the country, the agricultural policy is concerned with increasing local rice production in order to decrease imports and reduce the balance of payments, which has lead to the

[1] The tidal zones are all part of the lowland ecologies.

recent introduction of NERICA. The NERICA varieties were introduced into The Gambia through Participatory Varietal Selection (PVS[2]) in 1998 (Gridney, Jones and Wopereis – Pura, 2002). PVS activities were initially hosted in three villages; Tujereng, Jifanga, and Ntoroba. NERICA were first introduced in these villages and later diffused to the surrounding near-by villages through farmers' own channels, National Agricultural Research Institute (NARI[3]) and Department of Agricultural Services (DAS[3]). At present NERICA varieties are cultivated in all the six agricultural regions of the country. The introduction of NERICA has indeed brought high hopes for increased rice productivity and poverty reduction. However, the extent to which NERICA adoption contributes to increased productivity and poverty reduction is still the empirical question, which this study addresses using a country-wide data of rice farmers in The Gambia.

1.2 Problem statement

Poverty and low rice production are two major problems challenging the government of The Gambia. The UN's Human Development Index places The Gambia at 161 out of 174 countries in 1998, which puts the country firmly in the low development category. In 1999, it was estimated that 57% of the population were below the US1% per day poverty

[2] PVS activities are executed by farmer scientists who are selected from different villages to evaluate the rice varieties use in PVS trials in terms of their good agronomic characteristics at all stages of the growth cycle and finally select the most suitable varieties for further production and dissemination.

[3] NARI is the main agricultural research institute of The Gambia and it is mandated to carry out both adoptive and inductive research.

[3] DAS is responsible for the execution of all other agricultural activities apart from research in The Gambia. It is mandated to collaborate with NARI in order to dissemination new technologies to farmers through its extension staff.

line and this makes poverty a serious issue in the country. With regard to the prevalence of poverty, the rural families who rely on small-scale family farms for their livelihoods are the most affected (United Nations, 2000). Estimates obtained from the 2003 Integrated Household Survey (IHS), indicated that 61 % of the people in the country has been classified as poor, of which 63.3 % is rural. By gender however, 48 % of males and 63 % of females are classified as poor, with 15.1 % of females and 8.5 % of males classified as extremely poor. Furthermore, it is estimated that 78 % of economically active women engaged in agriculture are considered extremely poor (IHS, 2003). To address these issues, there is an urgent need to improve and diversify productivity in the agricultural sector by using appropriate technologies.

Moreover, agricultural productivity (especially rice production) has been on the decline. Between 1994 and 2003, rice productivity declined from 1.48 tonnes per hectare to 1.14 tonnes per hectare (Bittage et. al 2002; Government of The Gambia: Farmer Managed Rice Irrigation Project, 2005). Due to low productivity of rice, the country is able to produce only 35,000 tonnes of paddy annually (Bellmon profile, 2002). However, compared to the annual consumption level of 106,000 tonnes, the above estimate is far below the national requirement. Therefore, scarce foreign exchange of approximately US$11 million has to be used for the importation of rice annually and this makes the low production of rice a major challenge for the government.

1.3 Research Questions

The study set out to provide answers to the following research questions:

- What is the actual and potential adoption rate of the NERICA varieties in The Gambia?
- Does the progress in NERICA adoption so far justify efforts being made for its wide dissemination in the country?
- Were any improvements on rice productivity and poverty a direct result of NERICA adoption or would they have improved anyway?
- Is NERICA adoption more of a benefit to women or men in the farming community?

1.4 Objectives of the study

The overall objective of the study is to assess whether NERICA adoption has brought any positive changes in the socio-economic well-being of the rice farming community of The Gambia. Specifically, the study aims to:

1. Provide estimates of actual and potential adoption rates and their determinants of the NERICA varieties.
2. Provide estimates of the impact of NERICA adoption on rice yields and income, which are used as proxy variables for productivity and poverty respectively.
3. Compare different parameter estimates of the impact of NERICA adoption on rice yields and income.
4. Assess the gender impact of NERICA adoption on rice yields and income.

1.5 Justification and significance of study

Agricultural growth is fundamental in fostering economic growth of any agrarian nation in order to feed the growing population (Datt and Ravallion, 1996). However, since area expansion and irrigation have not made much impact on agricultural development in the developing world, agricultural growth will depend more and more on yield- increasing technological change (Hossain, 1989). In the same vein, the World Bank (2008) noted that the adoption of new agricultural technology, such as the high yielding varieties that led to a green revolution in Asia could lead to significant increases in agricultural productivity in Africa and stimulate the transition from low productivity subsistence agriculture to a high productivity agro-industrial economy.

Furthermore, studying how individuals are able to escape poverty is a central issue of economic development theory. Past researches on poverty revealed that 75% of the poor people (those who consume less than $1% a day) work and live in the rural areas. Projections suggest that over 60% of the poor people will continue to do so in 2025; whereas micro level evidence shows high rural poverty persistence (IFAD, 2000; Datt, 1998; Gaiha, 1998). These are good reasons to emphasize research on high yielding technologies that can substantially reduce poverty in the rural settings.

Moreover, with reference to past researches conducted on the adoption of high yielding technologies, one realizes that the results of the studies do not seem to agree with each other about certain aspects of the impact of such technologies on the livelihoods of farmers. In 2008, Kijima *et al.* conducted a study on the impact of NERICA adoption in Uganda and found that the adoption of NERICA has the potential to reduce poverty significantly without deteriorating the income distribution. Furthermore, Mendola (2006) observes that the adoption of high yielding varieties has a positive effect on household well-being in Bangladesh. Winters *et al*. (1998) and Mwabu *et al.* (2006); Janvr and Sadoulet (2002) all showed a positive impact of adoption of high yielding agricultural technologies on the livelihoods of farmers. However, a study in Bangladesh by Hossain *el al.* (2003) shows that the adoption of high yielding rice varieties has a positive effect on the richer households but a negative effect on the poor. In Zimbabwe, Bourdillion *et al*. (2002) observes that the adoption of high yielding varieties of maize increased the crop incomes of adopters only moderately. The disagreement of these findings clearly justifies the need for further research on this topic.

In addition, the results obtained from this study will assist The Gambia government to set up relevant policies for the rice sub-sector of the economy. Increasing the level of rice production and productivity is a major policy objective of The Gambia. To achieve this objective, the government needs information on the productivity of promising rice varieties that are being promoted nationally. This information cannot be provided unless research is made to assess the impact of such rice varieties on productivity and this further justifies the need to conduct research on yield increasing technologies.

Moreover, the results obtained from this study will go a long way in assisting policy makers in terms of judging the intrinsic merits of the NERICA technology on the target population and also in terms of making decision on whether to widely disseminate the technology or not. Furthermore, the study will provide relevant information to the donor community who are actively assisting in the promotion and dissemination of NERICA across the African continent. Information on impact assessment will provide the donors a clear testimony of the returns on their investments. This will assist such donors to decide whether to continue funding for the same activities or whether to redirect efforts to others areas that seem to be more promising.

Finally, it will open more rooms for further research on the topic. Since the impact of NERICA adoption on productivity and poverty has not been assessed before for countries like The Gambia, the results obtained from of this study will give a sense of direction to people who want to conduct further research on the same topic.

1.6 Organization of thesis

The thesis is organized in five chapters. Chapter one presents an introduction of the study. Chapter two gives a detailed review of literature. Chapter three presents the methodological frameworks. Chapter four gives the empirical results and discussions of the study. The final chapter presents the summary, conclusions and recommendation of the study.

Chapter Two:

Literature Review

Chapter two presents relevant literature on the origin, history and cultivation of the rice crop taking specific consideration of the case of NERICA varieties. It also presents the basic concepts and theoretical foundation of adoption and impact studies and also approaches to impact evaluations. It further examines literature on agricultural technology adoption and impact studies and also the concept of poverty.

2.1 Rice cultivation in the developing world

2.1.1 The origin and history of rice

According to Grist (1986), rice has been cultivated for such countless ages that its origin must always be a matter for conjecture. He noted that the evidence of the origin of rice given by botanist is based largely on the habitats of wild species. He further points out that it is presumed that the cultivated species have developed from certain species of the wild rice, which he believes is possible, but considered unlikely, that any of the wild rice are descended from cultivated rice. He concludes that there seems to be no agreement among experts as to whether rice was first a dryland crop which then adopted to wet conditions or vice versa.

Moreover, Grist (1986) divided the genus *Oryza* into twenty-five species, which he believes were distributed through tropical and subtropical regions of Asia, Africa, Central, and South America and Australia. He indicated that both diploid (2n=24) and tetraploid species occur, the diploids being more numerous. However, he emphasized that the taxonomy of *Oryza* is very complex and that no final agreement has been reached on synonymy or relationships between some of the species. These facts, according to him, follow Purseglove (1968), but he admitted that there is still some doubt about the status of *Oryza perennis* Moench.

Moreover, researchers have identified only two types of cultivated species of Oryza: *O. glaberrima* Steud and *O. sativa* Linn. *Oryza glaberrima* is believed to have originated from West Africa where it is known to be an upland crop but is being replaced by *O. Sativa.* However, the two cultivated species do not exhibit much difference morphologically. The main differences between them is found to be in ligule size and glume pubescence, but it is noted that *O. glaberrima* always has a red pericarp and that hybrids between *O. glaberrima* and *O. sativa* are sterile. *Oryza glaberrima* is considered to have arisen from the wild species *O. Breviligulata* but other scientists believe that *O. perennis Moench* was its origin (Grist, 1986).

Rice specie by name *O. rufipogon Giff* is believed to be more closely related to *O. sativa* of Asia. This specie is found to be widely distributed in a number of countries. It grows as a common weed in the rice fields of Asia, Australia and America. Morphologically, it resembles *O. sativa* but it has a red or black pericarp. When *O. rufipogon* and *O. sativa* grow together, hybrids are produced naturally giving intermediate forms which contaminate the cultivated crop. This reduces the rice quality and gives rise to redgrained plants. The two rice species are resemble in such a way that it is always difficult to weed the rice field when they grow together. Such resemblance might be explained by the fact that these species have been growing together for a long time. According to Vavilov

(1970), the longer a group has been established in an area, the larger will be the number of species to be found there. He concludes that the wealth of forms and varieties of rice found in the Himalayas which are closely allied to many Chinese varieties points to this region as the centre of origin of rice.

Chang (1975) concludes that rice was first domesticated in the area between northern India and the Pacific coast adjoining Vietnam and China. He points out that recognizable races of rice resulted from man‘s extension of its culture and persistent selection within a geographical region, rapid changes in predominant varieties occurring within an area due to extensive contacts among people. Moreover, Ting (1949) concluded that in view of the number of wild rice found in southern China, rice cultivation probably started in this region and spread northwards. Rice glumes found in the Yangtse River in burnt clay, thought to belong to the late neothithie, have been classified as *O. sativa f. spontanea ssp. Keng* and show strong resemblances to rice cultivars now grown in eastern China (Ting 1949 and 1961).

Copeland (1924) adds linguistic evidence to prove that rice originated in the south-east Asia. He points out that in Chinese and many other languages in south-east Asia, agriculture and rice or food and rice are synonymous, indicating that rice was first cultivated in this part of the world. In Japan, the three daily meals are *asa gohan* morning rice, hiru gohan afternoon rice and yoru gohan evening rice. The Chinese term for rice, *tao,* is believed to correspond etymologically to similar terms for rice in Indo-China, Burma and Thailand, but the Malaysian and Indian terms appear to be unrelated. These evidences all point to the conclusion that the centre of origin of *Oryza sativa L.* is southeast Asia, particularly India and Indo-China, where the richest diversity of cultivated forms of rice have been recorded (Chandraratna, 1964).

2.1.2 Introduction of rice in Africa

It is presumed that *Oryza stapfii* Roschev, and *Oryza glaberrima* Steud, have been first cultivated in the margins of the Neolithic Sahara. A historian by name Ibn Batouta (AD 1350) mentions the existence of rice in Nigeria, which was believed to be the Northern part of Nigeria in the sixteen century. However, the earliest cultivation of *O. sativa L*. in Nigeria was about 1890 when the upland varieties were introduced to the high forest zone in the Western part of the country. During this period, shallow swamp varieties from Guyana and Sri Lanka were found to have been established in smaller tributaries of several rivers where they quickly replaced the Africa rice (O. glaberrima), which was then extensively grown (Grist, 1986).

Moreover, the Africa rice which is presumed to have originated in the Middle Niger Delta about 3500 years ago has also been gradually replaced in Africa by the Asian rice *O. sativa*. However, the date and mode of introduction of the Asian rice in West Africa is still unknown. It has been suggested that the Asian rice was introduced by Portuguese traders who visited the coastal regions, but there is also a possibility that it came across Africa by the caravan desert routes or may be it had already been in cultivation in West Africa when the first Portuguese arrived (Jordan, 1965).

2.1.3 The cultivation and importance of rice in Sub Saharan Africa (SSA)

Rice is one of the most important cereal crops cultivated in Sub-Saharan Africa (SSA). It is ranked as the fourth most important crop in terms of production after sorghum, maize and millet (FAOSAT, 2006). Rice occupies 10% of the total land under cereal production and produces 15% of the total cereal production (FAOSTAT, 2006). Approximately 20 million farmers in SSA grow rice and about 100 million people depend on it for their livelihoods (Nwanze et al., 2006). These findings are indeed a true testimony that rice is a paramount staple food for a growing number of people in SSA. Between 1961 and 2003, the annual consumption of rice increased annually by 4.4% and that among the major cereals cultivated, rice is the most rapidly growing food source in Africa (Kormawa et al., 2004). Also between 1985 and 2003, the annual increase in rice production was 4%, while production growth for the first and second most important cereals crops (sorghum and maize) was only 2.5% and 2.4%, respectively.

The production of rice in Sub-Saharan Africa has steadily increased since the 1970s, reaching almost 7 Mt of milled rice at the end of the last decade. The increase in rice production is about 70 percent due to expansion in area and 30 percent due to yield increase (Fagade, 2000; Falusi, 1997). Much of the expansion has been in the rainfed systems, particularly the two major ecosystems that make up 78% rice land in Western and Central Africa (WCA): the upland and rainfed lowland systems (Dingkuhn *et al*., 1997). Nonetheless, demand for rice in WCA has far outstripped the local production

(WARDA, 2007). The gap between rice demand and regional supply is still increasing; in 1998 it was about 4 Mt of milled rice for sub-Saharan Africa as a whole. Nigeria was the major rice importer with almost 1 Mt in 1999/2000 (Mbabaali, 2000).

Sub-Saharan Africa has become a major player in international rice markets, accounting for 32% of global imports in 2006, at a record level of 9 million tonnes that year. Africa‘s emergence as a big rice importer is explained by the fact that during the last decade rice has become the most rapidly growing source of food in Sub-Saharan Africa (WARDA, 2008). Indeed, due to population growth (4% per annum), rising incomes and shift in consumer preferences in favour of rice, especially in urban areas (WARDA, 2008), the relative growth in demand for rice is faster in SSA than anywhere in the world (WARDA, 2005) and The Gambia is not an exception.

In The Gambia, rice is the most important staple food crop and source of calories in terms of consumption. The per capita consumption of rice in the country is estimated to be 110kg per person per annum, one of the highest in Africa (WARDA, 1996). Of the 106,000 tonnes of rice consumed per annum, only 20,000 tonnes is produced internally. The huge deficit is met through importation from Asia. In 2000 alone, US$ 10.9 million was spent on importation of 93,900 metric tonnes of rice (The Gambia Central Statistics Department, 2001).

2.2 Rice ecologies in West and Central Africa

The potential for rice development is largely determined by the agro-ecological conditions in which rice is produced. Rice is grown in a vast range of agro-ecological zones from the humid forest to the Sahel. Within these regional agro-ecological zones, five main rice-based systems can be distinguished with respect to water supply and topography in Sub-Saharan Africa (Windmeijer *et al.*, 1994): Table 1.

1. Rainfed upland rice on plateaus and slopes;
2. Lowland rainfed rice in valley bottoms and floodplains with varying degrees of water control;
3. Irrigated rice with relatively good water control in deltas and floodplains;
4. Deep-water, floating rice along river beds and riverbanks; and
5. Mangrove swamp rice in lagoons and deltas in coastal areas.

Table 1: Share of rice ecologies in rice planted areas by country

Country	Total area *(ha)*	Irrigated	Rainfed lowland	Rainfed upland	Deepwater floating	Mangrove swamp
Mauritania	23,000	23,000	0	0	0	0
Senegal	75,000	33,750	35,250	0	0	6,000
Mali	252,000	52,920	30,240	7,560	161,280	0
Burkina Faso	25,000	6,750	16,250	2,000	0	0
Niger	28,000	14,000	0	0	14,000	0
Chad	31,000	620	1,860	0	28,520	0
Cameroon	15,000	14,700	300	0	0	0
Gambia	19,000	1,330	12,160	3,040	0	2,660
GuineaBissau	65,000	0	14,300	18,850	0	31,850
Guinea	650,000	32,500	162,500	305,500	65,000	84,500
Sierra Leone	356,000	0	103,240	245,640	0	10,680
Liberia	135,000	0	8,100	126,900	0	0
Côte d'Ivoire	575,000	34,500	69,000	454,250	17,250	0
Ghana	81,000	12,150	12,150	56,700	0	0
Togo	30,000	600	5,400	24,000	0	0
Benin	9,000	360	360	8,190	0	0
Nigeria	1, 642,000	262,720	788,160	492,600	82,100	16,420
West Africa (total)	**4 ,011,000**	**481,320**	**1,243,410**	**1,764,840**	**360,990**	**160,440**

Source: Lançon F. and O. Erenstein (2002)

However, three main rice ecologies can be found across West and Central Africa. These are the rainfed lowlands, rainfed uplands and the irrigated systems. These ecologies can be found across agro-ecological zones.

2.2.1 Rainfed upland

The upland rainfed rice-based systems cover the largest area (44% of the total rice cultivated area), mainly in coastal areas in the humid and sub-humid agro-ecological zone (Defoer *et al*., 2002). Rice yields in upland systems average about 1 t ha^{-1}. Weed competition is the most important yield reducing factor (Johnson, 1997) followed by drought, blast, soil acidity and general soil infertility. Farmers traditionally manage these stresses through long periods of bush fallow. However, population growth has forced farmers to reduced the fallow periods and concentrate their farming activities towards the fragile upper parts of the upland slopes. The slash and burn method of land clearing has aggravated the weed pressure and also a decline in soil fertility due erosion (Oldeman and Hakkeling, 1990). Farmers also face high risks of crop failure and generally lower productivity levels. In upland areas where the growing season is short, very early maturing varieties with tolerance to drought and blast like NERICA are those required. Traditionally, farmers use long-duration rice cultivars which further undermine the fragility of the system and limit the cropping intensity. Thus, the resulting decline in productivity and income aggravate the incidence of poverty and environmental degradation (Cleaver, 1993; Cleaver and Schreiber, 1994).

2.2.2 Rainfed Lowland

The rainfed lowland systems (flood plains and valley bottoms) constitute 31% of the rice cultivation area in West and Central Africa. The rice yields in rainfed lowlands are substantially higher than those in rainfed uplands, but still low, averaging 2 t/ha (Defoer *et al*., 2002). The rice yields in these systems are highly dependent on the level of water control. The lowland systems have a potential yield of 3 t/ha at low input levels. At high input level with good water control, the potential yield can go up to 5 or 6 t/ha (Defoer *et al*., 2002). Biophysical factors affecting rice yield in rain fed lowlands systems include weed, drought, flooding, iron toxicity, soil nutrient supply, blast, rice yellow mottle virus and African rice gall midge. The major socio-economic constraints include resource availability, production risk, knowledge on best-bet crop management practices, and human health problems.

2.2.3 Irrigated ecology

Only 12–14% (0.5 million ha) of the total rice area in West and Central Africa is irrigated (Defoer *et al*., 2002). This includes substantial areas in Cameroon (80%), Niger (55%), Mali (30%) and Burkina Faso (20%). Irrigated rice in these countries (except Cameroon) is mainly in the Sudan Savannah and Sahel, which account for nearly 60% of the irrigated rice area in West and Central Africa. Irrigation systems include dam-based irrigation, water diversion from rivers and pump irrigation from surface water or tube-wells (Defoer *et al*., 2002). Average farmer‗s yields in the Sahel are found to be around 4 to 5 t/ha per season, with potential yields varying from 6 to 11 t/ha per season. Very high yield potential are found in drier zones than in others, because of high solar radiation and low disease stress. Irrigated rice-growing areas are divided into three subcategories based on temperature. However, only two are found in West and Central Africa. These are the areas with favourable low-temperature and tropical irrigated zones. African rice gall midge, rice yellow mottle virus and blast are the major pests found in the irrigated rice ecosystems (Defoer *et al*., 2002).

2.3 The NERICA varieties

2.3.1 Origin and characteristics of NERICA varieties

NERICA originated from two species of cultivated rice; the African rice (*O. glaberrima* Steud) and Asian rice (*O. sativa*). The best trails of the two cultivated varieties were used to produce progenies (Known as interspecifics), which are now referred to as NERICA. The Asian parent of NERICA is well known for its high yield potential, while, the African parent is highly recommended for its ability to thrive in harsh environment. These desirable characteristics from both parents are combined to produce the rice varieties referred to as NERICA (WARDA, 2008).

Initially, numerous conventional efforts were made to improve the performance of the Asian rice (*O. sativa*) for use in African farming systems but because the Asian rice lacks the resistance or tolerance to many African stresses, the efforts were very limited in success. For this reason, in 1992 Africa Rice Center (WARDA) and its partners started the Interspecific Hybridization Project in an attempt to combine the useful traits of both species (*O. sativa* and *O. glaberrima*). Crossing both species was complicated by incompatibility causing hybrid mortality, hindering heterogenic recombination (Jena and Khush, 1990) and progeny (F1) sterility (Second, 1984). Through back-crossings with the *O. sativa* parent coupled with another culture, this problem was overcome. The result was the first interspecific rice progenies (Jones *et al*., 1997a, b, c).

Moreover, NERICA varieties are characterized by a good number of attributes that make them extremely desirable to the society. NERICA generally have a shorter duration than most of the traditional varieties and this attribute is in almost all cases the first cited by any NERICA adopter. Most of NERICA varieties are also known for their early vigour, which is a very important trait of a rice variety‘s ability to effectively compete with weeds, thereby improving the productivity of scarce labour. Furthermore, some NERICA varieties are tolerant to drought and soil acidity and also exhibit good cooking and consumption qualities that are acceptable to the local community. NERICA also exhibit a very high yield potential of up to 6 tonnes per hectare under favourable conditions together with a protein content that is generally higher than most of the imported rice widely available in African local markets (WARDA, 2008).

2.3.2 The introduction and dissemination of NERICA in SSA

The NERICA varieties have been introduced and disseminated across Sub-Saharan Africa through networks such as *Réseau ouest et centre africain du riz*/ West and Central Africa Rice Research Network (ROCARIZ), Africa Rice Initiative (ARI), International Network for Genetic Evaluation of Rice (INGER-Africa) and collaborative projects such as Participatory Varietal selection (PVS), Community-based Seed Production Systems (CBSS) and Participatory Learning and Action Research (PLAR).

ROCARIZ was mainly a research network. It was very instrumental in the development of NERICA varieties for Africa by giving its members the opportunity to take an active part in the crossing of Oryza glaberrima and Oryza sativa. It also allowed its members to participate in the on-farm testing and release of new rice varieties. More importantly it contributed to closer and increased research collaboration between WARDA and National Agricultural Research Systems (NARS) scientists and also among NARS.

ARI project was mainly established to ensure the availability of quality NERICA seeds and to serve as an instrument of dissemination of WARDA products from production and development to processing and marketing. It covers the whole of SSA and maintains a presence in each participating country through stakeholder platform. The establishment of ARI has further contributed to the strengthening of the relationship between extension services and research institutions, thus facilitating the dissemination of NERICA varieties across SSA.

INGER-Africa is a rice testing network operated by WARDA since 1994. Its mission is to ensure wide and rapid dissemination of rice germplasm in SSA. It was created to meet the needs of most national rice research programmes in SSA, which have limited access to diverse genetic materials and rely on international centers to broaden their crop genetic bases. It has released about 200 improved rice varieties over the last 25 years in West Africa alone. Between 1997 and 2006 it multiplied, purified and dispatched seeds of NERICA for 29 countries in SSA.

Moreover, PVS and CBSS have been very complementary in the introduction and dissemination of NERICA across SSA. CBSS ensures that quality seeds are produced for PVS trails, while, PVS makes use of scientist farmers to cultivate the seed produced from CBSS and evaluate them at all stages of development. At the end of the PVS trials, the most robust and promising varieties are selected and disseminated to the farming community for further production. PVS trials have been very instrumental in the initial release of NERICA in countries like The Gambia, Benin, Burkina Faso, Cote d'Ivoire, Guinea, Mali, Nigeria and Togo.

Finally, PLAR has also contributed towards the successful dissemination of NERICA by bringing thousands of farmers into contact with NERICA varieties for use in low-input rainfed systems through participatory field experimentation, demonstrations and seed multiplication programme in Cote d'Ivoire, Guinea, Ghana, Mali and The Gambia (WARDA, 2008).

2.3.3 Cultivation and Management of NIRICA rice varieties

Site selection, land preparation, seed sowing and weed control are some of the most important issues that must be taken into consideration when it comes to the cultivation and management of NERICA varieties.

The location where to cultivate NERICA is very important to consider when one is preparing to embark on the production of NERICA. So far, the NERICA varieties that have been release in The Gambia are upland varieties; for this reason it will be a good start to select the cultivated area in the upland ecology. The upland NERICA varieties can grow under any agro-ecosystem under upland as long as there is enough moisture to sustain the crop throughout the growth period. Some NERICA varieties (NERICA 6) were even found to do well under hydromorphic conditions. Nevertheless, one must not try to cultivate upland NERICA under water-logged conditions. These agro-ecological zones are found to be very inappropriate for the survival of these crops (WARDA, 2008).

Once a good site has been selected for the NERICA varieties, the next step is to prepare the land for its cultivation. Preparing land for NERICA cultivation is not a difficult issue. Farmers can use conventional tillage operations of ploughing and harrowing using either a tractor or animal traction. Medium tillage can also be used and in fact this is the method used by small-scale farmers after clearing and burning the debris to dibble in the NERICA seeds using a hand hoe.

Furthermore, care should be taken when sowing NERICA seeds so as to maintain uniform crop establishment and optimum plant densities for the attainment of optimum yields. During this period, it is highly recommended to use seed dressing, pre-germinated seeds and a sowing depth of 2 to 4 cm for uniform plant establishment. Moreover, when more than 80% of the seeds germinate during the pre-germination test, it is recommended to use a seeding rate of 50-60 kg ha^{-1} for dibble sowing and 80kg ha^{-1} for sowing by drilling. Five to seven seeds can be sown per stand and later thinned to 2-4 seedlings at 14-21 day old. However, if the germination rate is less than 80%, the seed rates should be increased accordingly (WARDA, 2008).

Moreover, weed management in NERICA rice-based cropping systems is a paramount endeavour for the attainment of a successful production season. In West Africa it is estimated that weed control alone takes between 27 and 37% of the total amount of labour investment in rice production (WARDA, 1998). This makes weed control an issue of great concern in rice production. Weeds are found to be a major constraint in the rainfed ecologies and those suitable for irrigated rice. Weed competition in these ecologies is estimated to reduce rice yield by up to 40% and potentially causing total crop failure if left uncontrolled (WARDA, 1998). Some of the most troublesome weeds affecting rice productivity in West Africa are *Paspalum scrobiculatum, Euphorbia heterophylla, Chromolena odorata, Oldenlandia herbacea, Tridax procumbens, Digitatria horizontalis, Tridax procumbens Cyperus esculentus* and *Cyperus rotundas* (WARDA, 2008). When using hand-weeding to control these weeds, weeding should be done within 15-21 days after sowing provided weed pressure is minimal in the field. However, when weed pressure is high, a second weeding is needed at panicle initiation stage (about 42-50 days after sowing) and a third weeding if necessary (WARDA, 2008).

2.4 Basic concepts and theories of adoption and impact studies

2.4.1 Definitions of agricultural technology adoption

Many scholars have made an attempt to give a concise definition of what the adoption concept actually denotes. Among the endeavours made, the definition given by Rogers (1983) is the one that is widely used in adoption and diffusion studies. He defined diffusion (aggregate adoption) as the process by which a technology is communicated through certain channels over time among members of a social system and adoption as the use or non-use of a new technology by a farmer at a given period of time. Feder *et al.,* (1885) also made distinction between individual adoption and aggregate adoption, defining individual adoption as the degree of use of a new technology in a long-run equilibrium when the farmer has full information about the new technology and its potential. He then defined aggregate adoption as the process of spread of a technology within a region. In a similar vein, Thirtle and Ruttan (1987) defined aggregate adoption as the spread of new technique within a population. Understanding of the similarities and differences between these definitions is imperative to executing an empirical study of adoption.

Furthermore, when implementing an adoption study, it is important to take cognizance of the fact that there are divisible (e.g., improve seed, fertilizer and herbicide) and indivisible (e.g. mechanization, irrigation) technologies. With divisible technologies the decision process involves area allocations as well as level of use or rate of application (Feder *et al*., 1985). For this reason, a distinction has to be made between technologies that are divisible and those that are not divisible with regard to the measurement of the intensity of adoption. Feder *et al*., (1985) notes that the intensity of divisible technologies can be measured at the individual level in a given period of time by the share of farm area under the new technology or quantity of input used per hectare in relation to the research recommendations.

2.4.2 Categories of adopters and stages of adoption

Adoption studies identified and described five categories of adopters in the social system. These categories include innovators, early adopters, early majority, late majority and laggards (Mosher, 1979; Rogers, 1983). A study by Rogers (1983) indicated that the majority of early adopters are expected to be younger, more educated, venturesome, and willing to take risk. On the contrary, the late adopters are expected to be older, less educated, conservative and not willing to take risk. However, Runquist (1984) believes that a restriction has to be made on the usefulness of the categorization of adopters as there is evidence indicating a movement from one category to the other, depending on the technology introduced.

Moreover, studies by Rogers and Shoemaker (1971) and Rogers (1983) described the technology adoption process as the mental process from the first knowledge of a new technology to the decision to adopt or reject it. These studies further indicated that the technology adoption process takes place within the mind of an individual and based on this theoretical background the studies identified five stages in adoption process. These are (1) awareness and the initial knowledge of the innovation (2) interest and persuasion towards the technology (3) evaluation or the decision whether or not to adopt the technology (4) trial and confirmation sought about the decision made and (5) adoption.

Since the adoption decision has to go through different stages before the new technology is finally adopted, Rogers (1983) concluded that adoption is not a random behaviour but is a result of sequence of events passing through the adoption stages.

2.4.3 Mode and sequence of agricultural technology adoption

Abera (2008) identified two common approaches in the adoption literature that explain the mode and sequence of agricultural technology adoption. The first approach emphasizes the adoption of the whole package while the second one stresses step-wise or sequential adoption of components of a package. He found that technical scientists often recommend the former approach while field practitioners specifically farming system and participatory research groups advance the later. He also notes that there is often a great tendency in agricultural extension programmes of developing countries to promote technologies as a package and farmers are expected to adopt the whole package.

There are studies that have been found to be against the whole package approach by strongly arguing that farmers do not adopt technologies as a package, but rather adopt a single component or a few suitable technologies (Mann, 1978; Byrlee and Hesse de Polanco, 1986). Several other studies on adoption reviewed by Nagy and Sanders (1990) and Leather and Smale (1991) concluded that farmers choose to adopt inputs sequentially by first adopting only one component of the package and sequentially adding components over time, one at a time. Furthermore, profitability, riskiness, uncertainty, lumpiness of investment and institutional constraints were found to be some of the major reason given for the sequential adoption of a package of technologies (Byerlee and Hesse de Polanco, 1986; Leather and Small, 1991).

2.4.4 Definitions and perspectives of Impact Assessment

The term *Impact* refers to the broad, long-term economic, social and environmental effects resulting from research. Such effects may be anticipated or unanticipated, positive or negative, at the level of the individual or the organization. Generally, these effects involve changes in cognition and behaviour. *Assessment* or *Evaluation*, on the other hand, is the judging, appraising, or determining the worth, value or quality of research, in terms of its relevance, effectiveness, efficiency, and impact (FAO, 2000). In a hand book for Practitioners, prepared by the World Bank, impact assessment is defined as an endeavour to determine more broadly whether a programme of intervention had the desired effects on individuals, households, and institutions; and whether those effects are attributed to the programme of intervention. It further notes that impact assessment can also explore unintended consequences, whether positive or negative, on beneficiaries (Baker, 2001). On a more general context, impact is defined as positive and negative, primary and secondary long-term effects produced by a development intervention, directly or indirectly, intended or unintended on programme participants (OECD/DAC 2002). Impact can also be produced in the form of output or outcome.

The outcomes produced as a result of impacts are defined as the likely or achieved shortterm and medium-term effects of an intervention‘s output; whereas the outputs are the products, capital goods and services which result from a development intervention that are relevant to the achievement of outcomes. The outputs produced from agricultural research include technologies like improved seeds, management tools and practices, information, and improved human resources. These outputs affect the behaviour of individuals, households and institutions, which ultimately impact the indicators of research goals. Generally, a research goal can be to alleviate poverty and protect natural resources so as to achieve sustainable food security. One would ideally and ultimately want to assess the impact of such research programmes in terms of how they contribute to meeting the desired goals. Usually, it is difficult to evaluate impacts in terms of ultimate broader goals. Therefore, research evaluations tend to concentrate on impacts in terms of measurable intermediate goals or objectives. In such cases an impact assessment would be effected to evaluate whether a given research programme has resulted in technologies, management strategies and capacity strengthening that lead to more agricultural production per hectare at lower cost per unit of output and the results obtained can be used as a measure of the general welfare of those affected by the development intervention (FAO, 2000).

Furthermore, when impact assessment is used in accountability exercises to justify a past programme of activities, the evaluation should assess the impacts in terms of all the goals and objectives that were set when the project, activity or programme was established. Thus, if the research goal included ensuring resource conservation in addition to productivity enhancement, then impact assessment should measure the positive or negative interactions between productivity increments and resource degradation that may have resulted from new technology to derive an overall evaluation of research impacts. However, when impact evaluation is used to provide an understanding for future planning, it is not as critical that it respond to past established goals and objectives (FAO, 2000).

2.4.5 Why and when should Impact Assessment be done?

Impact assessment is done for various reasons and these include accountability, improving programme design, planning and prioritizing. When development interventions are implemented there is always the need to evaluate the performance of such programmes in order to establish how well the desired goals or objectives were attained and report to stakeholders the returns to their investment, thereby creating an avenue for accountability and also paving the way for continued support for further investment. Assessing impacts will also make it possible to learn lessons from the past that can be applied in improving efficiency of research programmes and implementation in future. Furthermore, impact evaluation is done to facilitate the planning of likely future impacts of institutional actions and investment of resources. The results obtained can be used in resource allocation and prioritizing future programmes and activities, and designing policies, programmes and projects.

Moreover, there are several stages at which impact can be assessed. Impact can be assessed during the different stages of any development project in order to account for future impacts. Impact evaluation at the planning stage is referred to as ex-ante impact assessment. Ex-ante evaluations are conducted at the planning stage of an intervention in order to estimate future impacts. It is applied to assist in decisions on approval and funding of research. It is also conducted to rank research programmes and set priorities for resource allocation. During the present stage there is monitoring and evaluation of ongoing research activities aimed at providing information to guide present activities and revision of on-going plans. At the end of an intervention another evaluation is conducted which is referred to as ex-post impact evaluation in impact assessment literatures. It looks at past events to measure the level of performance and achievements registered by an intervention or gaps that need to be addressed in future.

2.5 Factors influencing adoption of new technology

There is an extensive body of literature on the economic theory of adoption. Several factors have been found to influence farmers‘ decision to adopt a given agricultural technology. Traditionally, economic analysis of agricultural technology adoption has focused on imperfect information, risk, uncertainty, institutional constraints, human capital, input availability and infrastructure as factors that explain the adoption decisions of farmers (Feder *et al.*, 1985; Foster and Rosenzweig 1995). Some studies classified the factors influencing adoption into broad categories such as farmer characteristics, farm structure, institutional characteristics and managerial structures (McNamara, Wetzstein and Douce, 1991) while others classify them under social, economic and physical categories (Kebede, Gunjal and Coffin 1990). However, for the purpose of this study the factors affecting farmers‘ decision to adopt a given agricultural technology are broadly classified as follows: economic, social and institutional factors.

2.5.1 Economic factors

There are several economic factors that influence the adoption of new agricultural technology. However, some of the important economic factors that have been found to significantly influence agricultural technology adoption are: farm size, expected benefits, off-farm hours.

Farm size has been recognized as an important economic factor influencing agricultural technology adoption by many adoption studies that investigate farmers' decision to adopt a given agricultural technology (Shakya and Flinn, 1985; Harper *et al*, 1990; Green and Ng'ong'ola, 1993; Adesina and Baidu-Forson, 1995; Nkonya, Schroeder and Norman 1997; Fernandez-Cornejo, 1998; Baidu-Forson, 1999; Boahene, Snijders and Folmer, 1999; Doss and Morris, 2001; and Daku, 2002). Some of these studies found positive effect of farm size on adoption (McNamara, Wetzstein, and Douce, 1991; Abara and Singh, 1993; Feder, Just and Zilberman, 1985; Fernandez-Cornejo, 1996, Kasenge, 1998) while others found a negative effect of farm size on adoption (Harper et al, 1990; Yaron, Dinar and Voet, 1992); yet still others found adoption and farm size to be independent of each other (Mugisa-Mutetikka *et al*., 2000).

A review by Wabbi, (2002) identified cost of technology, level of expected benefit and off-farm hours as other economic factors that influence technology adoption. The decision to adopt a technology is often considered as an investment decision, which Caswell *et al.*, (2001) found to present a shift in farmer's investment decision. Because technology adoption presents an increase in cost incurred by a given farmer, technologies that are capital intensive are only affordable by wealthier farmers (El Oster and Morehart,

1999) and hence the adoption of such technologies is limited to farmers who have the wealth (Khanna, 2001). Moreover, the profitability of a given technology can serve as a motivation for the adoption of such technology. Farmers are rational being, they will only adopt a technology if they found it beneficial. Abara and Singh (1993) noted that if farmers do not perceive a significance difference between two options, then it is less likely that they will change their behaviour by adopting a new technology. In the same vein, McNamara, Wetzstein, and Douce, 1991; Fernandez-Cornejo (1996) concluded that a higher percentage of total household income coming from the farm through increased yield tends to correlate positively with adoption of new technologies. Furthermore, the availability of time to adopt a new technology can be an important determinant of adoption. For this reason, practices that heavily draw on farmer‘s leisure may inhibit adoption (Mugisa-Mutetikka *et al*., 2000).

2.5.2 Social factors

Social factors such as education, age and gender were found to explain farmers‘ adoption decision in some studies conducted on agricultural technology adoption. Studies that were able to establish an effect of education on the adoption decision of farmers in most cases relate it to years of schooling (Ferder and Slade 1984; Tjornhorm, 1995). Rogers (1983) notes that the complexity of a technology often poses a negative effect on adoption and that education is thought to reduce the amount of complexity perceived in a technology thereby increasing its adoption. Furthermore, the age of an adopter was found to positively influence adoption of sorghum in Burkina Faso (Adesina and Baidu-Forson, 1995).However, studies on adoption of land conservation practices in Niger (BaiduForson, 1999), rice in Guinea (Adesina and Baidu-Forson, 1995), Hybrid Cocoa in Ghana (Boahene, Snijders and Folmer, 1999) found age to be either negatively correlated with adoption or not significant at all. Moreover, the gender of an adopter was also found in some studies to significantly explain the adoption decision of a farmer (Doss and morris, 2001; Overfield and Fleming, 2001).

2.5.3 Institutional factors

Institutional factors like information and extension contacts are also found to be significant determinants of the adoption of an agricultural technology. The significance of information as a determining factor of technology adoption can be explained by the fact that when a farmer acquires full information about a given technology, it reduces the uncertainty about that technology‘s performance and this may change an individual‘s assessment from purely subjective to objective over time (Caswell et al., 2001). Moreover, when a farmer has information that a given technology is highly profitable, it positively influence that farmer‘s decision to adopt the technology (Feder and Slade, 1984). However, if the experience within the general population about a specific technology is limited, more information can negatively influence its adoption (McGuirk, Preston and Jones, 1992; Klotz, Saha and Butler, 1995). Furthermore, a study by Yaron, Dinar and Voet, (1992) shows the influence of extension contact can counter balance the negative effect of lack of years of formal education in the overall decision to adopt some technologies, thereby positively impacting on technology adoption.

2.6 Empirical studies of NERICA adoption and its impact

2.6.1 NERICA diffusion and adoption

Diffusion and adoption studies on NERICA have just concluded in some West African countries. In most of the other countries where NERICA have been disseminated, these studies are still on-going. The results of a recently concluded study on NERICA diffusion and adoption in Côte d'Ivoire revealed that a low diffusion rate (9%) limited the adoption of NERICA to only 4% in the year 2000. However, the study concluded that the adoption rate in the population could have been up to 27% had the whole population been exposed to the NERICA technology (Diagne, 2006).

In a similar study conducted in Benin in 2004, the NERICA diffusion rate was estimated at 26%. The study showed the actual adoption rate of NERICA to be 18%, which was by far lower than the estimated potential adoption rate of 57%. It also showed that about 68% of the farmers who were exposed to NERICA varieties in Benin in 2004 adopted them. Furthermore, the land area under NERICA cultivation in Benin in 2003 was estimated to 2000 hectares, which was found to be almost three times lower than the potential cultivated area (had all farmers known about NERICA) of 5500 hectares (Adegbola *et al.*, 2006).

Moreover, the diffusion rate of NERICA was estimated to be 39% in Guinea; a diffusion rate much higher than that of Côte d'Ivoire and Benin. The population adoption rate (where all the farmers in Guinea exposed to NERICA) of NERICA was further estimated to 58%, which was more than twice the actual adoption rate of 28% observed in the sample (Diagne *et al*., 2006a). The study also revealed that up to 53% of the farmers who were exposed the NERICA varieties had adopted in 2001. The total area under NERICA cultivation in Guinea has been estimated to be 28,000 hectares in 2002 and 51,000 hectares in 2003 (Diagne *et al.*, 2006b).

2.6.2 Determinants of NERICA adoption

Several socio-economic factors have been found to be significant determinants of NERICA adoption. The analysis of the socio-economic determinants of NERICA adoption in Côte d'Ivoire shows that rice cultivation partially for sale, household size, upland rice cultivation, past participation in PVS trials and living in a PVS hosting village positively influenced NERICA adoption at 5% significance level, whereas, age and having a second occupation negatively affected NERICA adoption at 5% significance level. Non-yield varietal attributes like short growth cycle, plant height, consumption and grain qualities were also found to significantly explain the adoption behaviour of farmers (Diagne, 2006b). The socio-economic determinants that positively influenced NERICA adoption in Guinea were participation in a training programme and living in a village where the NGO SG2000 has previously had activities (Diagne *et al.*, 2006b). In Benin, land availability and living in a PVS-hosting village were found to be the significant determinants that positively affected NERICA adoption. In addition to the socio-economic determinant, varietal attributes such as swelling capacity and short growing cycle were found to be significant determinants of NERICA adoption in Benin

(Adegbola *et al*,. 2006).

2.6.3 Impact of NERICA adoption

Results on the impact of NERICA adoption are presently available for only a few countries in Sub-Saharan Africa. For Côte d'Ivoire, the results of the impact assessment of NERICA adoption on rice yield show a heterogeneous and statistically significant impact of +741kg/ha for only female farmers (Diagne, 2006b).

In Guinea, the results of the analysis of the impact of the introduction of NERICA technology on rice biodiversity show a relatively high level of NERICA adoption. However, the high level of NERICA adoption did not lead to a parallel reduction in the number of pre-existing cultivated rice varieties (Barry *et. al.*, 2006). The explanation given to this outcome was that because of the short duration of NERICA, they were used by farmers as a complement to traditional varieties in order to enhance the varietal diversity of rice.

In Benin, a positive impact of NERICA adoption has been found on rice yield, production and incomes of producers. An additional rice yield gain of 1587kg per hectare was achieved by NERICA adopting farmers, giving them a per capita rice production gain of 109kg and additional income of 14 100 FCFA (Adegbola *et al.*, 2006). The result of another impact study conducted in Benin in the 2004 season show that the impacts of NERICA adoption are higher for women than men. It shows a surplus of production of 850 kg of paddy per hectare for women as compared to 517kg of paddy per hectare for men, and an additional gain of 171 978 FCFA ($337) per hectare compared to 141 568 ($277) for men (Agboh-Noameshie *et al*., 2006). Furthermore, another study on impact of NERICA adoption on child schooling in Benin found a 6% increase in school attendance rate, a 14% increase in the gender parity index and a 11 400 FCFA ($20) increase in school expenditure per child (Adekambi *et al.*, 2006).

Moreover, the impact of NERICA adoption on consumption spending, calorie intake and poverty has also been assessed in Benin. The study found that NERICA adoption had a positive impact of +147.51 FCFA ($ 0.30) on household spending of adult equivalent. The impact was higher for households headed by women +161.75 FCFA ($ 0.32) as compared to those headed by men 128.34 FCFA ($ 0.26). Furthermore, the study revealed a 19% reduction in the spending deficit ratio of the poor and an improvement in daily calorie intake of 35.85 Kcal per adult equivalent (Adekambi *et al.*, 2006).

Furthermore, a study on the impact of NERICA adoption on the income of rural households in the East African country of Uganda, where rice cultivation has been recently introduced, attempted to compare actual crop income with hypothetical income without NERICA adoption. The results of the study found that on average a shift from maize to NERICA varieties with proper crop rotation increased income by between $273 and $ 481 per hectare (WARDA, 2008).

2.7 The Concept of poverty

2.7.1 Definition of poverty

There is no single, universally accepted definition of poverty. The notion of poverty is determined in different ways by different institutions. The indicators of poverty also defer from one location to the other. Development agencies often employ quantitative measures of poverty by setting a threshold of one or two dollars for the easy assessment of poverty at global level. Indicators such as infant mortality and literacy rates are also employed by such agencies to assess poverty. For effective assessment of poverty, a clear understanding of the different definitions of poverty will serve as a pre-requisite. However, the numerous definitions of poverty have different measuring dimension (Makoka and Kaplan, 2005).

Poverty has been defined by the United Nations High Commission for Refugees (UNHCR) as a human condition characterized by the sustained or chronic deprivation of resources, capabilities, choices, security and power necessary for an adequate standard of living and other civil, cultural, economic, political, as well as social rights (UNHCR 2004). In the same vein, Copenhagen Declaration of 1995 describes absolute poverty as a ―a condition characterized by severe deprivation of basic human needs, including food, safe drinking water, sanitation facilities, health, shelter, education and information‖. Moreover, World Bank (2001) identifies *extreme poverty* as being people who live on less than US $1 a day and *poverty* as less than US $2 a day. It further notes that about 1.1 billion humans worldwide had less than $1 in local purchasing power a day (World Bank, 2001). This shows the need for concerted efforts to arrest the problem of poverty.

When one views poverty in terms of economic deprivation, lack of income is a standard feature of most definitions of poverty (Makoka and Kaplan, 2005). However, this view of poverty does not take account of the myriads of social, cultural and political aspects of the phenomenon. Nevertheless, for the purpose of this study, economic deprivation is a meaningful and acceptable definition of poverty.

2.7.2 Absolute and relative poverty

Poverty is determined in both absolute and relative terms. An individual is said to be in absolute poverty if he or she is unable to attain the minimum standard of living conditions deemed socially acceptable in a given locality. Absolute poverty is usually ascertained based on nutritional requirements and other basic commodities. Relative poverty, on the other hand, is established by comparing the lowest segments of a population with upper segments, usually measured by differences in income. Absolute and relative poverty trends do not always move in the same direction. For instance, if there is a decline in the well-being of high income earners at the same time more people or households fall below the poverty line, relative poverty may decline while absolute poverty increases (Dessalien, 2000).

2.7.3 Perspectives of Poverty

Poverty can be viewed from both objective and subjective perspectives. The objective perspective involves deciding on certain factors (Normative judgements) which are believed to be the constituents of poverty and what is required to move people out of their impoverished situations. With the subjective approach, the emphasis is based on individual utility. This approach uses people‘s subjective views to evaluate their preferences of the goods and services available. However, because of the obstacles encountered when trying to aggregate multiple individual utilities across a population, economists have traditionally based their work on the objective approach (Dessalien, 2000). Advocates of this approach argue that individuals do not in all cases present the best judgment of what is best for them. The argument placed by the advocates is that, even though all individual value food consumption; some may place a higher value on certain types of commodities that are not the best for their well-being. For this reasons, they conclude that when the subjective approach is used, it may undervalue or overvalue food consumption, leading to conflicting assessments as to who are the poor. However, the international community has recently started to build a serious interest in measuring subjective poverty. This is because of certain limitations associated with objective indicators and the value of understanding the perspectives of the poor in shaping policies and programmes. As a result, participatory poverty assessments methodologies have been gaining grounds (Dessalien, 2000).

2.7.4 Quantitative and qualitative indicators of poverty

Both quantitative and qualitative indicators are used to measure objective and subjective poverty. Makoka and Kaplan (2005) demonstrated this with an example thus: ―an objective approach to poverty measurement may determine that perceptions of deteriorating academic standards (a qualitative indication) are the principal cause of declining school enrolment. Likewise, a subjective approach to poverty measurement may reveal that household composition (which can be quantified) is a central characteristic of poverty‖. However, confusion may arise when both quantitative and qualitative indicators are used to measure objective and subjective poverty. This happens because the main methodologies for obtaining objective poverty indicators are survey questionnaires which collect mainly quantitative data whereas the main instruments used to ascertain subjective perspective of poverty mainly rely on qualitative information (Dessalien, 2000).

Chapter Three:

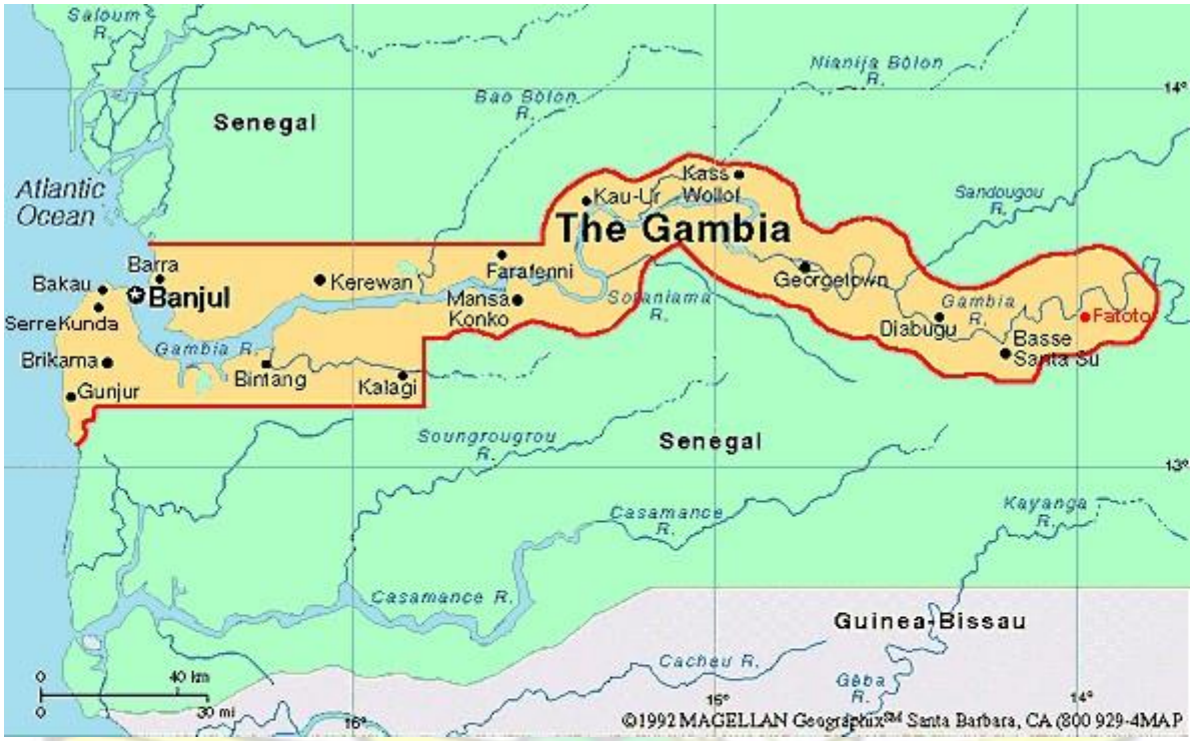
Methodology

Chapter three presents a detailed description of the study area, the survey design and the methodology of data analysis. It also presents the different approaches of impact evaluations and also various methods of assessing poverty.

3.1 The study area

The Gambia is located in the Sahel region of West Africa; a region characterized by recurrent droughts, loss of vegetation cover and rapid environmental degradation. It is considered as one of Africa's smallest countries. It has a flat, elongated finger of territory that has an average width of only 30 km extending from the Atlantic coast for about 375 km and is entirely surrounded on land by Senegal's territory (Fig.1). The Gambia occupies the Gambia River's flood plain, which is flanked by low hills. It has a land area of about 11,300 km^2 and a population of about 1.5 million (UN, 2005), which makes it one of the most densely populated countries in Africa.

Figure 1: Map of The Gambia showing the major towns



In 2009, the population of The Gambia has been further estimated to be 1,782,893 with a growth rate of 2.67% per annum (The Government of The Gambia, 2009). The Gambia has a variety of ethnic groups comprising of 99% African origin. The percentage of inhabitants is divided into different tribes. Mandinkas being the largest tribe form 42% of the total population. The Fulas, comprising of 18% of the total population, are the second largest ethnic group. This is followed by the Wollofs, Jolas and Sarahulis which constitute 16%, 10% and 4% of the total population respectively. The rest of the population comprises of less common tribes, which form the remaining percentage (The Government of The Gambia, 2009).

The Gambia has a semi-arid tropical climate with one rainy season followed by a seven months dry season. From November to June the temperatures are cool and dry. Average daily temperatures are 28.2° C in the dry season and 28° C in the rainy season. The rainy season starts from June and ends in October. Rainfall has decreased by 30 percent over the last three decades, and this has negatively impacted the country‘s limited natural resource base. In September and October the soil moisture level is usually low and this can adversely affect crop harvest (The Gambia information site, 2009). Soil fertility is deteriorating due to population pressure and the continuous cultivation of the marginal lands.

Given the rainfall pattern of the country, three major agro-ecological zones can be identified. These are: Sahelian, Sudan-Sahelian and Sudan-Guinea zones. The Sahelian Zone has a Sahelian micro-climate with dry season savannah vegetation. The rainfall in this zone is highly unpredictable and is less than 600-mm annually with an effective cropping season of less than 79 days. The soils have low water retention capacity making it a high-risk area for long-duration crops. For this reason, only early maturing and drought tolerant crops are those prevalent in the area. The major crops cultivated in the area are: cassava, sesame and cowpea. Moreover, the Sudan-Sahelian Zone lies within the 600-900 mm of rainfall area. This area has a longer cropping season (79-119 days). The upland areas of the zone are well suited to groundnut, cotton and sorghum. The flood plains along The Gambia River and associated lowland valley systems are an excellent rice growing catchment under tidal swamp irrigation. In addition, the Sudan-Guinea Zone lies within the 900-1200 mm rainfall area. The cropping season in this area is the longest, lasting between 120-150 days. The principal crops cultivated in this agro-ecology are: early millet, groundnut, rice (rain-fed upland and lowland, irrigated lowland, mangrove and mangrove salt-tolerant), maize, vegetable, sesame and cowpea (The Gambia information site, 2009).

Furthermore, The Gambia has no significant mineral or natural resource deposits and has a limited agricultural base. The Gambian economy is divided into four major sectors: Services, Tourism, Industry and Manufacture, and Agricultural sectors. The total GDP of The Gambia was estimated at US$779 million in 2008 with an annual growth rate of 5.5% per annum. The service sector contributed 58.30% of the GDP. The agricultural products: peanuts, rice, millet, sorghum, fish, palm kernels, vegetables, livestock and forestry contributed 33%, while, tourism, industry and manufactured goods constituted the remaining percentage (The Gambia, 2009). Although, the country has no confirmed mineral or natural resource base; there is high possibility for the presence of oil and gas offshore. This was confirmed by a Seismic study that was recently conducted in the country. If the results of the study become a reality, then the significance of the service sector as the highest contributor of the GDP would be significantly reduced.

Moreover, The Gambia has a liberal market based economy that is characterized by traditional subsistence agriculture relying heavily on groundnuts for export earnings. However, lower world market prices and variations in climatic conditions have made the export income more insecure. For this reason, farmers have started to shift from the production of cash crops such as groundnuts to food staples for local consumption, in order to ensure their food security. The staple food crops that have been given much attention now are: maize, millet, sorghum and rice. Furthermore, because of the insecurity involved in the production of cash crops, rural cash income has slowly been redirected from the production of such crops to wage earning in the service sector, partly as seasonal labour in the tourism industry and also in other industries and services.

The agricultural sector still remains the most important sector of the Gambian economy. It provides employment and income for 80 per cent of the population and accounts for 70% of the country‘s foreign exchange earnings. In 2004, it accounted for more than 30 per cent of gross domestic product (GDP). Within agriculture‘s share of the GDP, peanut production accounts for 6.9%, rice and other crops 8.3%, livestock 5.3%, fishing 1.8%, and forestry 0.5%. Agriculture remains the prime sector to raise income levels, for investments, to improve food security and reduce levels of poverty. Agricultural production is the only means of income creation for the majority of rural families most of whom live below the poverty line (The Gambia information site, 2009).

About 54% of the agricultural land area in The Gambia is good quality arable land (5,500 square kilometers), out of which about 39% (1,880 sq. km) is currently farmed by the 41,000 subsistence farmers in the country. About 810 sq. km. (81,000 hectares) are irrigable, all in the Central River Region (CRR) (56%) and Upper River Region (URR) (44%). About 2,300 hectares of this potential area are currently under irrigation. Crop production is quite diversified. Cash crops such as cotton and groundnuts are grown in the upland areas and rice in lowland, riverine areas (rainfed swamps or under irrigation) for both subsistence and cash. Since rice is a major staple of the country, an increase in its production can make a very significant impact in the livelihood of average Gambians. Other principal subsistence cereal crops grown are maize, sorghum and millet. Women form the largest percentage of the people involved in agricultural production, about 51%

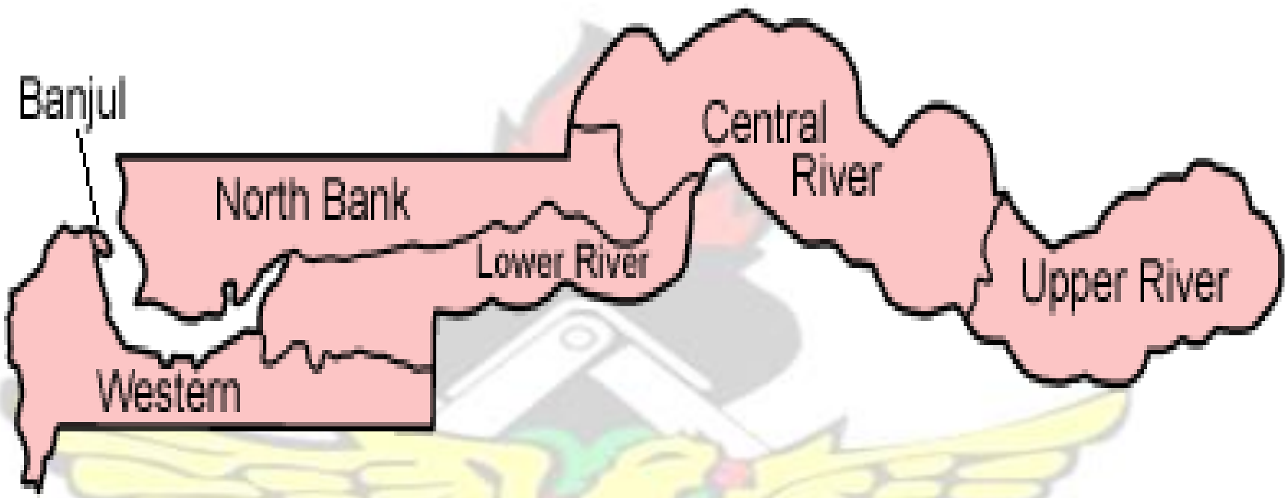
of the agricultural sector is composed of women farmers (The Gambia information site, 2009).

In spite of the involvement of women in agricultural production, land is predominantly communally owned and is controlled mainly by men. It is held in trust for the villages by district councils. The head of the village allocates plots for cultivation. The basic farming unit is the compound, which includes an average of about 15 people who are usually members of the same family. The women of the compound grow rice, cultivate vegetables and raise livestock on a small scale. Men cultivate coarse grains, groundnuts and other crops in the uplands. However, erosion and soil degradation caused by drought and declining rainfall, together with over farming, overstocking, and increased demand for firewood has seriously affected the country's resource base. More than 90 per cent of farmers have sheep and goats, and virtually all of them have poultry. Livestock are largely allowed to graze uncontrolled, which contributes to degradation of the vegetative cover (The Gambia information site, 2009).

3.2 Survey design

The survey[4] was implemented from November 2006 to September 2007 in 70 rice growing villages, which were selected from the six agricultural regions of the country (Fig 2).

Figure 2: Map of The Gambia showing the Agricultural Regions



3.2.1 Sampling

Multi-stage stratified random sampling was used to select the villages. In the first stage a list of all the rice growing villages where NERICA seed were disseminated (NERICA villages[5]) from the cereal programme of the National Agricultural Research Institute

[4] The study drew particularly on experience and methodology from previous surveys conducted in other West African countries (Diagne, 2006 in Cote d'lvoire; Diagne et al,. 2004 in Guinea; Spencer et al,. 2006 in Nigeria).

[5] In other countries the survey concentrated on villages where PVS activities were conducted instead of villages where NERICA seeds were disseminated. However, the Gambia survey concentrated on NERICA seed dissemination villages because there were few PVS villages in the country at the time of the survey.

(NARI) of The Gambia was obtained. This was later stratified between other villages where NERICA seeds were not disseminated (non-NERICA villages). The survey[6] included 5 NERICA villages and 5 non-NERICA villages in each agricultural region except Western Region where 10 NERICA and 10 non-NERICA villages were selected. The NERICA villages were the first identified in each agricultural region, followed by a random selection of non-NERICA villages within a radius of 5-10 kilometers. The selection of the NERICA villages within each region was also stratified between districts in order to evenly select NERICA villages country-wide. The chance of selecting a nonNERICA village was dependent upon the selection of a NERICA village within that vicinity.

The second stage of sampling involves a stratified random sampling of men and women rice farmers in each selected village. Ten rice farmers were selected[7] from each village for a total sample size of 600 rice farmers. However, more women farmers were selected during the sampling. Only 39 men rice farmers were selected in addition to the women farmers. This is due to the fact that rice is mainly cultivated by women farmers in The Gambia. Out of the 70 villages selected, few men rice farmers were identified in only 20 villages; the rest were all women rice producers.

3.2.2 Data collection strategy

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[6] Initially the survey was to include 10 NERICA villages and 10 non-NERICA villages. However, due to constraint faced in Western Region, the remaining regions were reduced to 5 NERICA and 5 nonNERICA villages.

[7] Ten rice farmers were randomly selected from each village except Western Region where five rice farmers were selected. This happened because the survey included more villages in Western Region.

The data were collected using two questionnaire schedules: village and farmer questionnaires. The village questionnaire was administered to obtain information from key informants in each village through focus group discussions. For each rice variety listed, among the information, the villagers were asked to identify the type of variety, ecology in which the variety is cultivated, the person who introduced the variety and if applicable the institution where the person come from, the introduction method used, variety height and cycle. This was followed by questions regarding the characteristics of each variety. These include the agronomic and morphological; post-harvest; cooking and organoleptic characteristics of each variety.

The farmer questionnaire was administered after the selection of rice farmers in each village. After the delivery of a copy of the full list of the village varieties to each enumerator, the farmers were then asked each whether he or she knew each of the listed varieties. If the answer to the question is yes, then the farmer is asked whether he or she has cultivated the variety in past five years (2002 to 2006). The knowledge of the variety is defined as a yes answer to the first question and the adoption as the cultivation of the variety. This was followed by questions regarding the socio-economic and demographic characteristics of each farmer.

3.3 Approaches to impact evaluations

In principle there are only three major approaches to impact assessment, each having its own merits and weaknesses. They are as follows: Quantitative or ―scientific‖ statistical method, qualitative method and participatory learning and action method.

3.3.1 A quantitative or "scientific" statistical method

This approach to impact evaluation employs an experiment to establish causation between the outcome and the treatment or intervention. Usually, a survey is used as a tool by econometricians and statisticians to effect such evaluation. The method hinges on asking a fundamental question: *What would the situation have been if the intervention had not taken place?* Such a situation cannot be directly observed but it is possible to approximate it by constructing an appropriate counterfactual. This is stimulated by comparing programme participants (treatment group) with a control or comparison group. Two broad categories of evaluation design can be found for the execution of such evaluation (Baker 2000): experimental designs (randomized) and quasi-experimental designs (nonrandomized).

I. *Experimental or randomized evaluation design:* Experimental design, also known as randomization, is generally considered the most robust of the evaluation methodologies (Baker, 2000). This design involves gathering a set of individuals (or other units of analysis) equally eligible and willing to participate in the programme and randomly dividing them into two groups. By randomly allocating the intervention among eligible beneficiaries, the assignment process creates comparable treatment and control groups that are statistically equivalent to one another, given appropriate sample sizes. In theory, the control groups generated through random assignment serve as a perfect counterfactual, free from the problem of selection bias that exits in all evaluations. The major advantage of the methodology is its simplicity; it takes the mean difference in the outcome of interest between treatment and control groups to assess the impact of an intervention.

Although, the method is straightforward in assessing the impact of an intervention, in practice there are several problems. First, it is unethical to randomly deny eligible members of the population access to an intervention that might be beneficial to them just for the purpose of implementing an impact study. Second, it can be politically difficult to provide an intervention to one group of a given locality and not another. Third, for certain interventions administered nationally there might be no nontreatment group that will enable one to use such approach. Fourth, there might be non-compliance and this could invalidate or contaminate the results. It is possible for people who are denied a programme benefit to seek it through alternative sources or those being offered a programme may not take up the intervention. Fifth, it may be difficult to ensure that assignment is truly random. And finally, experimental methods can be expensive and time consuming to implement.

II. *Quasi-experimental* (nonrandomized) *evaluation design:* This is the methodology used by this study to assess the impact of NERICA adoption. The non-experimental design (nonrandom) can be used to carry out an evaluation when it is impossible to construct treatment and comparison group through experimental design (Baker, 2000). This technique generates comparison groups that resemble the treatment group, through econometric methodologies, which include matching methods, double difference, instrumental variable methods, and reflexive comparisons. When treatment and control groups are selected after the intervention by non-random methods, these techniques are usually used to evaluate impact. The techniques applies statistical controls to address differences between treatment and comparison groups and also sophisticated matching techniques to construct a comparison group that is as similar as possible to the treatment group.

The main advantage of these techniques is that they can draw on existing data sources and are often quicker and cheaper to implement. However, the non-experimental methods also have certain limitations. First, when these techniques are used, the reliability of the results is often reduced as methodology is less robust statistically. Second, the methods used to evaluate impact can be statistically complex. And finally, there is a problem of selection bias. There are two types of selection bias: those due to observables and those due to unobservables. An observable selection bias could include differences between treatment and comparison group in term of age, sex, geographical location or experience. Unobservables that can create selection bias could include differences in ability, willingness to work, social or political affiliations. Both types of selection bias can lead to inaccurate results, including underestimation or overestimation of actual programme impacts, negative impacts when actual programme impacts are positive (and vice versa), and statistically insignificant impacts when actual programme impacts are significant and vice versa (Baker, 2000).

3.3.2 A qualitative method

This approach uses key informants to assess impacts. It is an inductive approach in which the data analyst is usually directly involved in the data collection. It uses interviews, participant observations, case studies, focus group discussions as the main tools of assessing impacts. It uses techniques which rely heavily on participants' knowledge of the conditions surrounding the project or programme being evaluated (Backer, 2000). The qualitative approach does not use any statistical means to evaluate impact as in the quantitative methods; it rather seeks to provide an interpretation of the processes involved in an intervention and of the impacts that have a high level of plausibility (Hulme, 2000). The validity of such evaluation is highly dependent on the arguments and materials presented; the strength and quality of evidence provided; the degree of triangulation used to crosscheck evidence; and the quality of methodology. However, a major weakness of such studies is that they usually fail to establish a direct causal link as they are unable to generate a ―without programme‖ control group. Instead, causality is inferred from the information gathered from beneficiaries and key informants and by comparison with data from secondary sources about changes in ―out-of-programme‖ areas. Furthermore, highly skillful practitioners, adequate funds and time are required to conduct such evaluations (Hulme, 2000; World Bank, 2000).

3.3.3 A participatory learning and action method

This method makes use of stakeholders at all stages of evaluation. It involves the stakeholders in the determination of the objectives of the study, identification and selection of indicators to be used, data collection and analysis. This method was developed by critiques of the other methods of impact evaluation which according to the advocators fail to take into account the complexity, diversity and contingency of winning a livelihood. They argue that the scientific methods ―…reduces causality to simply unidirectional chains, rather than complex webs; it measures the irrelevant or pretends to measure the immeasurable; and it empowers professionals, policy-makers and elites, thus reinforcing the *status quo* …‖ (Hulme, 2000). Although, the approach presents some good values of impact assessment, it is still in its infancy.

3.4 Measures of poverty

Several methods are used to measure poverty. Some of the measures identified by Makoka and Kaplan (2005) are briefly presented below together with the advantages and disadvantages of each measure.

3.4.1 Poverty incidence or Poverty rate, P_0

Poverty incidence or poverty rate, usually denoted as P_0, is the share of the population whose consumption (or income) falls below the poverty line. It quantifies the share of population that cannot afford to buy a basket of goods. When individual are used as the unit of analysis, the measure is referred to as Poverty Headcount Index.

Mathematically, the poverty rate P_0 is given as:

$1_N \quad 1_q \quad N_p$

$$P_0 = \frac{1}{N}\sum_{i=1}^{N} I(y_i \le z) = \frac{1}{N}\sum_{i=1}^{N_p} 1 = \frac{N_p}{N}, \ldots\ldots\ldots\ldots\ldots (1)$$

Where: N = total population

I(.) = an indicator function taking a value of 1(poor) if the bracketed expression is true and 0 (non-poor)

Z = poverty line

Np= number of poor in the population

The major advantages of the poverty rate as a measure of poverty have been given as its simplicity to construct and understand. It also adequately assesses the overall progress in reducing poverty. However, it has some major limitations too. First, it assumes that the poor are all in the same situation and therefore does not take into account the differences in well-being among different poor households. Second, it is not sensitive to changes in the welfare of individuals as long as they remain below the poverty line and finally it does not take into account the intensity of poverty.

3.4.2 Poverty Gap Index, P_1

The *Poverty Gap Index* denoted as P_1, is the average of the proportionate gaps between poor people's living standards and the poverty line. It is also called the Depth of Poverty Index.

Mathematically, it is defined as:

$$P_1 = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{z - y_i}{z}\right) I(y_i \le z) = \frac{1}{N}\sum_{i=1}^{q}\left(\frac{z - y_i}{z}\right) \text{…………(2)}$$

Note: equation (2) has the same variables as in equation (1)

The *Poverty Gap Index* measures the depth of poverty i.e. the degree to which the mean income of the poor differs from the established poverty line. The major advantages of the *Poverty Gap Index* are that it measures the average shortfall of poor people and also shows how much would be transferred to the poor to bring their expenditure up to the poverty line. However, its major limitations are that it does not capture differences in the severity of poverty among the poor and it also ignores any inequality among the poor people.

3.4.3 The Squared Poverty Gap Index, P_2

This measure of poverty is similar to the Poverty Gap Index except that poverty gaps are squared, thus giving the largest weighting to the largest poverty gap. It captures differences in income levels of the poor and is also referred to as the Severity of Poverty Index.

Mathematically, it is defined as:

$$P_2 = \frac{1}{N}\sum_{i=1}^{q}\left(\frac{z-y_i}{z}\right)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

The advantage of this measure of poverty is that it takes into account the poverty gap and also the inequality among the poor. However, its major limitation is that it is not easy to interpret, the reason why it is not widely used.

3.4.4 The Foster-Greer-Thorbecke Poverty Index

The Headcount Index, the Poverty Gap Index, and the squared poverty Gap Index belong to this group of poverty measures. They are referred to as decomposable poverty measures. If a poverty measure of a group is a weighted average of the poverty measures of the individuals in a group, then it is said to be decomposable (Aguirregabiria, 2003).

The general formula for this class poverty measures is:

$$P_\alpha = \frac{1}{N}\sum_{i=1}^{q}\left(\frac{z-y_i}{z}\right)^\alpha \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where $\alpha \geq 0$

Note: larger values of α put higher weight on the poverty gaps of the poorest people.

3.4.5 The Human Poverty Index

The Human Poverty Index (HPI) is the only non-income measure of poverty. It measure deprivations in three basic dimensions of the human development. These dimensions are: first, a long and healthy life – as measured by the probability at birth of not surviving to the age of 40. Second, knowledge – as measured by adult literacy rate. Third, a decent standard of living – as measured by the unweighted average of two indicators, the percentage of population without sustainable access to an improved water source and the percentage of children under weight for age (UNDP, 2005).

The HPI is calculated as follows:

$$HPI = \left[\frac{1}{3}\left(P_1^{\alpha} + P_2^{\alpha} + P_3^{\alpha}\right)\right]^{\frac{1}{\alpha}} \quad \text{.............................(5)}$$

Where: P_1 = the probability at birth of not surviving to age 40 (times 100)

P_2 = Adult literacy rate

P_3 = Unweighted average of population without sustainable access to an improved water source and children under weight for age

□□3

However, the analysis on poverty for this study is based on the Poverty incidence or Poverty rate (Poverty Headcount index) and Poverty Gap Index (Depth of Poverty Index). These poverty measures are considered by the study because they are easier to compute and they can also be easily interpret and understood by almost everyone.

3.5 Method of Data analysis

3.5.1 ATE estimation of NERICA adoption rates

The study follows the ATE estimation methodology by Diagne and Demont (2007), to consistently estimate NERICA adoption rates and their determinants in The Gambia (see, for example, Heckman and Vytlacil, 2007a and 2007b; Imbens 2004; Wooldridge, 2002; Heckman, 1996; Angrist *et al*., 1996; Rosenbaum and Rubin, 1983). As pointed out by Diagne and Demont (2007), this approach is necessary because commonly used adoption rates estimators suffer either from what is referred to as ―non-exposure‖ bias or selection bias. As a result, they yield biased and inconsistent estimates of population adoption rates even when based on a randomly selected sample. The ―non-exposure‖ bias results from the fact that farmers who have not been exposed to a new technology cannot adopt it *even* *if they might have done so if they had known about it* (Diagne, 2006). This results in the population adoption rate being underestimated. One would think that the solution to the ―non-exposure‖ bias problem is to take the adoption rate among those exposed to the technology as the true estimates of the population adoption rates. But, the sample adoption rate within the sub-population of farmers exposed to the technology is *not* a consistent estimate of the true population adoption rate either, even if the sample is random (Diagne, 2006). Because of selection bias, it may either underestimate or overestimate the true population adoption rates. For the same reasons of population nonexposure and selection bias, the causal effects of the determinants of adoption cannot also be consistently estimated using simple probit, logit or tobit adoption models that do not control for exposure[8]. The non-exposure bias also makes it difficult to interpret the coefficients of classical adoption models when the diffusion of the technology in the population is incomplete (Besley and Case, 1993 Saha *et al*., 1994, and Dimara and Skura, 2003).

The true population adoption rate corresponds to what is defined in the modern treatment evaluation literature as the *average treatment effect*, commonly denoted as ATE. The ATE parameter measures the effect or impact of a ―treatment‖ on a person randomly selected in the population (Wooldridge, 2002, chapter 18). In the adoption context ―treatment‖ corresponds to exposure to a technology and the ATE parameter is a measure of the potential demand of the technology by the target population under complete

[8] In this study, the word ―exposure‖ is used strictly to mean awareness of the existence of the new technology and does not necessarily implies any learning of its characteristics.

exposure. The adoption outcome measured by the ATE parameter is the population mean *potential* adoption rate. The difference between the population mean potential adoption outcome and the population actual (observed) adoption outcome is the non-exposure bias, also known as adoption gap, which exist because of incomplete diffusion of the technology in the population. Another parameter of interest is the *average treatment effect on the treated*, commonly denoted as ATE1 or ATT (Wooldridge, 2002, chapter 18). ATE1 is the mean adoption outcome within the sub-population of exposed farmers. The difference between the population mean adoption outcome (ATE) and the mean adoption outcome among the exposed (ATE1) is the population selection bias (PSB). The consistent estimation of ATE and ATE1, which are the main focus of the treatment effect methodology, requires controlling appropriately for the exposure status. The details of the estimation procedures of the ATE parameters in the adoption context are given below.

Based on the ATE estimation framework, every farmer in the population has two potential adoption outcomes: with and without exposure to a technology (treatment). To operationalize the framework, let y_1 be the potential adoption outcome of a farmer when exposed to the NERICA and y_0 be the potential adoption when not exposed to them. The potential adoption outcome can be either adoption status (a dichotomous 0-1 variable) or a measure of intensity of adoption such as the total land area allocated to NERICA. To measure the adoption rates of NERICA, the study has taken into account the fact that several NERICA varieties have been release in The Gambia for adoption by farmers but due to data limitation it is not possible to determine the adoption status or intensity of adoption for each NERICA variety. Moreover, because of the complexity of determining the intensity of adoption, the study rather estimates the adoption status of the NERICA as a group. The adoption or non-adoption of the NERICA is defined as the cultivation or non-cultivation of at least one NERICA variety. Then, the ―treatment effect‖ for farmer *i* is measured by the difference $y_{i1} - y_{i0}$. Hence, the expected population adoption impact of exposure to the NERICA is given by the mean value $E(y_{i1} - y_{i0})$, which is, by definition, *the average treatment effect*, ATE.

But, the inability to observe both an outcome and its counterfactual makes it impossible in general to measure $y_1 - y_0$ for any given farmer. However, since exposure to NERICA is a necessary condition for its adoption, we have $y_0 = 0$ for any farmer whether exposed to the NERICA or not. Hence the adoption impact of a farmer *i* is given by y_{i1} and the average adoption impact (of exposure) is given by $ATE = E(y_1)$. Unfortunately, we observe y_1 only for the farmers exposed to NERICA. Hence, we cannot estimate the expected value of y_1 by the sample average of a randomly drawn sample since some of the y_1 in the sample would be missing.

If a binary variable w is introduced to represent the exposure status of a farmer to NERICA varieties, where $w = 1$ denotes exposure and $w = 0$ otherwise; the average adoption impact on the exposed subpopulation is given by the conditional expected value $ATE1 = E(y_1 | w = 1) = P(y_1 = 1 | w = 1)$, which is by definition the *average treatment effect on the treated*, commonly denoted by ATE1. Since, we do observe y_1 for all the exposed farmers, the sample average of y_1 from the sub-sample of exposed farmers will consistently estimate ATE1, provided the sample is random. The adoption impact of the non-exposed subpopulation $ATE0 = E(y_1 \mid w = 0) = P(y_1 = 1 \mid w = 0)$ can also be identified and estimated. Then ATE can be decomposed as a weighted sum of ATE1 and ATE0 as:

$$ATE = E(y_1) = P(w = 1)\,ATE1 + [1 - P(w = 1)]\,ATE0 \quad \text{.................. (6)}$$

where $P(w = 1)$ is the probability of exposure

Given the above expressions, the *observed* adoption outcome y can be expressed as a function of the two potential adoption outcomes y_1 and y_0 and the treatment status variable w as:

$$y = wy_1 + (1 - w)y_0 \quad \text{..(7)}$$

However, since $y_0 = 0$ for any farmer whether exposed to the NERICA or not, the expression of the observed adoption outcome variable as a function of the two adoption potential outcomes and the exposure variable reduces to $y = wy_1$. This shows that the observed outcome variable is a combination of the exposure and adoption outcome variable. Hence, the population observed mean is given as $E(y) = E(wy_1)$, which is the population mean joint exposure and adoption parameter denoted as JEA. This is different from the true population adoption rate (ATE), which is given as $E(y_1)$. The difference between the JEA and ATE parameters is the population non exposure bias (NEB), also called the population adoption gap (GAP): $NEB = GAP = E(y) - E(y_1)$. The population selection bias (PSB) is given by: $PSB = ATE1 - ATE = E(y_1 | w = 1) - E(y_1)$.

The estimation of ATE from the above equations is not a straightforward issue, because we do not observe y_1 for the non-exposed subpopulation ($w = 0$). Then, how can ATE be estimated if we do not observe y_1 for $w = 0$? The answer lies on the conditional independence assumption (Wooldridge, 2002; chapter 18), which states that the treatment status w is independent of the potential outcomes y_1 and y_0 conditional on the observed set of covariates z that determine exposure (w). The ATE estimators based on the conditional independence assumption are either a pure parametric regression-based method where the covariates are possibly interacted with treatment status variable (to account for heterogeneous impact), or they are based on a two-stage estimation procedure where the conditional probability of treatment $P(w = 1 | z) = P(z)$, called the propensity score , is estimated in the first stage and ATE, ATE1 and ATE0 are estimated in the second stage by parametric regression-based methods or by non-parametric methods. The study uses two different estimators to estimate ATE: 1) semi-parametric weighting estimator 2) parametric method.

Semi-parametric weighting estimator of ATE

The following equations can be used to obtain non-parametric and semi-parametric ATE, ATE1 and ATE0 estimates of the NERICA population adoption rates using the observed NERICA adoption status (i.e. y is the 0-1 binary indication of the adoption of at least one NERICA variety), the NERICA exposure status w, and a vector of selected household demographic and socio-economic variables, x and z (see Diagne and Demont, 2007). The estimation is based on two-stage procedure where the conditional probability of treatment $P(w = 1 | z) \equiv P(z)$, called the propensity (PS) is estimated in the first stage and ATE, ATE1 and ATE0 are estimated in the second stage.

$$\hat{ATE} = \frac{1}{n}\sum_{i=1}^{n} \frac{y_i}{\hat{p}(z_i)} \quad \text{.......... (8)}$$

$$ATE1 = \frac{1}{n}\sum_{i=1}^{n} y_i - \frac{1}{n_e}\sum_{i=1}^{n_e} y_i \quad \text{.......... (9)}$$

$$\hat{ATE}0 = \frac{1}{n - n_e}\sum_{i=1}^{n} \frac{(1 - \hat{p}(z_i))}{\hat{p}(z_i)} y_i \quad \text{.......... (10)}$$

where $\hat{p}(z)$ is a consistent estimate of the propensity score evaluated at z and $n_e = \sum_{i=1}^{n} w_i$ is the sample number of exposed farmers.

Parametric estimation of ATE

The parametric estimation procedure is executed by first specifying a parametric model. The method uses only the sub-population of exposed farmers to identify ATE. The identification is based on the following equations, which hold under the conditional independence assumption (see Diagne and Demont, 2007):

$$E(y \mid x, w = 1) = g(x, \beta) \quad \text{(11)}$$

where g in equation is a known (possibly nonlinear) function of the vector of covariates x and the unknown parameter vector β which is to be estimated using standard Least Squares (LS) or Maximum Likelihood Estimation (MLE) procedures using the observations (y_i, x_i) from the subsample of exposed farmers only with y as the dependent variable and x the vector of explanatory variables. With an estimated parameter $\hat{\beta}$, the predicted values $g(x_i, \hat{\beta})$ are computed for all the observations i in the sample (including the observations in the non-exposed subsample) and ATE, ATE1 and ATE0 are estimated by taking the average of the predicted $g(x_i, \hat{\beta})$ $i=1,..,n$ across the full sample (for ATE) and respective subsamples (for ATE1 and ATE0):

$$A\hat{T}E = \frac{1}{n}\sum_{i=1}^{n} g(x_i, \hat{\beta}) \quad \text{(12)}$$

$$A\hat{T}E1 = \frac{1}{n}\sum^{n} w_i \, g(x_i, \hat{\beta}) \quad \text{(13)}$$

$n_e \quad i=1$

$$\hat{ATE}0 = \frac{1}{n - n_e}\sum_{i=1}^{n}(1-w_i)g(x_i,\hat{\beta}) \text{..................................} \mathbf{(14)}$$

The effects of the determinants of adoption as measured by the *K* marginal effects of the *K*-dimensional vector of covariates *x* at a given point $\bar{x}$ are estimated as:

$$\frac{\partial E(y \mid \bar{x})}{\partial x_k} = \frac{\partial g(\bar{x},\hat{\beta})}{\partial x_k} \quad k = 1,..,K \text{ ....} \mathbf{(15)}$$

where x_k is the k^{th} component of *x*.

The study used both the semi-parametric weighting estimators (equation 8,9, and 10) and the parametric regression based estimators (equation 12,13, and 14) by following more or less the same procedures by Diagne and Demont (2007) to estimate ATE, ATE1, ATE0, the population adoption gap ($\hat{GAP} = \hat{JEA} - \hat{ATE}$)[9], and the population selection bias (

[9] The joint exposure and adoption parameter (JEA) is consistently estimated by the sample average of the *observed* adoption outcome values: $\hat{JEA} = \frac{1}{n}\sum_{i=1}^{n} y_i$.

$PS\hat{}B$ $ATE\hat{}1$ $AT\hat{}E$). The propensity score $\hat{P}(z)$appearing in the semi-parametric estimation procedure is estimated using a probit model of the determinants of exposure: $P(z)$ (z) where Φ is the standard normal cumulative distribution with density function identified by Diagne (2007) as (t) ($\frac{1}{2}$)exp($\frac{t^2}{2}$) , z the observed vector of covariates determining exposure to the NERICA varieties and γ is the parameter vector being estimated. The marginal effects in equation (15) are also estimated using ATE parametric model. For comparison purposes, the study has also estimated a ―classic‖ probit adoption model (which, as discussed above is in fact a model of the determinants of joint exposure and adoption): $P(y$ 1| x) (x) where x (z, x) is the vector of covariates determining both exposure (w) and adoption (y_1) and θ is the parameter vector to be estimated. All the estimations were done in Stata using the Stata add-on *adoption* command developed by Diagne (2007).

3.5.2 Estimation of the impact of NERICA adoption

The study follows the impact estimation methodology by Diagne (2006b), which is based on the potential outcome framework. As highlighted by Diagne (2006b), the potential outcome framework is the conceptual framework underlying standards methods for establishing the causal effects of treatments on observed outcomes. It also underlies the design of agricultural experiments and justifies the statistical procedures used to analyze the data from such experiments. Under such framework, treatment refers to adoption of the NERICA varieties by which every farmer has two potential outcomes[10]: an outcome when a adopting a NERICA variety denoted as y_1 and an outcome when not adopting a NERICA variety denoted as y_0. Letting d to stand for adoption status, whereby $d = 1$ represent NERICA adoption and $d = 0$ otherwise. Then, the observed outcome can be written as a function of the two potential outcomes: $y = dy_1 + (1 - d)y_0$. For any observational unit the causal effect of NERICA adoption on its observed outcome is simply the difference of its two potential outcomes: $y_1 - y_0$. However, the two potential outcomes are mutually exclusive for any observational unit. This missing data problem makes it impossible to measure the effect of NERICA adoption on the observed outcome for any observational unit. Although the causal effect of NERICA adoption for any observational unit cannot be estimated, it is possible to estimate the mean causal effect of NERICA adoption across all observational units: $E(y_1 - y_0)$, where E is the mathematical expectation operator. Such population parameter is called the average treatment effect in the literature and is usually denoted by ATE. The mean causal effect of NERICA adoption restricted to the treated observational units only: $E(y_1 - y_0 | d = 1)$, can also be identified and estimated. This population parameter is called the average treatment effect on the treated in the literature and is usually denoted by ATE1 (or ATT). Another population parameter that can be identified and estimated is the average treatment effect of the untreated: $E(y_1 - y_0 | d = 0)$, usually denoted by ATE0 (Diagne 2006b).

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[10] The outcomes analysed in the empirical section are rice yields and income which have been taken as indicators for productivity and poverty respectively.

When NERICA adoption is random in the population, the mean different in the outcome of interest between NERICA adopters and non-adopters is an unbiased estimate of the impact of NERICA adoption. Unfortunately, randomization is unattainable under on-farm setting where the observational units are farmers‘ plots and treatment means farmers making individual choices with regard to which variety to cultivate and how much input to use in each plot. For simplicity, one would think it will be better to compare the mean yield across farms of two rice varieties and take the mean difference in yield as true impact estimate. However, as indicated by Diagne (2006b), the differences in the set of varieties cultivated by farmers make it illogical to compare the mean yield across farms of two varieties when the two varieties are not cultivated by every farmer. The meaningful comparison in situations where farmers cultivate different set of rice varieties is the mean yield across all farms with and without the adoption of a given variety by farmers (Diagne, 2006b). However, because farmers‘ allocation of varieties to different plots is non-random, the mean difference between adopters and non-adopters of a given rice variety is a bias estimate even if farmers themselves are randomly selected (Diagne, 2006b).

In the treatment literature, data arising from household surveys are called observational data. The main problems associated with such data are bias and non-compliance. The biases are of two types (Rosenbaum, 2001; Lee, 2005): overt and hidden biases. Overt bias is the difference in the observed outcome y between adopters and non-adopters not caused by NERICA adoption but which is due to differences in characteristics that can be observed. Hidden bias, on the other hand, is the difference in the observed outcome y between adopters and non-adopters not cause by NERICA adoption but which is due to unobservable characteristics. Non-compliance also called the endogenous treatment variable problem in econometrics (Imbens and Rubin, 1997; Imbens and Angrist, 1994; Heckman and Vytlacil, 2005) arises in observational studies because the subjects of treatment are people who may or may not stick to their assigned treatments if treatment was to be assigned randomly. For this reason, a difference in an individual‘s potential outcomes $y_{1i} - y_{0i}$ may not be due to NERICA adoption but rather to the unobserved factors that caused that individual not to stick to his or her assigned treatment. As a result, the average treatment effect for the entire population is different from the mean treatment effect that would have occurred if treatment was randomly assigned and every person in the population complied with their assignment (Imbens and Rubin, 1997; Imbens and Angrist, 1994). A causal interpretation is given only to the situation where everyone complies with his or her assigned treatment.

Imbens and Angrist (1994) who provided the solution to the non-compliance problem divided the population from observational data into four groups based on compliance status: *compliers* (those who adhere to their assigned treatment), *always takers* (those who manage to always take the treatment regardless of their assignment), *never takers* (those who never take the treatment regardless of their assignment) and *defiers* (those who do the opposite of what their assignment asked them to do). Imbens and Angrist (1994) have given a causal interpretation only to the sub-population of compliers and they call such a population parameter the *local average treatment effect* (LATE). The LATE parameter is difficult to identify because the compliance status of a person cannot in general be observed. However, with the monotonicity assumption (the assumption of no defiers in the population), Imbens and Angrist (1994) show that if there are no defiers in the population, then the size of the three remaining groups and the LATE parameter can be identified and estimated.

Because the adoption of a variety is a farmer choice, we are faced with the noncompliance or endogenous treatment problem discussed above. Therefore, the ATE estimate of the impact of adoption does not have a causal interpretation. Thus, we need the LATE estimate, which is the estimate with causal interpretation of the impact of NERICA adoption on rice yields and income. Since one cannot adopt a technology without being aware or exposed to it, the assumption of no defiers (monotonicity assumption) by Imbens and Angrist (1994) is by some means satisfied. This successfully rules out the cases of defiers and always takers. Hence, when assessing the impact of adoption of a technology on any farmer outcome, the population is divided into only two groups: the group of compliers, which represents the group of potential adopters (those who will adopt the technology when exposed to it), and the group of never takers, which represents the group of never adopters (those who will never adopt the technology when exposed to it). Thus, the mean impact with a causal interpretation (the LATE estimate) applies only to the subpopulation of the potential adopters.

The overt and hidden biases together with the non-compliance or endogenous problems have been addressed in the biostatics and econometric literatures by several methods. These methods can be classified under two broad categories with regard to the type of assumption they require to arrive at consistent estimators of causal effects. First, methods have been developed that remove only the overt bias based on the ―ignorability‖ or conditional independence assumption (Rubin, 1974; Rosenbaum and Rubin, 1983). These methods postulate the existence of a set of covariates x , which when controlled for, renders the treatment status d independent of the potential outcomes y_1 and y_0. The estimators using the conditional independence assumption are either a pure parametric regression-based method or a two stage estimation procedure where the conditional probability of treatment $P(d=1|x) = P(x)$, refer to as the propensity score is estimated in the first stage and ATE, ATE1 and ATE0 are estimated in the second stage by parametric regression-based methods or by non-parametric methods, which include various matching methods (see Imbens 2004)[11]. For the purpose of this study, the conditional independence based estimators of ATE, ATE1 and ATE0 used are the OLS and inverse propensity score weighting estimators (IPSW), which are given by the following formulas(see Imbens, 2004; Lee 2005, pp 65-69)[12]:

$$\widehat{ATE} = \frac{1}{n}\sum_{i=1}^{n}\left\{\frac{d_i y_i}{\hat{p}(x_i)} - \frac{(1-d_i) y_i}{1-\hat{p}(x_i)}\right\} \qquad \textbf{(16)}$$

$$\frac{1}{n}\sum d$$

[11] The propensity score-based estimators exploit the fact that the conditional independence assumption implies the independence between d and the potential outcomes y_1 and y_0 conditional on $P(x)$ as well (Rosenbaum and Rubin, 1983). They also use the additional assumption that $0 < P(x) < 1$.

[12] The asymptotic distributions of the three estimators are given in Lee (2005), pp. 67-69.

$$A\hat{T}E1 = \frac{1}{n_1}\sum_{i=1}^{n}\left[\frac{d_i - \hat{p}(x_i)}{1 - \hat{p}(x_i)}\right]y_i \text{ ....} \textbf{(17)}$$

$$A\hat{T}E0 = \frac{1}{n - n_1}\sum_{i=1}^{n}\left[\frac{d_i - \hat{p}(x_i)}{\hat{p}(x_i)}\right]y_i \text{ ....} \textbf{(18)}$$

Where n is the sample size, $n_1 = \sum_{i=1}^{n} d_i$ is the number of treated (i.e. the number of NERICA adopters) and $\hat{p}(x_i)$ is the propensity score estimated with a probit model.

Second, there are methods designed to remove both overt and hidden biases and deal with the endogenous treatment problem. Such methods are the instrumental variable (IV) based methods (Heckman and Vytlacil, 2005; Imbens 2004; Abadie, 2003; Imbens and Angrist, 1994). These methods (IV) assume the existence of at least one variable z called instrument that directly influence treatment status but has no direct influence on the outcomes y_1 and y_0, once the effects of the covariates are controlled for. The study uses two IV-based estimators to estimate the LATE of NERICA adoption on yield and income. The first one is the non-parametric Wald estimator proposed by Imbens and Angrist (1994). This estimator requires only the observed outcome variable y, the treatment status variable d and an instrument z .The second IV estimator is Abadie‘s (2003) generalization of the LATE estimator of Imbens and Angrist (1994) to cases where the instrument is not totally independent of the potential outcome y_1 and y_0; but will become so conditional on some vector of covariates x that determine the observed outcome y .

The study adopts exposure to NERICA as an instrumental variable for operationalizing the expressions of Imbens and Angrist (1994) LATE estimator and that of Abadie (2003). This was found by Diagne (2006b) to be the natural instrument for the NERICA adoption status variable for two reasons. First, one cannot adopt a NERICA without being exposed to it (i.e. exposure does cause adoption). Second, it is rational to assume that exposure to NERICA affects yield and income only through adoption (i.e. the mere exposure to NERICA without adoption does not affect rice yield and income of farmers). Thus, the two requirements for the exposure status variable to be a valid instrument are met. Now, let z be a binary outcome variable taking the value 1 when a farmer is exposed to the NERICA and the value 0 otherwise. Let d_1 and d_0 be binary variables denoting the two potential adoption outcomes status of the farmer with and without exposure to the NERICA, respectively (with 1 indicating adoption and 0 otherwise). Since one cannot adopt a NERICA without being exposed to it, then, $d_0 = 0$ for all farmers and the observed adoption outcome is given by $d = zd_1$. The subpopulation of potential adopters is described by the condition $d_1 = 1$ and that of actual adopters is described by the condition $d = 1$ (which is equivalent to $z = 1$ and $d_1 = 1$). By assuming that z is independent of the potential outcomes d_1, y_1 and y_0 (this assumption is equivalent to assuming that exposure to NERICA is random in the population), then the mean impact of NERICA adoption of the subpopulation of NERICA potential adopters (i.e. LATE) is given by (Imbens and Angrist, 1994; Imbens and Rubin 1997; Lee, 2005):

$$E(y_1 - y_0 | d_1 = 1) = \frac{E(y | z = 1) - E(y | z = 0)}{E(d | z = 1) - E(d | z = 0)} \quad \textbf{(19)}$$

The right side of (19) can be estimated by its sample analogue:

$$\left\{ \frac{\sum_{i=1}^{n} y_i z_i}{\sum_{i=1}^{n} z_i} - \frac{\sum_{i=1}^{n} y_i (1 - z_i)}{\sum_{i=1}^{n} (1 - z_i)} \right\} \left\{ \frac{\sum_{i=1}^{n} d_i z_i}{\sum_{i=1}^{n} z_i} - \frac{\sum_{i=1}^{n} d_i (1 - z_i)}{\sum_{i=1}^{n} (1 - z_i)} \right\}^{-1} \quad \textbf{(20)}$$

This is the *Wald* estimator[14].

Moreover, because it is unrealistic[15] to assume that exposure to NERICA is random in population, the study proceeds with Abadie‘s LATE estimator which does not require such assumption but instead requires a much weaker conditional independence assumption: the instrument z is independent of the potential outcomes d_1, y_1 and y_0 conditional on a vector of covariates x determining the observed outcome y[16]. With these assumptions, the following results can be shown to hold for the conditional mean outcome response function for potential adopters $f(x, d) \equiv E(y | x, d; d_1 = 1)$ and any function g of (y, x, d) (see, Abadie, 2003; Lee, 2005):

$$f(x,1) - f(x,0) = E\{y_1 - y_0 | x, d_1 = 1\} \quad \textbf{(21)}$$

$$E\{g(y,d,x) | d_1 = 1\} = \frac{1}{P(d_1 = 1)} E\{\kappa \cdot g(y,d,x)\} \quad \textbf{(22)}$$

[14] The study used the equivalent IV estimation procedure in Stata which provides the standard error of the estimate directly.

[15] See Diagne, 2006 for discussion and evidence against this hypothesis.

[16] For completeness, it is also assumed that the conditional probability of NERICA exposure *P*(d=1 | *x*) is strictly between zero and 1 and that of NERICA potential adoption $P(d_1=1 \mid x)$ is strictly positive for all values of *x*.

z where □□1□ ________(1□ *d*) is a weight function that takes the value 1 for a potential *p*(*z* □1| *x*)

adopter and a negative value otherwise. The function *f*(*x*,*d*) is called a *local average response function (LARF)* by Abadie (2003). Estimation proceeds by a parameterization of the LARF *f*(□*; x, d*)= E(*y* | *x*, *d*; d_1=1). Then, using equation 17 with *g*(*y*,*d*, *x*) =□*y* □ *f* (□;*x*,*d*)□^{2}, the parameter □ is estimated by a weighted least squares scheme that minimizes the sample analogue of *E*□□□*y* □ *f* (□;*x*,*d*)□^{2}□. The conditional probability *P* (*z*=1|*x*) appearing in the weight □ is estimated by a probit model in a first stage. Abadie (2003) proves that the resulting estimator of □ is consistent and asymptotically normal. Once, □ is estimated, equation 21 is used to recover the conditional mean treatment effect *E*□y_1 □ y_0| *x*, d_1 □1□ as a function of *x*. The LATE is then obtained by averaging across *x* using equation (22). For example, with a simple linear function *f* (□,*d*,*x*)= □$_0$ □□*d* □□*x* where □= (□$_0$,□,□); then *E*□y_1 □ y_0| *x*, d_1 □1□=□ . In this case, there is no need for averaging to obtain the LATE, which is here equal to □ . A simple linear functional form for the LARF with no interaction between *d* and *x* implies a constant treatment effect across the subpopulation of potential adopters. In the estimations provided for this study, an exponential conditional mean response function with and without interaction is postulated to guaranty both the positivity of predicted outcomes (yield and income) and heterogeneity of the treatment effect across the sub-population of potential adopters. Because exposure (i.e. awareness) is a necessary condition for adoption, it can be shown that the LATE for the sub-population of potential adopters (i.e. those with d_1=1) is the same as the LATE for the sub-population of *actual* adopters (i.e. those with d=zd_1=1).

Chapter Four:

Results and Discussions

Chapter four is presented in four sections. Section one gives the socio-demographic characteristic of the sample famers by adoption status; section two presents the estimates of NERICA adoption rates and their determinants; section three gives a descriptive analysis of the impact of NERICA adoption on rice yields and income while section four gives an econometric analysis of the impact of NERICA adoption.

4.1 Socio-demographic characteristics of farmers

Table 2 presents some socio-demographic characteristics of the surveyed farmers by adoption status. The table shows no significant difference between NERICA adopting and non-adopting farmers with regard to gender. This finding suggests that NERICA adoption is uncorrelated with gender. However, the insignificant difference in terms of gender between NERICA adopters and non-adopters could be attributed to the fact that the sample is composed many of woman rice farmers. Therefore, one should not expect significant difference in adoption status with regard to gender. Significant difference at 1% level has been found between NERICA adopting and non-adopting farmers with regard to the years of experience in upland ecology. NERICA adopters were found to have higher number of years of experience in the upland ecology. This finding suggests that NERICA adoption is positively correlated with years of experience. Consistent with this finding is Adesina and Baidu-Forson (1995) who also found adoption to be positively correlated with years of experience in Guinea with regard to farmer adoption of mangrove rice varieties.

Table 2: Socio-demographic characteristics of farmers by adoption status

Variable	NERICA adopters	Non-NERICA adopters (N=363)	Difference
NERICA village	(N=237)0.68 (0.03)	0.38 (0.03)	0.30 (0.04)***
Woman	0.92 (0.02)	0.94 (0.01)	-0.02 (0.02)
Mean age	45.06 (0.88)	44.57 (0.77)	0.49 (1.17)
Household size	16.36 (0.79)	15.76 (0.76)	14.13 (1.09)
Farm size (in hectares)	0.55 (0.03)	0.61 (0.03)	-0.06 (0.04)
Mean yield in 2006 (tonnes/ha)	1.015 (0.03)	0.889 (0.02)	0.117 (0.03)***
Mean yield in 2005 (tonnes/ha)	1.088 (70.85)	1.034 (52.00)	0.054 (84.89)
Contact with NARI	0.09 (0.02)	0.02 (0.01)	0.07 (0.02)***
Contact with DAS	0.35 (0.03)	0.28 (0.02)	0.06 (0.04)
Practice upland rice cultivation	0.66 (0.03)	0.45 (0.03)	0.21 (0.04)***
Practice lowland rice cultivation	0.72 (0.03)	0.85 (0.02)	-0.13 (0.04)***
Practice irrigated rice cultivation	0.14 (0.02)	0.15 (0.02)	-0.01 (0.03)
Practice mangrove rice cultivation	0.07 (0.02)	0.08 (0.01)	-0.01 (0.02)
Years of experience in the upland ecology	10.33 (0.69)	7.24 (0.54)	3.09 (0.88)***

Robust standard error in parenthesis***Significant at 1% significance level

Moreover, about 68% of the NERICA adopters reside in villages where NERICA seeds have been disseminated to rice farmers by NARI and DAS. This finding shows the importance of accessibility to seeds as major determinant of adoption. The mere fact that a farmer is exposed to a given high-yielding rice technology is not a sufficient condition that ascertains adoption. The farmer should be able to get access to the seeds before adoption can be effected. Moreover, the mean ages of the NERICA adopting and nonadopting farmers have been found to be almost the same, suggesting that NERICA adoption decision is uncorrelated with age. This finding is consistent with Diagne *et al.* (2009) who found no significant difference between the average ages of NERICA adopting and non-adopting household heads in Benin.

Furthermore, there is no significance difference in farm size between the NERICA adopters and non-adopter. This finding suggests that farmer adoption of NERICA in The Gambia is not dependent on farm size. However, it contrasts with the findings of Diagne *et al.* (2009) and Mendola (2006) who found a significant difference in farm size between technology adopters and non-adopters with the adopters cultivating larger farm area. The current study targeted small-scale rice farmers, the majority of whom has small land holdings. For this reason, one should not expect a significant difference in land area cultivated between NERICA adopters and non-adopters. In addition, there is no significant different in household size between adopters and non- adopters, also suggesting the lack of correlation between farmers‘ decision to adopt NERICA and their household size. The prevalence of extended family system in the rural areas of the country guarantees that household sizes do not differ significantly from one geographic location to the other and also among households within the same locality. Moreover, significant difference has been found between adopters and non-adopters with regard to farmer contact with the main agricultural research institute (NARI). This is not surprising, since NARI is coordinating the NERICA dissemination activities in the country, it is expected that a good number of NERICA adopters would be farmers that have contact with the institute. However, the insignificant different between NERICA adopters and non-adopters with regard to farmer contact with DAS can be explain by the fact this institute embodies all the agricultural extension workers in the country who are evenly assigned to officiate at farmer level across all the six agricultural regions. This is partly the reason why there is no significant different between NERICA adopters and non-adopters with respect to their affiliation with this institute.

Additionally, four main rice ecologies were identified during the nationwide survey. Base on the location or gender of a farmer, significant difference can be found between NERICA adopters and non-adopters across these ecologies. There is a significant difference between NERICA adopting and non-adopting farmers with respect to farmer practice of upland rice cultivation. Greater percentage of NERICA adopters was found to be upland farmers. The NERICA that are released in The Gambia at the moment are upland rice varieties. Therefore, one should expect greater percentage of its adopters to be those practicing upland rice farming. With regard to the other ecologies there is little or no significant difference between NERICA adopting and non-adopting farmers. This finding can be somehow surprising to scientists who are very much conversant with the yield potentials of each of these rice ecologies. Generally, of all the rice ecologies, the upland gives the lowest yields. Why would a farmer that cultivate rice in the irrigated, lowland or mangrove ecology adopt NERICA (an upland variety) if those ecologies give higher yields? The answer to this question can be intertwined with famer demand for non-yield attributes of a given rice variety, which is the main reason why farmer adoption of NERICA is generally uncorrelated with type of ecology.

4.2 NERICA adoption rates and their determinants

4.2.1 Sample diffusion and adoption rates of NERICA varieties in The Gambia

NERICA were first introduced in The Gambia in 1998 through Participatory Varietal Selection: PVS (Gridney, Jones and Wopereis – Pura, 2002). The PVS activities were initially hosted in three villages (Tujereng, Jifanga and Ntoroba[13]). NERICA were first introduced in these villages and later diffused to the surrounding near-by villages and other agricultural regions through farmers own channels, National Agricultural Research Institute (NARI) and Department of Agricultural Services (DAS). During the early stages of the PVS activities, the diffusion rate of NERICA was low in the population. It started to increase rapidly only after the official introduction of the NERICA varieties in 2003 through collaborative efforts of The Gambia government and the Africa Rice Center (AfricaRice, ex-WARDA).

The sample diffusion and adoption rates of NERICA from 2001 to 2006 are shown in Table 3. Out of 600 farmers, only 277 were exposed to NERICA. This translates to 46% diffusion rate of NERICA within the sample villages. The highest exposure rate was observed among farmers in Western Region (WR) and the lowest in Central River Region

[13] Tujereng and Jifanga are located in the Western Region, while Ntoroba is located in the North Bank Region.

north (CRRn). The exposure rates in the other regions were relatively high except for North Bank Region (NBR) and Upper River Region (URR).

Table 3: Evolution of NERICA in The Gambia

Description	Regions						Total
	WR	LRR	CRRs	NBR	CRRn	URR	
Number of farmers	100	100	100	100	100	100	600
Number of farmers exposed to NERICA	68	41	56	39	34	39	277
Proportion of farmers exposed to NERICA (%)	68	41	56	39	34	39	46
Adoption of NERICA varieties							
Proposition of farmers who have adopted at least one NERICA (%)							
2001	7			1		1	2
2002	18	2		1		4	4
2003	30	4		3	3	5	8
2004	44	8	2	11	5	12	14
2005	52	13	17	22	15	25	24
2006	54	37	49	29	34	34	40
Proportion among NERICA-exposed farmers who have adopted at least one							
2001	63			50		100	60
2002	82	100		50		100	81
2003	88	100		38	100	71	79
2004	94	100	67	58	100	75	84
2005	85	100	90	69	100	86	85

2006	79	90	88	74	100	87	86

The high exposure rates of farmers to NERICA in WR and CRR could be explained by the fact that the main agricultural research institute, which coordinates NERICA dissemination activities in the Gambia, is stationed in the regions. Hence, we should expect more farmers in these regions to be aware of the existence of the NERICA varieties. Moreover, the fact that upland rice farming is mainly practiced in WR could further explain why most of the sample farmers in this region were exposed to NERICA. In contrast, the low diffusion rates in the other regions could be attributed to the prevalence of lowland or irrigated rice cultivation.

The result based on the sample adoption rates was 2% in 2001, which increased gradually to 40% in 2006. The highest sample adoption rate, in 2006, was observed in WR (54%) and the lowest in NBR (29%). With the exception of CRRs, the sample adoption rate was less than 40% for all the remaining regions (see Table 3). When the sample adoption rates are compared with that of the adoption rates among the exposed farmers, it can be clearly seen that the adoption rates among the exposed farmers are much higher. In 2006, the adoption rates among the exposed are higher than 70% for all the agricultural regions. However, because of non-exposure and selection biases that are associated with incomplete diffusion of a technology within the population, the sample adoption rates or the adoption rates among the exposed farmers cannot be taken as realistic estimates of the population adoption rates of NERICA in The Gambia.

The sample adoption rates are affected by non-exposure bias problem, which result from the inclusion in the computation of adoption rate of non-adopting farmers who might have adopted NERICA if they knew about them. This results in the underestimation of the true population adoption rates. To address this problem, one would think it would be better to take the adoption rates among the sub-population of exposed farmers as the true estimate of the population adoption rates. But, the sample adoption rate within the subpopulation of exposed farmers is also not a consistent estimate of the true population adoption rates. It may likely overestimate the true population adoption rate. The reason for this is a positive population selection bias by which the subpopulation most likely to adopt a given technology is first exposed. The positive selection bias arises from two sources. The first source is farmers' self selection into exposure, reflecting the fact that exposure is partly a farmer's choice. The second source of selection bias results from the fact that some farmers (the so-called progressive farmers, in particular) and communities are targeted by research and extension people. It is most likely that the farmers that have been targeted for exposure to a technology are precisely those who are more likely to adopt it. Hence, the adoption rate in the targeted subpopulation is most likely to overestimate the true population adoption rate. To address these problems, the study uses the counterfactual setting framework to obtain a consistent ATE-based estimate of the NERICA population adoption rates and its determinants.

4.2.2 Determinants of farmer's exposure to the NERICA

Table 4 shows the result of the probit regression of the probability of exposure to the NERICA rice varieties. The results show that the important factors determining farmer‘s exposure to NERICA with positive coefficient estimates statistically significant at 5% level at least are: living in a village where NERICA seeds have been disseminated to farmers (NERICA village), farmer contact with NARI, practice of upland rice cultivation, living in Western and Central River Region (south). The only significant determinant with negative coefficient estimate is practice of lowland rice farming. Moreover, the marginal effect shows that being in Western Region or NERICA village are the most significant determinants of exposure to NERICA. NERICA village increases the probability of exposure by 29% while being in Western Region increases the probability of exposure by 28%.

The high significance of NERICA village in determining farmer exposure to NERICA is indeed not surprising. At the initial phase of the NERICA dissemination activities in The Gambia, only few villages within each agricultural region were privileged to have access to NERICA seeds. The villages that had access to NERICA seeds used the communal lands for initially cultivation of the varieties. Consequently, it should be expected that more rice farmers from such villages be aware of NERICA. Also as expected, farmers from Western and Central River Region (south) or those who have contact with NARI should be more likely to know about NERICA. The NERICA dissemination project, in The Gambia, is coordinated by NARI and the fact that NARI has its main station in Western Region and sub-station in Central River Region (south) explains why farmers who have contact with NARI and those located in Western and Central River Region (south) are more likely to the exposed to NERICA. Additionally, the initial introduction of NERICA through PVS to farmers in Western Region could further explain for the high probability of farmer exposure to NERICA in the region. Furthermore, the significant positive and negative effects of practice of upland and lowland rice cultivation respectively on farmer exposure to NERICA are understandable. The first-generation of NERICA introduced to farmers in The Gambia are upland varieties. Hence, we should expect farmers who practice upland rice cultivation to be aware of their existence.

Table 4: Probit regression of the probability of exposure to NERICA

	Coefficient	Marginal Effect
NERICA village	0.76 (0.12)***	0.29***
Number of modern varieties known in the village	0.03 (0.03)	0.01
Log of farm size in 2005	-0.02 (0.03)	- 0.01
Age	-0.01 (0.00)	0.00
Household size	0.00 (0.00)	0.00
Extension advise received by farmer	-0.23 (0.18)	-0.09
Woman	-0.33 (0.24)	-0.13
Maximum years of schooling	-0.01 (0.02)	-0.01
Training	-0.31 (0.27)	-0.12
Farmer contact with NARI	0.58 (0.29)**	0.23**
Farmer contact with DAS	0.21 (0.14)	0.08
Practice upland rice cultivation	0.32 (0.13)**	0.13***
Practice lowland rice cultivation	-0.32 (0.15)**	-0.13**
Living in Western Region	0.74 (0.17)***	0.28**
Farmer born in the village	0.04 (0.11)	0.02

Living in Central River Region (south)	0.50 (0.16)***	0.20***
Constant term	-0.24 (0.39)	
Observations	600	
Log likelihood	-351	
Pseudo R-2	0.15	
LR Chi squared	125	
Df	16	

Robust standard error in parenthesis***Significant at 1% significance level *Significant at 10% significance level

4.2.3 Determinants of NERICA adoption rates

Table 5 presents the coefficient estimates of the probit regression of the determinants of NERICA adoption. The result of the ATE probit model, which is restricted to the subpopulation of exposed farmers, is compared with the full sample estimates of the Classic probit joint exposure and adoption model. A number of variables determining farmer adoption of the NERICA varieties are shown to be significant in both models. These include: living in a village where NERICA seeds have been disseminated to farmers: NERICA village (positive impact and statistically significant at 5% level at least), farmer contact with DAS (positive impact and statistically significant at 5% level at least), cultivation of rice for consumption (positive impact and statistically significant at 1% level) and practice of lowland rice cultivation (negative impact and statistically significant at 5%

level). Moreover, a few other variables are shown to be statistically significant in only one of the models. The variable significant in only the ATE probit adoption model is maximum years of schooling (positive impact and statistically significant at 5% level). The ones significant in only the classic probit joint exposure and adoption model are: i) being a woman (negative impact and statistically significant at 5% level), and ii) living in Western and Central Region south (positive impact and statistically significant at 1% level).

The determinants of adoption in both models have more or less the expected signs. However, the significant negative impact on adoption of being a woman in the Classic probit joint exposure and adoption model is indeed not expected. Rice is almost entirely cultivated by the women farmers in The Gambia. Consequently, one should expect being a woman to be positively correlated with adoption. The significant negative impact of being a woman on adoption in the Classic probit joint exposure and adoption model could be attributed to the fact that Classic probit joint exposure and adoption model use some sample farmers who are not exposed to NERICA to estimate the coefficients of the determinants of adoption. This can lead to bias because farmers who are not exposed to NERICA cannot adopt them even if they might have done so provided they were exposed. As a result, the coefficient estimates of the Classic probit joint exposure and adoption model are likely to be inconsistent for the determinants of adoption. Hence, the coefficient estimates of the ATE probit adoption model, which controls for exposure, are the true estimates of the determinants of NERICA adoption.

The positive and significant impact of living in a village where NERICA seeds have been disseminated to farmers (NERICA village) on adoption is not surprising. It should be noted that the mere exposure (awareness) to NERICA is not a sufficient condition for its adoption. Farmers must have access to NERICA seeds before any adoption can be effected. Since there is high probability of getting access to NERICA seeds in villages where NERICA seeds have been disseminated to farmers (NERICA villages), we should expect more farmers from such villages to adopt NERICA. Moreover, since NERICA seeds are disseminated to farmers through the Department of Agricultural Services (DAS), we should expect farmers that have contact with the institute to also adopt NERICA. Furthermore, rice is mainly cultivated in The Gambia for household consumption. Since consumption dictates rice production in almost all the agricultural regions of the country, it should not be surprising to find a significant positive impact of rice cultivation for consumption on NERICA adoption. In addition, NERICA rice varieties mature earlier than most of the traditional varieties. Therefore, farmers cultivating rice purposely for consumption should be expected to adopt them in order to provide food for the household during the hungry season. Moreover, the first-generation of NERICA introduced to farmers in The Gambia are upland varieties. Hence, we should least expect farmers who are more experienced in lowland rice cultivation to adopt them. Also, since NERICA are improved varieties, we should expect its adoption to be positively correlated with years of schooling.

Table 5: Probit regression of the determinants of NERICA adoption: coefficient estimates

	ATE Probit adoption model	Classic Probit Joint exposure and adoption model
NERICA village	0.51 (0.21)**	0.79 (0.12)***
Woman	-0.70 (0.49)	-0.53 (0.22)**
Number of modern varieties known in the village	-0.05 (0.06)	0.02 (0.03)
Born in the same village	0.15 (0.21)	0.04 (0.12)
Age	-0.01 (0.01)	-0.01 (0.00)
Household size	-0.01 (0.01)	0.00 (0.00)
Maximum years of schooling	0.06 (0.03)**	0.00 (0.02)
Log of rice area in 2005	0.06 (0.06)	-0.02 (0.04)
Training	-0.77 (0.55)	-0.44 (0.29)
Credit	0.68 (0.75)	0.71 (0.36)

Cultivation of rice for consumption	1.09 (0.42)***	0.81 (0.27)***
Contact with DAS	0.71 (0.29)**	0.39 (0.14)***
Contact with NARI	0.01 (0.31)	0.58 (0.30)
Extension advise received by farmer	0.01 (0.31)	-0.25 (0.18)
Practice upland rice cultivation	-0.19 (0.23)	0.24 (0.13)
Practice lowland rice cultivation	-0.53 (0.26)**	-0.37 (0.16)**
Living in Western Region	-0.31 (0.25)	0.48 (0.18)***
Living in Central River Region (south)	0.12 (0.26)	0.49 (0.17)***
Constant term	0.99 (0.81)	-0.89 (0.47)
Observations	277	600
Log-likelihood	-96	-340
Pseudo R-2	0.16	0.16
Wald Chi squared	42	133
Df	18	18

Robust standard error in parenthesis; ***Significance at 1% significance level; ** Significance at 5% significance level;

4.2.4 Estimated NERICA population adoption rates

Table 6 presents the results of the predicted probability of NERICA adoption rates with the ATE correction for non-exposure and selection bias. ATE semi-parametric and ATE Probit models are used to acquire consistent estimates of NERICA adoption rates. The full population adoption rate (ATE), which informs on the demand of the technology by the target population, is estimated to be 83% by both ATE semi-parametric and ATE Probit models respectively. This means that the NERICA adoption rates in The Gambia could have been 83% in 2006 instead of the actually observed 40% joint exposure and adoption rate, if the whole population of rice farmers was exposed to NERICA in 2006 or before. The 40% joint exposure and adoption rate implies a very negative non-exposure bias -43% (adoption gap) when the sample estimate under incomplete diffusion is wrongly used to represent the true population adoption rate.

Moreover, it is interesting to note that the 86% adoption rate among the presently NERICA exposed subpopulation (ATE1) is very closed to the full population potential adoption rate (ATE). This indicates an insignificant population selection bias, which is confirmed by the data analysis. The insignificant population selection bias is a further indication that all the sample farmers had almost equal opportunity of adopting NERICA. Furthermore, the potential adoption rate among the subpopulation of farmers that are exposed to NERICA (ATE0) was estimated to be 82% by both models. This shows that about 82% of those farmers would have adopted NERICA if exposure was complete in 2006 or before. This estimate is also very close to the full population potential adoption

(ATE) estimate.

Table 6: ATE estimates of the Predicted NERICA probability of adoption with ATE correction for Non-exposure and Population selection bias

	ATE semi-parametric estimates	ATE probit estimates

NERICA adoption rates (Probability of adoption of at least one NERICA variety):	0.83 (0.06)***	
NERICA adoption rate in the full population (ATE)		0.83 (0.02)***
NERICA adoption rate within the NERICE-exposed subpopulation (ATE1)	0.86 (0.09)***	0.86 (0.02)***
NERICA adoption rate within the subpopulation not exposed to NERICA (ATE0)	0.82 (0.06)***	0.82 (0.03)***
Joint exposure and adoption rate of NERICA (JEA)	0.40 (0.04)***	0.40 (0.01)***
Adoption gap of NERICA (GAP)	-0.43 (0.03)***	-0.43 (0.02)***
Expected population selection bias when using the within NERICA – exposed sub-sample estimate (PSB)	0.03 (0.05)	0.03 (0.01)

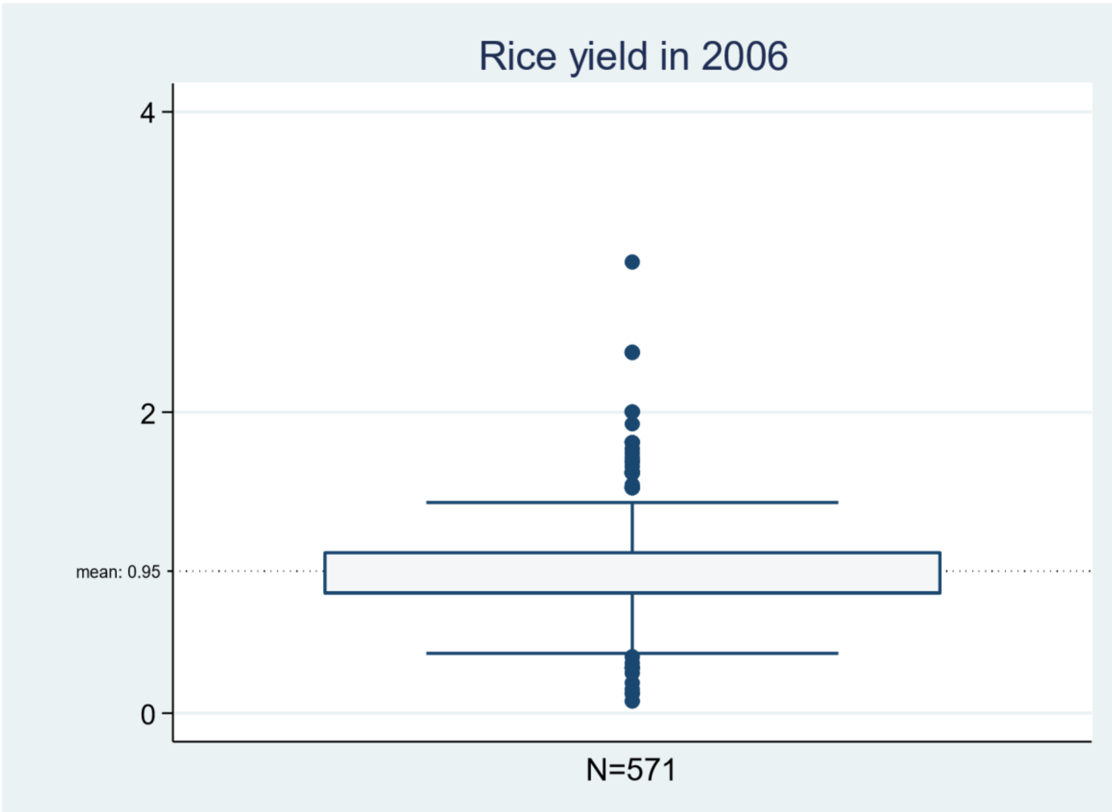
Robust standard error in parenthesis; ***Significance at 1% significance level

4.3 A descriptive analysis of the impact of NERICA adoption

4.3.1 Descriptive analysis of the impact of NERICA adoption on productivity

Figure 3 presents a box plot distribution of rice yields in the sample. About 29 rice farmers have been dropped from the sample, which reduced the total sample size to only 571 rice farmers. The rice farmers dropped are those who cultivated rice in the early stages of the rainy season in 2006 but due to certain constraints the rice crop did not reach maturity stage successfully. The estimated sample mean yield of 0.95 tonnes per hectare is within the average yield reported for upland rice farmers. It is also close to the average yield of 0.995 tonnes per hectare for upland varieties reported by Dalton (2006) from a sample of 50 farmers from some of the PVS villages in the forest zone of Cote d'Ivoire. However, it is lower than the results of 1.2 tonnes per hectare obtained from a similar study by Diagne (2006) in Cote d'Ivoire and also lower than the average upland rice yield of 1.5 tonnes per hectare of NERICA in two states of Nigeria by Spencer *et al*. (2006). It is also much lower than the average yield of 2.3 tonnes per hectare for NERICA varieties estimated by Kijima *et al*. (2006) based on a sample of 254 NERICA farmers.

Figure 3: Box plot distribution of rice yields in the sample



The average rice yield presented in this study came from farmers practicing rice farming mainly in lowland and upland rainfed ecologies of The Gambia. Most of these farmers have small farm holdings and practice rice farming with minimal usage of farm inputs like fertilizers, which could be the reason for the low average yield. The yield estimates for 2006 and 2005 have shown that the rice yield were better in 2005 (see table 2), which suggests the existence of unfavourable weather conditions like drought in 2006. Furthermore, the relatively high mean yields obtained from other studies could the attributed to favourable abiotic conditions for the farmers of those regions. For instance, the discussion regarding the soil fertility, crop rotation and fertilizer use conditions among the survey farmers in Uganda suggested favourable weather conditions in terms of soil nutrients availability.

Table 7 compares the mean yield of NERICA adopters and non-adopters for all farmers and also by gender. The results show that NERICA adopting farmers had an average mean yield significantly higher than the non-NERICA adopting farmers. The mean difference in yield between the two groups is estimated at 117kg per hectare, which is statistically significant at 1% significance level. This results contrast well with the results of a similar study by Diagne (2006b) in Cote D'Ivoire, which shows non-NERICA adopting farmers with an average rice yield higher than that of the adopting ones by up to 250kg per hectare (a difference significantly different from zero at 5% significance level). However, the percentage of NERICA adopters that practice lowland rice cultivation (26%) in Diagne (2006b) was found to be lower than that of the of the nonNERICA farmers (46%). As indicated in the literature review, the average yield of rice farmers in Sub-Saharan Africa is 1 and 2 tonnes per hectare for upland and lowland respectively. This difference in the yield potentials across ecologies could have resulted to the statistically significant lower mean yield of -250kg for the NERICA adopting farmers in Diagne (2006b). On the other hand, there is not much difference between NERICA adopters and non-adopters with regard to the type of rice farming practice in the other ecologies (lowland, mangrove and irrigated). This could have resulted in significant higher mean yield for the NERICA adopting farmers in this study. Moreover, the results based on the agronomic trial conducted in M'be in Cote d'Ivoire on the yield potential of NERICA under unfavourable conditions like drought have shown the yields of NERICA to be higher than both of their parents (*O. sativa* and *O. glaberrima*) when there is drought (WARDA, 1999). This agronomic trial results could further explain for the significant difference in mean yield between the two groups in 2006 provided they had experienced unfavourable weather conditions like drought.

Table 7: Average yield and differences between NERICA Adopters and NonAdopters

	All Farmers	Women	Men
Number of observations	571	532	39
Number of NERICA adopters	232	214	18
Mean yield of NERICA adopters (tonnes/ha)	1.016	1.000	1.195
	(0.026)	(0.026)	(0.110)
Mean yield of Non NERICA adopters (tonnes/ha)	0.889	0.894	0.967
	(0.017)	(0.018)	(0. 081)
Difference in mean yields between NERICA adopters and non-adopters (tonnes/ha)	0.117	0.105	0.227
	(0.031)***	(0.031)***	(0.136)

Robust standard errors in parenthesis; ***Difference significant at 1% significance level

Furthermore, the results based on gender show significant difference in mean yields (105kg per hectare) only for the women NERICA adopting farmers. The men are the ones with no statistically significant difference at 5% significance level. Nevertheless, the results based on the observed difference in mean yield are just descriptive and therefore, have no causal interpretation on the variable of interest. Hence, care must be taken not to attribute the observed difference in mean yield between adopters and non-adopters entirely to NERICA adoption. Besides NERICA adoption, rice yields can be affected by numerous socio-demographic and ecological location characteristic variables that can be observed. As argued in the methodological section, these differences can explain to a large extend the observed differences in yields between NERICA adopters and nonadopters. The difference between the two groups in the unobserved socio-demographics and environmental characteristics can also explain the observed differences in yield. Therefore, these differences between the two groups must be controlled for before the difference in mean yield can be given any causal interpretation.

4.3.2 Descriptive analysis of the impact of NERICA adoption on poverty

The analyses on poverty for this study are based on the rural poverty line for Gambia in 2004 of D3087.55[14] (Fatty, 2004). Table 8 presents the results on rice producer income and prevalence of poverty by adoption status. The results indicate that NERICA adopters have higher annual income (D12923) than non-adopters (D9424). The mean difference in annual income between the two groups is statistically different from zero at 1% significance level. This finding suggests that NERICA adoption has significant impact on income.

[14] Dalasi (D) is the official local currency of The Gambia. At the time of the survey $1 was approximately equivalent toD25.

Table 8: Individual farmer income and prevalence of poverty by adoption status

Characteristics	Adopters	Non-adopters	Difference
Annual income per capita (Dalasi)	12923(1113)	9424 (669)	3499 (1299)***
Individual farmer income (Dalasi/day)			
All farmers	35 (3)	25 (2)	10 (4)***
Women	35 (3)	24 (2)	11 (4) ***
Men	37 (8)	59 (15)	-22 (16)
Income deficit ratio			
All farmers	0.10 (0.01)	0.12 (0.01)	-0.02 (0.02)
Women	0.10 (0.02)	0.12 (0.01)	-0.02 (0.02)
Men	0.12 (0.06)	0.05 (0.04)	0.06 (0.07)
Prevalence of poverty base on headcount (%)			
All farmers	22 (2)	26 (3)	-4 (4)
Women	22 (3)	28 (3)	-5 (3)
Men	22 (7)	09 (10)	12 (12)

Robust standard errors in parenthesis; ***Difference significant at 1% significance level

The finding is consistent with a study on poverty by Diagne *et al.* (2009) who have also found significant difference in per capita annual expenditure between NERICA adopting and non-adopting household heads in Benin. However, because of the differences in the indicators use to assess poverty, the study conducted by Diagne *et al.* (2009) may not serve as meaningful comparison for the results of this study. For this reason, the result is compared with that of Mendola (2006) who has also used income as indicator of poverty and found significant higher impact of technology adoption on wellbeing of adopting households. This finding may as well suggest that the significant higher annual income for NERICA adopting farmers in this study is an indication that NERICA adoption is positively correlated with poverty reduction. Moreover, when differentiated by gender, the result revealed higher significant daily income only for the women NERICA adopting farmers.

Furthermore, the income deficit ratio of the sample is estimated at 11%. The result based on adoption status indicates an income deficit ratio of 10% for NERICA adopters and 12% for non-NERICA adopters. However, the difference between the two groups is not statistically significant at 5% significance level. Furthermore, when differentiated by gender, the results indicate an income deficit ratio of 10% for NERICA adopting women farmers and 12% for their non -NERICA adopting counterparts. The men are the ones with higher income deficit ratio for NERICA adopters. This finding suggests that NERICA adoption has greater impact on poverty reduction for women farmers. Nevertheless, none of the difference between the two groups is statistically significantly different from zero at 5% significance level.

Moreover, the analysis on the prevalence of poverty based on headcount indicates that the incidence of poverty is higher among NERICA non-adopting farmers (26%) than among the NERICA adopters (22%). When differentiated by gender, the results indicate that poverty is higher among the men NERICA adopting farmers than the women adopters (see table 8). This may further suggest that NERICA adoption has greater impact on poverty reduction for the women farmers. However, the poverty headcount estimates presented in this study are far below the national household poverty headcount rate of 55% (Fatty, 2004). Does this mean that the majority of rice farmers in The Gambia are rich? The poverty headcount estimates presented in this study are based on individual rice producer income. It does not take into account other household members. This happens because the study did not collect data on income for other household income earners. Hence, the poverty headcount estimates, presented in this study, are likely to underestimate the true poverty rate. Nonetheless, as discussed earlier these results are merely descriptive and therefore do not explain much about the causal effect of NERICA adoption on poverty. The differences between NERICA adopters and non-adopters in the variable of interest can be as a result of selection bias and non-compliance problems often associated with observational studies (Heckman and Vytlacil, 2005; Imbens and Angrist, 1994).

4.4 An econometric analysis of the impact NERICA adoption

The difference between NERICA adopting and non-adopting farmers in the variables of interest based on the results obtained from the descriptive analysis may not be solely due to NERICA adoption because of selection bias and non-compliance problems. Therefore, the study consistently estimates the impact of NERICA adoption on rice yield and income using the *local average treatment effect* (LATE) which corrects for the problem of selection bias and non-compliance, and then compares the results with the corresponding ATE estimates that do not correct for hidden bias and non-compliance problems.

The LATE estimation on rice yields and income is done by using two different estimation methods proposed by Imbens and Angrist (1994) and Abadie (2003). As explained in the methodological section, both methods use the instrumental variable approach to solve the selection bias and non-compliance problems. The LATE estimation method proposed by Imbens and Angrist (1994) assumes that the instrumental variable is random in the population. However, the method proposed by Abadie (2003) does not require this strong assumption; it rather requires the *local average response function* LARF which uses as explanatory variables (in addition to the NERICA adoption status variable) a set of famers' socio-economic and demographic characteristic variables. Moreover, to account for heterogeneous impact, the adoption status dummy variable is interacted with some of the covariates x . Furthermore, the study estimated an exponential LARF (using a nonlinear weighted least squares procedure) to avoid having some of the predicted values of the reported yield and income to be negative.

The ATE based estimates used are the OLS with and without interaction; the inverse propensity score weighting estimators (IPSW), Nearest Neighbourhood Propensity Score Matching (NNPSM) and fully parametric ATE estimation method based on a non linear least squares regression assuming an exponential functional form for the relationship liking the outcomes to the NERICA adoption status variable and the vector of covariates *x* (for details, see Imbens and Wooldridge, 2008; Lee, 2005 or Imbens, 2004).

4.4.1 Results of the econometric analysis on the impact of NERICA adoption on average rice yield

Table 9 presents the OLS estimates of the coefficients for the determinants of rice yields. The corresponding ATE estimates are presented in table 10. OLS with and without interaction are the simplest procedures that can be used to control for differences in farmers‗ observed characteristics that influence their observed rice yields. Results from Table 9 based on the non-interacted model show that beside NERICA adoption, which significantly increases farmers‗ observed rice yields (+0.146) at 1% significance level, a number of other socio-demographic variables are also statistically significant at 1% level. They include: practice lowland irrigated rice cultivation (+0.277) and being located at the Central River Region (north) (+0.125). In addition, the coefficients for household size (+0.001), practice upland (+0.040) and lowland rice cultivation (+0.016) are positive but not statistically different from zero at 5% significance level. Furthermore, the coefficient for being in a NERICA village (-0.000), being a woman (-0.108), age (-0.002) and farmer contact with extensions workers are negative but also not statistically significant in explaining the differences in farmers‗ observed rice yields. In contrast, none of the coefficients of the interacted terms in the interacted model are statistically significant. The finding nullifies the assumption of heterogeneous impact based on farmers‗ observed differences in rice yield. This is confirmed by the result of the F-statistics for the joint significance shown at the bottom of the table, which indicates that they are jointly not statistically significantly different from zero.

Table 9: OLS estimated coefficients for the determinants of rice yield with and without interaction

		OLS with adoption dumm with covariates	
	Coefficient estimates for OLS without interaction	Coefficients of the non-interacted terms	Coefficients of the interacted terms
NERICA adoption in 2006	0.148(0.032) ***	0.223 (0.189)	
NERICA Village	-0.000 (0.032)	-0.031 (0.045)	0.049 (0.066)
Woman	-0.108(0.060)	-0.119 (0.094)	-0. 021 (0.125)
Age	-0.002 (0.001)	0.001 (0.002)	-0.005 (0.002)
Household size	0.001 (0.001)	0.001 (0.002)	0.003 (0.003)
Contact with extension workers	-0.039 (0.043)	-0.051 (0.058)	0.012 (0.087)
Experience in upland rice cultivation	0.040 (0.034)	-0.032(0.048)	-0.007 (0.067)
Experience in lowland rice cultivation	0.016 (0.041)	-0.046(0.066)	0.081 (0.085)
Experience in lowland irrigated rice cultivation	0.277 (0.051)***	0.257 (0.059)***	0.039 (0.129)
Central River Region (north)	0.125 (0.047)***	0.078 (0.054)	0.105 (0.122)
Constant term	0. 941 (0.092) ***	0.905 (0.118)***	
Number of observations	497	497	
R-squared	0.20	0.22	
Adj R-squared	0.18	0.19	
F-statistics for the joint significance of all coefficients	F (10,846) 12.14***	F(19,477) 7.07 ***	

F-statistics for the joint significance of coefficients of the non-interacted term	F (9,477) 2.20**
F-statistics for the joint significance of coefficients of the interacted terms	F (4,477) 0.79

Robust standard errors in parenthesis; ***Significant at 1% significance level; ** Significant at 5% significance level

Moreover, the estimated ATE (mean impact in the population), ATE1 (mean impact for the sub-population of NERICA adopters) and ATE0 (mean impact for the sub-population of non-adopters) of the impact of NERICA adoption on rice yield based on OLS and exponential without interaction, which assume a constant impact across the population, are all positive and statistically different from zero at 1% significance level. The ATE estimates based on OLS and exponential with interaction and inverse propensity score weighting (IPSW), which do not assume a constant impact, confirm the heterogeneity of the impact of NERICA adoption across the population. The estimates based on OLS and exponential are all positive and significantly different from zero at 1% significance level for all farmers and women in particular. The men are the ones with significant estimates in the OLS model but insignificant estimates in the model with the exponential functional form. This makes the estimates for all farmers and that of the woman more robust statistically (Table 10). However, none of the estimates based on the IPSW is statistically significant at 5% significance level. Moreover, the ATE estimates based on the Nearest Neighbourhood Propensity Score Matching (PSM) shown at the bottom of table 9 indicate significant estimates of 0.168 t/ha, 0.175 t/ha, 0.162 t/ha for ATE, ATE1 and ATE0 respectively. The estimates are shown only for all farmers, the ones based on gender could not be provided simply because the NNPSM do not have an option for the analysis to be disintegrated by gender. Nevertheless, because the ATE based estimates rely on the validity of the conditional independence assumption, which rules out the dependence of potential outcomes on the unobserved socio-demographic and environmental conditions, they may incorporate substantial amount of hidden bias. Additionally, since adoption is a choice variable, we are faced with the problem of noncompliance but this is also not taken into consideration with the ATE estimates. Hence, the estimates based on ATE cannot be given a causal interpretation. They are presented just for the purpose of comparison. The parameters that have a causal interpretation on the variable of interest are the LATE estimates, which correct for selection bias and noncompliance problems.

Table 10: ATE estimates of the impact of NERICA adoption on average rice yield

	All Farmers	Women	Men
Estimates based on OLS without interaction			
Number of observations	571	532	39
Number of NERICA adopters	232	214	18
Mean impact in the population (ATE)	0.114 (0.029)***	0.114 (0.029)***	0.114 (0.029)***
Mean impact in the subpopulation of NERICA adopters (ATE1)	0.114 (0.029)***	0.114 (0.029)***	0.114 (0.029)***
Mean impact in the subpopulation of NERICA non-adopters (ATE0)	0.114 (0.029)***	0.114 (0.029)***	0.114 (0.029)***
Estimates on OLS with adoption interacted with the covariates			
Mean impact in the population (ATE)	0.116 (0.031)***	0.108 (0.032)***	0.237 (0.107)**
Mean impact in the subpopulation of NERICA adopters (ATE1)	0.109 (0.029)***	0.099 (0.030)***	0.229 (0.114)**
Mean impact in the subpopulation of NERICA non-adopters (ATE0)	0.121 (0.035)***	0.113 (0.036)***	0.244 (0.109)**
Estimates base on exponential without interaction			
Number of observations	571	532	39
Number of NERICA adopters	232	214	18
Mean impact in the population (ATE)	0.115 (0.032)***	0.114 (0.031)***	0.136 (0.038)***
Mean impact in the subpopulation of NERICA adopters (ATE1)	0.116 (0.032)***	0.114 (0.031)***	0.135 (0.036)***
Mean impact in the subpopulation of NERICA non-adopters (ATE0)	0.115 (0.032)***	0.114 (0.032)***	0.136 (0.038)***
Estimates base on exponential with adoption interacted with the covariates			
Mean impact in the population (ATE)	0.108 (0.031)***	0.104 (0.032)***	0.158 (0.099)
Mean impact in the subpopulation of NERICA adopters (ATE1)	0.105 (0.029)***	0.102 (0.031)***	0.142 (0.104)
Mean impact in the subpopulation of NERICA non-adopters (ATE0)	0.110 (0.035)***	0.106 (0.037)***	0.173 (0.104)
Estimates based on the inverse propensity score weighting			
Number of observations	571	532	39
Number of NERICA adopters	232	214	18

Mean impact in the population (ATE)	-0.015 (0.074)	-0.015 (0.078)	-0.010 (0.651)
Mean impact in the subpopulation of NERICA adopters (ATE1)	-0.022 (0.094)	-0.052 (0.102)	0.327 (0.430)
Mean impact in the subpopulation of NERICA non-adopters (ATE0)	0.010 (0.078)	-0.009 (0.081)	-0.299 (1.076)
Estimates based on Propensity Score Matching Mean impact in the population (ATE)	0.168 (0.089)**	-	-
Mean impact in the subpopulation of NERICA adopters (ATE1)	0.175 (0.089)**	-	-
Mean impact in the subpopulation of NERICA non-adopters (ATE0)	0.162 (0.089)**	-	-

Robust standard errors in parenthesis; ***Significant at 1% significance level; **Significant at 5% significance level

Table 11 presents the LATE estimates of the impact of NERICA adoption on average rice yields. The results are shown for all farmers and for women and men separately. The upper bloc of Table 11 shows the LATE estimates based on the Wald estimator, along with estimates of the population share of NERICA potential adopters. This is followed by the LATE estimates based on OLS local average response function (LARF) with and without interaction. The lower blocs show the LATE estimates based on an exponential LARF with and without interaction. The results based on Wald estimates for the population share of NERICA potential adopters are high (88% for all farmers and 87% for women) and statistically different from zero at 1% significance level. Due to the small sample size, the Wald estimates for men could not be provided. The Late estimates of the impact of NERICA adoption based on the Wald estimates are positive but not statistically different from zero at 5% significance level. The Wald estimate for all farmers is +0.114 tonnes per hectare and the one for women farmers is +0.105 tonnes per hectare. As discussed in the methodological section, the Wald estimator assumes that the instrumental variable (awareness to NERICA) is random in the population. This assumption is unrealistic because who gets to know about NERICA is not randomly distributed in the population. Hence, the LATE estimate for the impact of NERICA adoption based on the Wald estimates may incorporate a substantial amount of bias. Consequently, the study proceeds with the LATE estimation strategy proposed by Abadie (2003), which does not require the strong assumption that the instrumental variable should be randomly distributed in the population. The LATE estimates proposed by Abadie (2003) are estimated with LARF based on OLS and exponential. The results based on OLS (LARF) without interaction yields constant (+0.148 tonnes per hectare) estimates, which are significantly different from zero at 1% significance level. The LATE estimate based on OLS (LARF) with interaction are positive (+0.150 tonnes per hectare) and significantly different from zero at 1% significance level for all farmers. When differentiated by gender, the results show significant estimate of +0.146 tonnes per hectare only for women farmers. The men are the ones with statistically insignificant estimate.

Table 11: LATE estimates of the impact of NERICA adoption on average rice yield

	All Farmers	Women	Men
Estimates based on Wald estimator			
Number of observations	571	532	39
Number of NERICA adopters	232	214	18
Number of NERICA exposed	265	246	19
Estimated population share of NERICA potential adopters	0.88 (0.038) ***	0.87 (0.038)***	-
Mean impact in the subpopulation of NERICA potential adopters (LATE)	0.114 (2.517)	0.105 (9.264)	-
Estimates based on OLS (LARF)			
Number of observations	571	532	39
Number of NERICA adopters	232	214	18
Number of NERICA exposed	265	246	19
LARF without interaction			
Mean impact in the subpopulation of NERICA potential adopters (LATE)	0.148 (0.042)***	0.14 (0.042)***	0.148 (0.042)***
LARF with adoption interacted with covariates Mean impact in the subpopulation of NERICA potential adopters (LATE)	0.150 (0.044)***	0.146 (0.047)***	0.211 (0.124)
Estimates based on an exponential local average response function (LARF) Number of observations	571	532	39
Number of NERICA adopters	232	214	18
Number of NERICA exposed	265	246	19

Estimated population share of NERICA potential adopters			
LARF without interaction			
Mean impact in the subpopulation of NERICA potential adopters (LATE)	0.149 (0.042)***	0.147 (0.041) ***	0.178 (0.051) ***
LARF with adoption interacted with covariates Mean impact in the subpopulation of NERICA potential adopters (LATE)	0.146 (0.034)***	0.143 (0.047) ***	0.182 (0.114)

Robust standard errors in parenthesis; ***Significant at 1% significance level; Moreover, the LATE estimates, based on an exponential LARF model without interaction, are also positive and significantly different from zero at 1% significance level. It shows an impact estimate of +0.149 tonnes per hectare for all farmers. When differentiated by gender, the estimate for women is shown to be +0.147 tonnes per hectare while that of the men is +0.178 tonnes per hectare. However, because the exponential LARF model without interaction assumes a constant impact of technology adoption across the population, it may not give the best picture of the heterogeneity of the impact of NERICA adoption. Hence, the study proceeds with the LATE estimates based on an exponential LARF with interaction, which guarantees the heterogeneity of the impact across the population. The LATE estimates of the impact of NERICA adoption on average rice yield based on an exponential LARF model with interaction are also positive and significantly different from zero at 1% significance level for all farmers and women in particular. It indicates an impact estimate of +0.146 tonnes per hectare for all farmers and +0.143 tonnes per hectare for the women. However, the estimate for men is not statistically different from zero at 5% significance level.

Furthermore, Abadie‘s LATE estimates which have a causal interpretation of the impact of NERICA adoption on average rice yield in this study, as indicated above, are estimated based on the OLS and exponential. However, since there is the possibility for some of the predicted estimates of rice yields based on OLS to be negative, the discussions regarding the impact of NERICA adoption on average rice yields will be based on the estimates provided with the exponential LARF with interaction which guarantees the positivity of the predicted rice yields and also ensures the heterogeneity of the impact across the population.

4.4.2 Results of the econometric analysis on impact of NERICA adoption on income

Table 12 presents the estimated coefficients of the exponential local average response function (LARF) with and without interaction for daily producer income per individual farmer. The ATE and LATE estimates are presented in table 13 and 14 respectively. The results from table 12 indicate that besides NERICA adoption, which influences daily producer income at 1% significance level, a number of other socio-demographic variables are also statistically significant at 1% level. This is clear manifestation that the results obtained from the descriptive analysis cannot be solely attributed to NERICA adoption. The socio-demographic variables that significantly influence producers‘ daily income at 1% level besides NERICA adoption include: non-agricultural income, gender, practice lowland irrigated rice cultivation, household size and regional location specific variables. Moreover, some of coefficients for the interacted terms are also statistically significant, thus confirming the heterogeneity of the impact of NERICA adoption based on observed daily income. The significant positive impact of being a woman in the interacted model suggests that the impact of NERICA adoption on daily income may be higher for women. In addition, the significance of the socio-demographic variables in explaining the differences in daily income between NERICA adopters and non-adopters is further given by the results of the F-statistics, which show that they are jointly significantly different from zero at 1% significance level. Since the study attempts to determine the causal effect of NERICA adoption on the variables of interest, the socio-demographic factors affecting income besides NERICA adoption must be controlled for before any causal interpretation of NERICA adoption can be given to the difference in daily income between the NERICA adopters and non-adopters.

Table 12: Estimated coefficients of the exponential (LARF) for daily income

	Coefficient estimates for OLS without interaction	OLS with adoption dum covariates	
		Coefficients of the non-interacted terms	Coefficients of the interacted terms
NERICA adoption in 2006	0.36 (0.08) ***	-0.02 (0.41)	
Non agricultural income	0.00 (0.00) ***	0.00 (0.00)***	0.00 (0.00)***
Woman	-0.30 (0.11) ***	-0.67 (0.16)***	0. 42 (0.24)**
Age	-0.00 (0.00)	-0.01 (0.00)	0.00 (0.01)
Educational level	-0.02 (0.01)	0.04 (0.02)***	-0.06 (0.03)***
Experience in lowland irrigated rice cultivation	0.58 (0.16)***	0.49 (016)***	
Experience in upland rice cultivation	0.07 (0.09)	0.03 (0.09)	
Experience in lowland rice cultivation	-0.08 (0.10)	0.14 (0.13)	
Household size	0.01 (0.00) ***	0.00(0.00)	0.01 (0.00)
Accessibility to credit	0.04 (0.23)	0.07 (0.66)	0.03 (0.70)
Central River Region (north)	3.28 (0.26)***	3.58 (034)***	
Western Region	3.65 (0.25)***	3.92 (0.33)***	
North Bank Region	3.58 (0.25)***	3.79 (0.33)***	
Upper River Region	3.03 (0.24)***	3.18 (0.33)***	

Lower River Region	3.00 (0.27)***	3.30 (0.35)***
Central River Region (south)	3.13 (0.25)***	3.39 (0.33)***
Number of observations	497	497
R-squared	0.68	0.69
Adj R-squared	0.67	0.68
F-statistics for the joint significance of coefficients of the non-interacted term		F (15,475) 896.55***
F-statistics for the joint significance of coefficients of the interacted terms		F (6,475) 0.95

Robust standard errors in parenthesis; ***Significant at 1% significance level; ** Significant at 5% significance level

Table 13 presents the ATE estimates of the impact of NERICA adoption on daily producer income. The results are presented for all farmers and women and men separately. The upper bloc of table 13 presents the estimates based on OLS with and without interaction. This is followed by the estimates based on an exponential functional form with and without interaction. The lower blocs of the table presents the estimates based on the inverse propensity score weighting (IPSW) and Nearest Neighbourhood Propensity Score Matching (NNPSM) estimates. The estimates based on OLS and exponential without interaction, which assume a constant impact across the population, are all positive and significantly different from zero at 1% significance level for all farmers, women and men separately. However, the estimates based on OLS and exponential with interaction, which guarantees the heterogeneity of the impact across the population, show significant estimates only for all farmers and women in particular. The men are the ones with statistically insignificant estimates. Additionally, none of the estimates base on Inverse Propensity Score Weighting (IPSW) and Nearest

Neighbourhood Propensity Score Matching (NNPSM) is statistically significant (see table 13). Nonetheless, as discussed in the previous sections, because of the hidden bias and non-compliance problems, the ATE estimates of the impact of NERICA adoption on daily income cannot be given a causal interpretation. They are estimated just for the purpose of comparison. Hence, the LATE estimates are needed, which are the parameters with causal interpretation of the impact of NERICA adoption on daily producer income.

Table 13: ATE estimates of the impact of NERICA adoption on daily income

	All Farmers	Women	Men
Estimates based on OLS without interaction			
Number of observations	571	532	39
Number of NERICA adopters	232	214	18
Mean impact in the population (ATE)	6.60 (2.66)***	6.60 (2.66)***	6.60 (2.66)***
Mean impact in the subpopulation of NERICA adopters (ATE1)	6.60 (2.66)***	6.60 (2.66)***	6.60 (2.66)***
Mean impact in the subpopulation of NERICA non-adopters (ATE0)	6.60 (2.66)***	6.60 (2.66)***	6.60 (2.66)***
Estimates on OLS with adoption interacted with the covariates			
Mean impact in the population (ATE)	6.59 (2.64)***	7.02 (2.73)***	-0.02 (9.82)
Mean impact in the subpopulation of NERICA adopters (ATE1)	6.87 (2.64)***	7.90 (2.77)***	-5.37 (9.91)
Mean impact in the subpopulation of NERICA non-adopters (ATE0)	6.39 (2.65)**	6.51 (2.74)**	4.56 (10.15)
Estimates base on exponential without interaction			
Number of observations	571	532	39
Number of NERICA adopters	232	214	18
Mean impact in the population (ATE)	9.70 (2.57)***	9.31 (2.46)***	15.04 (4.34)***
Mean impact in the subpopulation of NERICA adopters (ATE1)	9.96 (2.56)***	9.84 (2.53)***	11.41 (3.25)***
Mean impact in the subpopulation of NERICA non-adopters (ATE0)	9.53 (5.58)***	8.96 (2.41)***	18.15 (5.34)***

Estimates base on exponential with adoption interacted with the covariates			
Mean impact in the population (ATE)	8.74 (2.86)***	8.86 (2.85)***	7.12 (13.26)
Mean impact in the subpopulation of NERICA adopters (ATE1)	8.50 (2.90)***	9.51 (2.97)***	-3.57 (9.85)
Mean impact in the subpopulation of NERICA non-adopters (ATE0)	8.91 (2.87)***	8.43 (2.82)***	16.28 (17.07)
Estimates based on the inverse propensity score weighting			
Number of observations	571	532	39
Number of NERICA adopters	232	214	18
Mean impact in the population (ATE)	1.60 (3.87)	3.81 (3.91)	-28.50 (58.39)
Mean impact in the subpopulation of NERICA adopters (ATE1)	2.95 (6.52)	4.31 (6.90)	-13.28 (23.85)
Mean impact in the subpopulation of NERICA non-adopters (ATE0)	0.68 (3.29)	3.47 (3.13)	-41.54 (102.01)
Estimates based on Propensity Score Matching Mean impact in the population (ATE)	18.81 (9.75)	-	-
Mean impact in the subpopulation of NERICA adopters (ATE1)	15.06 (9.75)	-	-
Mean impact in the subpopulation of NERICA non-adopters (ATE0)	22.36 (9.75)	-	-

Robust standard errors in parenthesis; ***Significant at 1% significance level; ** Significant at 5% significance level

Table 14 presents the LATE estimates of the impact of NERICA adoption on producers‘ daily income estimated by the instrumental variable (IV) estimator proposed by Abadie (2003) and by Wald estimator proposed by Imbens and Angrist (1994). The upper bloc of the table presents the estimates based on Wald estimator. The middle and lower blocs show Abadie‘s LATE estimates based on OLS and exponential with and without interaction. The estimates, based on Wald estimator, are positive for all famers and women in particular. However, the estimates for men could not be provided because of small sample size problem. Nevertheless, none of the estimates based on Wald estimator is statistically different from zero at 5% significance level. Moreover, since the Wald estimator is based on the assumption that the instrumental variable is randomly distributed in the population; the LATE estimate based on the Wald estimator cannot be given a causal interpretation. Hence, the study proceeded with Abadie's LATE estimates which do not require the assumption that the instrumental variable be randomly distributed in the population. Abadie's LATE estimates based on OLS and exponential without interaction, which do not account for the heterogeneity of the impact across the population, are all positive and significantly different from zero at 5% significance level at least for all farmers and women and men separately.

Table 14: LATE estimates of the impact of NERICA adoption on daily income (Dalasi)

	All Farmers	Women	Men
Estimates based on Wald estimator			
Number of observations	571	532	39
Number of NERICA adopters	232	214	18
Number of NERICA exposed	265	246	19
Estimated population share of NERICA potential adopters	0.88 (0.035) ***	0.87 (0.042)***	-
Mean impact in the subpopulation of NERICA potential adopters (LATE)	10.21 (996.78)	12.95 (398.89)	-
Estimates based on OLS (LARF)			
Number of observations	571	532	39
Number of NERICA adopters	232	214	18
Number of NERICA exposed	265	246	19
LARF without interaction			
Mean impact in the subpopulation of NERICA potential adopters (LATE)	7.02 (0.00)***	7.02 (0.00)***	7.02 (0.00)***

LARF with adoption interacted with covariates			
Mean impact in the subpopulation of NERICA potential adopters (LATE)	7.06 (0.15)***	7.53 (0.16)***	1.12 (0.09)***
Estimates based on an exponential local average response function (LARF) Number of observations	571	532	39
Number of NERICA adopters	232	214	18
Number of NERICA exposed	265	246	19
Estimated population share of NERICA potential adopters			
LARF without interaction			
Mean impact in the subpopulation of NERICA potential adopters (LATE)	10.96 (4.97)***	10.39 (4.76) ***	18.29 (8.05) **
LARF with adoption interacted with covariates			
Mean impact in the subpopulation of NERICA potential adopters (LATE)	10.16 (4.69)**	10.59 (4.59) **	4.62 (20.60)

Robust standard errors in parenthesis; ***Significant at 1% significance level; ** Significant at 5% significance level

Moreover, Abadie‘s LATE estimates based on OLS and exponential with interaction, which guarantee the heterogeneity of the impact across the population, are positive and significantly different from zero at 1% significance level for all farmers. When differentiated by gender, the estimates based on OLS indicate higher impact for women (+D7.53) than men (+D1.12). However, both estimates are statistically different from zero at 1% significance level. Furthermore, the estimates based on the exponential with interaction show significant estimate at 1% level only for all farmers (+D10.16) and women (+D10.59) in particular. The men are the ones with insignificant estimate. Additionally, since the income estimates are based on farmers‘ reported income which cannot be negative, the discussions will, therefore, be based on the estimates provided with the exponential functional form with interaction which guarantees the positivity of the predicted income and also ensures the heterogeneity of the impact across the population.

4.4.3 Discussions of the econometric analysis of the impact of NERICA adoption on average rice yields

The LATE estimates, based on the exponential functional form, which is the true estimate of the impact of NERICA adoption on average rice yields, have shown a positive impact of NERICA adoption on rice productivity for small-scale rice farmers in The Gambia. The impact is even greater for the women farmers. How can the positive impact of NERICA adoption on rice productivity be explained? The positive impact of NERICA adoption on rice yields might have a lot to do with the president‘s back to the land call. The adoption of the NERICA varieties by the president has resulted in the wide spread of NERICA across the country like wild fire. Rural communities, in response to the call, cleared more upland areas which were subsequently cultivated with NERICA. This observation serves as background information with regard to the impact of NERICA adoption on rice yields. Can the impact of NERICA adoption be attributed to the president‘s back to the land call? Indirectly yes, because farmers have to first adopt NERICA before any significant increase on yields can be realized. However, when one looks at the impact of NERICA adoption from the direct perspective, NERICA adoption can only result in positive impact on yields provided the upland farmers that adopted NERICA were cultivating upland varieties that yield lower than NERICA. Is this the case for The Gambia? Upland rice farming before the introduction of NERICA was mainly practiced in the

Western Region of the country. This is consistent with Bittage *et al.* (2002) who have also identified the Western Region as the region where upland rice farming is mainly practiced in the country. Based on this information, one can conclude that research and extension efforts to disseminate improved upland rice varieties before the introduction of NERICA concentrated in the Western Region. Consequently, the upland farmers in the other regions might not have access to improved upland rice varieties, which means that these farmers were mainly cultivating traditional upland varieties that yield in general lower than NERICA. Hence, the adoption of NERICA by these farmers will result in an increase in rice yields and this explains why NERICA have in general a positive impact on average rice yields in The Gambia.

The impact of NERICA adoption on average rice yield based on gender is greater for women farmers. This is consistent with the finding of Diagne (2006b) who has also found a statistically significant impact of +741kg/ha for only female farmers. Is there any explanation for this finding? Rice is traditionally a crop grown by women in The Gambia. The women have specialized in rice production as far back as the period of Atlantic slave trade and have adopted hundreds of rice varieties to specific environmental conditions (Jobson, 1623; Moore, 1738). The fact that rice is a woman‘s crop gives the women the upper hand whenever it comes to rice cultivation. The specialization of women in rice production gives them a better understanding of the rice crop in terms of experience when compared to men most of whom have just started rice cultivation with the introduction of NERICA. Moreover, besides rice cultivation, the men are engaged in the production of other crops like groundnut, millet and cotton. This gives them less time to fully concentrate on rice production. On the other hand, most of the women devote their time entirely to rice cultivation during the rainy season. For this reason, they are able to better manage the rice crop than the men and this explains why NERICA adoption yields higher impact on rice productivity for women. Nevertheless, the comparison of rice yields between men and women could have been better executed provided the sample size for men is fairly large. Unfortunately, the sample size for men in this study is very small. Out of the 600 rice farmers surveyed, only 39 men were found to have cultivated rice. The small sample size for men could have resulted into bias and in fact this was evident during the data analysis. The estimates for women were significant at 1% level in almost all the models used and this makes the estimates for the women very robust. The men are the ones with estimates that changes significance from one model to the other. Although, the study has attempted to make a comparison between men and women, much importance will not be attached to the estimates for men due to the small sample size for these farmers across the country.

Furthermore, it should be noted that NERICA adoption cannot produce significant impact on rice yield for every farmer. Farmers switching from varieties that yield higher than NERICA cannot realize any significant impact of NERICA adoption on rice yields. However, farmers have been witnessed switching from the adoption of lowland rice varieties to NERICA. Apparently, the lowland rice varieties yield higher than NERICA. Why do such farmers adopt NERICA if the varieties they abandon yield higher than NERICA? Do we conclude that such farmers will stop cultivating NERICA once they realize that they are not gaining any significant increase on rice yields? The answer to these questions lies in the non-yield varietal attributes that explain the adoption behaviour of farmers. Indeed, the short duration and good cooking attributes of NERICA are well appreciated by farmers. Some farmers are adopting NERICA not because of the yields but the non-yield attributes of the NERICA varieties. Consistent with this argument are Dalton (2004), Diagne (2006b), Adesina and Baidu-Forson (1995) and Adesina and Zinnah (1993) who have found non-yield varietal attributes to significantly explain farmers adoption behaviour. This explains why some farmers, who do not realize significant increase in yields from NERICA adoption, still continue to adopt the NERICA varieties.

4.4.4 Discussions of the econometric analysis of the impact of NERICA adoption on income

The significant impact of NERICA adoption on daily producer income from the LATE estimate based on the exponential with interaction is indeed not at all surprising. NERICA adoption does not have a direct effect on income. It can only affect income through rice yields. If NERICA adoption has a positive impact on yields then one should expect similar effects on income. However, care must be taken not to always conclude that because adoption has positive impact on yields, therefore it will significantly lead to an increase in income. We should take note of the fact that agricultural production is investment oriented. It is the amount of cost incurred in the production of a particular crop that determines whether the production of such crop will lead to significant increase in income or not. If the cost incurred is very high, then one should not expect significant increment in income and vice versa. However, as highlighted in the previous sections, the majority of the sample farmers for this study are women who practice rice cultivation with zero or minimal usage of inputs like fertilizers and pesticides. Consequently, they achieve low yields from rice production. Nevertheless, since the low yields are achieved with little investment, one should still expect significant increase in income from rice production for these farmers.

Moreover, the positive impact of NERICA adoption on daily producer income indicates that NERICA adoption can significantly contribute to poverty reduction in The Gambia. This is consistent with the finding by DfID (2003) that a 1% increase in agricultural productivity reduces the percentage of poor people living on less than 1 dollar a day by between 0.6 and 2% and that no economic activity generates the same benefit for the poor. Hence, the positive impact of NERICA adoption on rice yields can result in an increase in income which can ultimately lead to poverty reduction.

Chapter Five:

Summary, Conclusions and Recommendation

This chapter gives the summary and conclusions of the study. It also presents some recommendation for future attempts to disseminate and assess the impact of NERICA adoption on rice yields and income of farmers.

5.1 Summary and Conclusions

The study reveals that the sample adoption rate does not consistently estimate the true population adoption rate even if the sample is randomly selected. This happens because farmers who are not exposed to NERICA could not adopt them even if they might have done so provided they were exposed. This results in the adoption rate being underestimated. One would think an obvious fix to this problem is to take the adoption rate within the sub-population of exposed farmers. However, due to selection bias the adoption rate within the sub-population of exposed farmers may also not serve as a good estimate of the true population adoption rate. It can either underestimate or overestimate the true population adoption rate. Consequently, the study uses the average treatment framework to consistently estimate the adoption rates of NERICA and their determinants in The Gambia.

The average treatment estimates show that the NERICA population adoption rate (ATE) in The Gambia could have been 83% instead of the 40% sample adoption rate provided exposure was complete in 2006. This shows a very negative non-exposure bias -43% (adoption gap) if the sample estimate is wrongly used to estimate the true population adoption rate in 2006. Moreover, the estimates for the sub-population of exposed farmers (ATE1) and that of the non-exposed farmers (ATE0) were estimated to be 86% and 82% respectively. These estimates show a very high unmet demand for NERICA in The Gambia, which has a policy implication in terms of judging the intrinsic merits of the desirability of the technology by the target population and also in terms of making decision to invest or not in its wide dissemination.

Moreover, because ATE based estimates of the impact of NERICA adoption on rice yields and income rely on the validity of the conditional independence assumption, which rules out the dependence of potential outcomes on the unobserved socio-demographic and environmental conditions, they may incorporate substantial amount of hidden bias. Additionally, since adoption is a choice variable, we are faced with the problem of noncompliance but this is also not taken into consideration with the ATE estimates. Hence, the estimates based on ATE cannot be given a causal interpretation. The parameters that have a causal interpretation on the variables of interest under this circumstance are the LATE estimates, which correct for selection bias and non-compliance problems.

Furthermore, the NERICA rice varieties have been developed by Africa Rice Center (AfricaRice ex-WARDA) basically with the aim of improving rice productivity and food insecurity and thereby contribute to poverty reduction in Sub-Saharan Africa. If one refers to the results of this study, one can conclude that these objectives have largely been met in countries like The Gambia. The high adoption rates of NERICA together with the 146kg/ha and D10.16 significant positive impact of NERICA adoption on rice yields and income respectively for The Gambian rice farmers is a clear manifestation that the NERICA varieties have the potential to increase rice productivity and reduce poverty significantly. This is also a clear justification for more concerted efforts to disseminate NERICA across the country.

In addition, the high per capita consumption of 110kg per person per annum of rice in The Gambia is an indication that the country needs to take robust measures to increase rice productivity. However, such measures cannot be taken unless high yielding rice varieties that have positive impact of productivity are identified in the country. Therefore, the results of this study has a policy implication since it will assist the government in its strive to identity and disseminate high yielding rice varieties that are highly desired by the farmers and consumers and also have the potential to impact positively on rice yield and income of the poor and resourceful farmers whose livelihoods are entirely dependent on agricultural production.

Finally, the impact of NERICA adoption on rice yield and income based on gender is significant only for the women farmers. This finding is not at all surprising. Rice is traditionally cultivated by women in The Gambia. The women have specialized in rice production as far back as the period of Atlantic slave trade and have adopted hundreds of rice varieties to specific environmental conditions. The majority of women engaged in agriculture devote their time entirely to rice production, which gives them a better understanding of the rice plant than men, most of whom have been involved in rice production with the official introduction of NERICA in The Gambia in 2003. Nevertheless, the comparison of rice yields and income between men and women could have been better executed provided the sample size for men is fairly large. Unfortunately, the sample size for men in this study is very small. Out of the 600 rice farmers surveyed, only 39 men were found to have cultivated rice. The small sample size for men could have resulted into bias, which might have led to the insignificant estimates obtained for men. Although, the study has attempted to make a comparison between men and women, much importance will not be attached to the estimates for men due to the small sample size for these farmers across the country.

5.2 Recommendation

In connection with the main findings from this study, the following are recommended:

- Since the majority of the farmers involved in this study are women most of whom allocate more land area to lowland rice varieties than upland, it is highly recommended that lowland NERICA be also developed and disseminated to rice farmers.

- Since the villages where NERICA seed have been disseminated to farmers (NERICA village) were found to be significant determinants of farmers' exposure and adoption of the NERICA varieties; increasing the number of these villages across the country will greatly enhance NERICA production.

- Not all NERICA varieties have same probability of adoption by farmers. Some NERICA varieties are more preferred by farmers to others. Consequently, future adoption studies of NERICA should try to identify NERICA varieties with high probability of adoption in order to multiply and disseminate such varieties massively.

- Finally, due to the yearly fluctuations in production level, it is imperative to continue this research in future with panel data for several years in order to measure the actual change in production and poverty that could be attributed to NERICA adoption.

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APPENDIX: Survey Questionnaire

WARDA/NARI

2007 IMPACT ASSESSMENT INVESTIGATION

Module 1: Identify the varietal heritage of each village

Name of Village………………………………………………………………

VARIETIES OF THE VILLAGE (varieties that are cultivated in the village)

Code of the variety	Names of the variety	Type of the variety	Type of rice farming or variety used (See code type of rice farming)			How long ago was this variety introduced in the village? (Write 50 for over 50 years)	Who introduced this variety in the village? (See code)	From which institution is that person (See code)	Introduction an method whe or introduction was perform by extension research institution	Cycle of the variety (Seedingharvest periods in months)	Height of the variety (See code)

NB: The full list of varieties must be drawn before asking the other questions.

Code type of the variety: 1=traditional 2=improved WARDA NERICA, 3=improved WARDA non-NERICA, 4=other improved

Code type of rice farming: 1= Upland, 2=lowland, 3=dry plain 4=flood plain, 5=mangrove, 6=floating

Code of who introduced: 1= development/institution/grouping agent 2=farmer from the village, 3= farmer from another village, Code of the institution of the person, who introduced the variety: 1=NARI, 2=Extension Service, 3=Projects, 4=NGO, 5=Farmer organization, 6=Private 7=others (specify)

Code of introduction method: 1=Demonstration, 2=PVS, 3=Study village, 4=others (explain) Code of the height of the variety: 1=short (knee level around 0,5 m), 2=medium (hip height around 1,5m) , 3=high (approaching head height, more than , more than 1,5m)

MODULE 2: COMMUNITY-BASED EVALUATION OF VARIETIES

Name of the Village……………………………………………………..

Variety code							
Name of the variety							

Agronomic and morphological characteristics							
Production							
Drought resistance							
Tillering							
Weed resistance capability							
Lodging resistance							
Shattering per individual plant							
How large is the panicle?							
Length of peduncle							
Yellow leaves							
Spots on leaves (diseases)							
Rotten stems							
Empty grains							
Sterile plants							
Insect attacks							
Attacks by rodents							
Attacks by birds							
Form of grains							
Colour of the paddy							
Post-harvest Characteristics (TALK TO WOMEN)							
Resistance to shedding during							
handling Ease of threshing							
Ease of pounding (hand							
shelling)Damage levels							
Grain colour (rice)							
Cooking and Organoleptic Characteristics							
Easy to cook							
Sticky grains after cooking							
Taste							
Flavour (aroma)							
Conservation after cooking							
Swelling capacity							
Varietal classification (from							

best to least good)

Note: Use code 9 where farmer(s) knows nothing about the characteristics referred to.

MODULE 3: VILLAGE INFRASTRUCTURES

Name of the District:____

Name of the sub-district:____
Name of circuit:____
Name of village: ____

1. Type of access road: [ ] [ ] [ ]
1 = Asphalt 2=track in good shape all year round 3= track hardly usable
4= track unusable in certain periods of the year, 5=use of a ferryboat, 6=use of a canoe, 7=path, 8=other specify)

2. Where road is untarred (asphalted), show distance from the nearest tarred road: [ ] Km
2' where road is tarred, since when*:*[ ]

3. How many vehicles come to the village per day? [ ]
Write 10 where there are more than 10 vehicles per day; otherwise, specify number.

i. Where there is less than one vehicle per day, how many come to the village per week? [ ]
ii. Is there a particular day on which these vehicles come; if yes, which one? [ ] 1=market day in the village, 2=market day in another village, 3=other
iii. If yes, how many vehicles pass on that day? [ ]

4. Water Points: [ ] [ ] [ ] [ ]
1=waterworks 2=borehole 3= developed source 4=improved wells 5=traditional wells 6=river/creek and others
iv. Existing but non operational water Points [ ] [ ]

5. School infrastructure and vocational training: [ ] [ ] [ ]
1=Primary School English, English-Arabic or Arabic 2=Junior High School English, English-Arabic or Arabic
3=Senior High School 4=nafa, 5=Islamic school
5' Where there is a primary school, since when: [ ]

6. Where there is no primary school, show distance to the nearest primary school:[ ] km.
7. Existence of health care infrastructures: [ ] [ ]

Code: 1= health station 2= health center, 3=nursery station, 4=hospital, 5=others (specify)
7' Where there is a nursery/nursery station, since when: [ ]

8. Where there is no first aid post, show distance to the nearest post:[ ] km.

9. Drugstore in the village: [ ] *1=yes* *2=no*

10. Where there is no drugstore or depot, show how far to the nearest drugstore: [ ]km

11. Electric power: [ ] *1= yes 2=no*

11' If there is power, since when: [ ]

12. Administrative Services in the village: [ ] [ ] [ ]
1=district, 2=sous-préfecture 3=préfecture 4 = mairie

13. If there are no administrative services, show distance to the nearest ones: [ ]km

14. Existence of market in the village: [ ] *1=yes 2=no market*

15. If there is no market show distance to the nearest market: [ ] km

15' If people go to market by car, how much does it cost: [ ] Dalasi.

16. If there is a market, how many villages are involved? [ ] *Code: 1=less than 5 2=5 to 10 3= 11 to 20 4= more than 20.*

17. Existence of shops (stands, stores, shops): [ ] *1=yes 2=no*

18. Existence of telephone: [ ] *1=yes 2=no*

19. Community based organisations and associations

Organizations	**Membership**		**Type of activities conducted**
Code 1	**Male**	**Female**	**Code 2**

Code 1: 1=cooperative 2=producers' grouping (farmers, cattle rearers, craftsmen), 3=mutual aid group, 4=savings fund, 5=other forms of association, 6=tontine fund, 7=agricultural produce fund, 8=credit programmes, 9= other (specify)

Code 2: 1= farm credit, 2=money deposit, 3= protection of community interests, 4=product commercialization, 5=mutual aid group members, 6= village life management, 7=agricultural production, 8=supplies, 9=literacy, 10=development, 11=other (specify)

20. Other institutions present in the village [ ] [ ] [ ]

Code: 1=rural credit, 2=SNPRV 3=NGO, 4=other institutions (specify)

21. Has the village profited from projects? [ ] [ ] [ ]

1=hydro-agricultural development project, 2=acquisition of community-based infrastructures,

3=acquisition of agricultural equipment, 4=extension, 5=training courses/awareness, 6=other (specify)

22. Who introduced rice farming in the village? And when?

. Upland

Who? [ ] When? [ ]

. Lowland

Who? [ ] When? [ ]

1=village inhabitant, 2= inhabitant of another village, 3= IRAG, 4=SNPRV, 5=SG2000,

6=another NGO (specify name), 7=farmer's organization, 8=other facilities (specify), 9=other (specify)

23. Who introduced lowland water control techniques such as dikelets, and channels? [ ] and when? [ ]

1= village inhabitant, 2=inhabitant of another village, 3= IRAG, 4=SNPRV, 5=SG2000,

6=another NGO (specify name), 7=farmers' organization, 8=other facilities (specify), 9= other (specify)

1. Labour

Activity	Internal labour				External labour			
	Daily pay Without food		Daily pay With food		Daily pay Without food		Daily pay With food	
	M.	F.	M.	F.	M. F.		M.	F.
Weeding								
Burning over								
Labour								
Balk making								
Labour seeding (by seed spreading)								
Nursery								
Transplanting								
Weeding								
Surveillance								
Harvest								
Threshing								
Transport								
Decorticating								
Others								

2. Price of paddy kg after harvest (   )

2.1 Where sales occur in the village:-----------------------------------per kg

2.2 Where sales occur at the most popular market: -----------------------per kg
(Name of the place)

3. **Village history**

3.1 Where (in which village/city and region) did your forefathers live before establishing this village? --

3.2 Is it the same region in which the village is located today? [ ] 1=yes 2=no

3.3 If no, in which other region of the country or from which other country do your forefathers come from? --

3.3 For how long has this village been founded by your forefathers?------------------------

3.4 What are the largest ethnic groups in the village?

Name of the group:-----------------------------; percentage: -------------------

Name of the group:-----------------------------; percentage:-------------------

3.4.1 Are there any minority ethnic groups in the village? If yes,

Name of group:---------------------------- ; number of households:------------------

Name of group:---------------------------- ; number of households:------------------

Name of group:---------------------------- ; number of households:------------------

Name of group:---------------------------- ; number of households:------------------

3.4.2 Do minority ethnic groups live separately (in another area)?

1=yes (which ones?---

2=No

3.5 During the past five years, how many families settled down in this village and/or in the dependent camps?

3.5.1 From which region in the country or which countries do these families come from? ---

Module 4: SOCIO-ECONOMIC DATA (Farmer Questionnaire)

Name of Region: ____

Name of district: ____
Name of village: ____

0 Date of interview:………………………….……

Surname & Name of investigator:………………………………………………..

1. Surname and names of farmer interviewed……..……………………….………

2. Sex: [ ] 1=male, 2=female.

3. Age: [ ]

4. Number of years of residence (in the village): [ ]

4 Is the farmer a native of the village? [ ]1=yes, 2=no

5 Ethnic groups: _________________________________

Code: 1=Mandinka, 2=Wollof, 3=Fula, 4=Jola, 5=Serere, 6=Sarahuli, 7=Manjako, 8=Balanta, 9=other (specify)

6 Size of the household (Number of persons living with you and sharing your meals daily)

[ ]

7 What is your level of education? [] 1=primary, 2=junior secondary school, 3=senior secondary school, 4=tertiary, 5=Islamic, 6=illiterate, 7=other (specify)

8 Have you received any vocational training? [ ] 1=yes, 2=no

9. Main activity:[ ] 1=agriculture, 2=rearing, 3=house chores, 4=commerce, 5=craftsman, 6=labourer, 7=none, 8=other (specify)

10. Secondary activity: [ ]1=agriculture, 2=rearing, 3=house chores, 4=commerce, 5=craftsman, 6=labourer, 7=none, 8=other (specify)

11 For how long have you been practicing the various types of rice farming (write 25 for over 25 years)?

1. Lowland [ ]

2. Upland [ ]

4. Flood prone plane [ ]

5. Dry plane [ ]

3. Mangrove [ ] 6. Floating rice farming [ ]

12. Type of rice farming practiced over 5 years:

Year	Type of rice farming practiced			Type of development		
2006						
2005						
2004						
2003						
2002						

Code type of rice farming practiced: 1= upland, 2=lowland, 3=dry plain 4=flood prone plain , 5=mangrove, 6=floating

Code type of development: 1=without development, 2=developed

13. Give the name of your three (3) best varieties (in order of preference):

1. ……………………………..
2. ……………………………..
3. ……………………………..

14 List the crops grown over the last 5 years: [ ] [ ] [ ] [ ] [ ] [ ]

<u>Crop code:</u> 1=rice, 2=maize, 3=millet, 4=Sorghum, 5=cassava, 6=groundnuts, 7=Findo 8=vegetables, 9=water melon, 10=sugar cane, 11=Cashew, 12=Orange trees, 13=mango trees, 14=palm oil, 15=other (specify)

15 Main sources of non agricultural income over the last 2 years: [ ] [ ] [ ]

Codes of main sources of income: 1=handicraft, 2=rearing, 3=processing, 4=commerce, 5=extraction (salt, honey, gravel, sand, mine), 6=salary (fixed, temporary, contracts, etc.)

16. With which institution(s) have you worked with regard to rice farming and for how long?

Institutions time (in years) Type of relation

1 ……………………………………[ ]
……./……/……
2……………………………………[ ]
……/…..../……

3……………………………….....[ ]
……./…..../……

4……………………………………[ ]
……./…..../…

Codes for types of working relations: 1=gift of seeds, 2=purchase of seed from the institution, 3=sales of agricultural seeds by the institution, 4=technical training conducted by the institution, 5=training, 6=credit, 7=Provides equipment (agricultural equipment), 8=sales of fertilizer, 9=gift of fertilizer, 10=other (specify),

16. Annual Production

Years	Rice farm area(ha)	Quantity of seeds used for all types of rice area	Quantity of rice produced (kg) 1 t = 1000 kg	Rice income	Income derived from other produce	Non agricultural income
2006						
2005						

17. Destination of rice production

Years of rice production	Destination	Types of varieties sold		
2006				
2005				
2004				
2003				
2002				

Destination codes: 1 = for family consumption only, 2 =family consumption and sale, 3 =sales only, 4=other (specify)

Code for type of variety: 1=Traditional 2=improved WARDA NERICA, 3=improved WARDA non-NERICA, 4=other improved

MODULE 5: KNOWLEDGE, USE AND MANAGEMENT OF VARIETIES

Surname & names of the investigator:……………………………………………………

Surname & names of farmer: …………………………………………………………

Name of the village: ………………………………………………………………………………

Variety Code	Name of the variety	Knowledge of the variety 1=yes, 2=no	Source of knowledge (see code)	Year of knowledge	Grown at least once 1=yes, 2=no	If yes First cropping year	Grown at least once over the last 6 years 1=yes, 2=no	**Cropping year:** **1=yes, 2=no**					
								2006	**2005**	**2004**	**2003**	**2002**	**2001**

Code for source of knowledge: 1=farmer from the village, 2= farmer from another village, 3= IRAG, 4=Extension Services, 5=NGO (specify name), 6=vocational organization, 7=other facility (specify), 8=local market, 9 = other (specify)

		Did you use your own seeds in the course of the year………. (Read year in the columns below and use codes 1=yes, 2=no)						Did you buy the seeds of that variety in the course of the year ………. (Read year in the columns below and use codes 1=yes, 2=no)						Did you sell the seeds of that variety in the course of the year………. (Read year in the columns below and use codes 1=yes, 2=no)					
Variety Code	Name of variety	2006	2005	2004	2003	2002	2001	2006	2005	2004	2003	2002	2001	2006	2005	2004	2003	2002	2001

Source/receiver: *1=farmer or relative from the village, 2= farmer or relative from another village, 3= NARI, 4=Extension service 5=NGO 6=farmers' organization, 7=local market, 8 =other (specify).* NB: show code for source or receiver in the second line below "Yes/ No" answer.