Quarterly Journal of International Agriculture 54 (2015), No. 1: 33-58

How Accessibility to Seeds Affects the Potential Adoption of an Improved Rice Variety: The Case of The New Rice for Africa (NERICA) in The Gambia

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Abstract

This study estimates the adoption gap of NERICA that exists in the population when access to seeds is a constraint. Treatment evaluation technique is applied to consistently estimate the potential NERICA adoption rate and its determinants using panel data from a stratified random sample of 515 rice farmers in The Gambia. The results show that the NERICA adoption rate could have been 76% instead of the observed 66% sample estimate in 2010 provided that every rice farmer had been aware of NERICA's existence before the 2010 rice growing season. However, further investigation finds that if all the rice farmers had been aware of and had access to NERICA seeds, adoption would have been 92%. This reveals that if awareness had not been a constraint, 16% of farmers would have failed to adopt NERICA due to lack of access to seeds. Farmer contact with extension services and access to in-kind credit are significant determinants of access to and adoption of NERICA varieties.

Keywords: average treatment effect, potential adoption, access to seeds, NERICA, The Gambia
JEL: C13, O33, Q12, Q16

1 Introduction

Rice is increasing becoming a critical staple for many countries in sub-Saharan Africa. In The Gambia, the demand for rice is far beyond its local production level. Per capita consumption of rice is estimated to be 117kg per annum, which is one of the highest in sub-Saharan Africa (PLANNING SERVICE UNIT, 2011). Of the 195,811 metric tons of rice consumed in 2011, only 51,137 metric tons were produced locally (GAMBIA AGRICULTURAL CENSUS, 2012). The huge deficit was met through imports from Asia. In 2000, US$10.9 million was spent on importing 93,900 metric tons of rice, which increased to US$28.97 million in 2009, to import 126,625 metric tons of rice (PLANNING SERVICE UNIT, 2011). This is a cause for concern for national food security and macroeconomic stability. As a result, the government is committed to a policy of attaining rice self-sufficiency to significantly reduce rice imports. To realize this objective, efforts to bridge the gap between local rice production and demand will require a higher level of adoption of high yielding improved rice varieties and practices than presently observed (WORLD BANK, 2007).

In an attempt to combat the problem, the New Rice for Africa (NERICA) was officially introduced into The Gambia in 2003. This rice variety is the result of crosses between the Asian rice (*O. sativa*) and the African rice (*O. glaberrima*). It combines desirable traits from both parents such as high yields, shorter duration, good taste, absence of lodging, high fertilizer returns, and greater resistance to major stresses as compared to the traditional varieties (JONES et al., 1997a and 1997b; AUDEBERT et al., 1998; JOHNSON et al., 1998; WOPEREIS et al., 2008). The first set of NERICA introduced in The Gambia consists of upland rice varieties. Since the introduction of NERICA, several initiatives have been taken by the government to widely disseminate it to rice farmers in order to significantly increase its adoption rate. These initiatives includes: the *Back to the Land Call*[1] by the president, Participatory Varietal Selection (PVS)[2], and a NERICA seed multiplication project[3]. To substantiate these efforts, there is an urgent need to consistently estimate the potential NERICA adoption rate to inform on the intrinsic merits of the desirability of the technology by the target population. Such information will assist policy makers to decide whether or not to intensify efforts to disseminate NERICA across the country.

1 The *Back to the Land Call* is a massive political campaign that mainly encourages farmers to cultivate rice, which is the main staple crop of the country. In response to the call, 26752 hectares of communal land have been cultivated by farmers to NERICA across the country (GAMBIA AGRICULTURAL CENSUS (2012).

2 PVS trials involve the selection of the most promising NERICA by rice farmers, which is disseminated to other villages through farmer to farmer contacts, extension and research.

3 The NERICA dissemination project assisted in the multiplication of the best NERICA selected by farmers through PVS trials.

Many studies determine the adoption rates of new technologies by simply computing the percentage of farmers using that technology (e.g., SAKA et al., 2005; NAMWATA et al., 2010; KHALIL et al., 2013). This approach leads to bias and inconsistent estimate of population adoption rate (DIAGNE and DEMONT, 2007). The results are biased because farmers who are not aware of the new technology cannot adopt it even if they might have done so provided they had known about the technology. As a result, studies that do not account for technology awareness underestimate the adoption rate of technologies that are not universally known in the population. To solve this problem, one may think that a better estimate could result from taking the adoption rate within the subpopulation of farmers who are aware of the technology. However, because of positive selection bias, such an approach is likely to overestimate the true population adoption rate (DIAGNE, 2006). In addressing these problems, DIAGNE and DEMONT (2007) used the Average Treatment Effect (ATE) framework to provide consistent estimate of the population adoption[4] rate of the NERICA that would be realized in Cote d'Ivoire when awareness is complete in the population. However, since awareness is not a sufficient condition for adoption, DIAGNE (2010), notes that such outcome would still underestimate the true population adoption rate if access to the NERICA seeds is incomplete in the population. Similarly, KABUNGA et al. (2012) note that awareness is not a sufficient condition for adoption to reach its full potential. They argue that farmers should be aware of and know the attributes of a particular technology to assess the population adoption rate. As a result, they extend the work by DIAGNE and DEMONT (2007) to account for knowledge of technology attributes in the adoption process. However, knowledge of technology attributes is not a prerequisite for its adoption. For adoption to occur, farmers must be aware of and have access to the technology. Hence, both awareness and access are important prerequisites for technology adoption. This fact has recently been highlighted by DONTSOP et al. (2013) who estimated the potential adoption rate of NERICA in Nigeria by controlling for awareness and access to NERICA.

To account for the importance of technology access in the adoption process, this study extends the works of DIAGNE (2010) and DIBBA et al. (2012) to determine the adoption rate of NERICA that would be realized in The Gambia when both awareness and access are complete in the population. It reveals that the current adoption rate of NERICA could be increased by 10% if steps are taken to ensure that the entire rice farming population is aware of the existence NERICA. However, a further investigation finds that if all the rice farmers had been aware of and had access to the NERICA seeds, the current adoption rate could have been increased by 26%. This shows a

[4] Adoption is defined, in this paper, to mean the use of the NERICA technology at the individual level. A farmer is NERICA adopter if he or she cultivated at least one NERICA variety during the 2010 rice production season.

significant adoption gap of 16 percentage points that can be attributed to lack of access to sufficient supply of NERICA seeds.

The paper is organized as follows. Section 2 provides a brief explanation of the main concepts used in this paper and also highlights the hypothesized determinants of adoption. Section 3 presents the sample selection procedure and data. Section 4 presents the Average Treatment Estimation procedures used to consistently estimate the NERICA population adoption rate and its determinants. Section 5 presents the estimates of the NERICA adoption rate and the factors affecting it; and Section 6 concludes with a summary of the main empirical findings and their policy implications.

2 Conceptual Framework

2.1 Technology Awareness and Access

In the adoption literature, the concept of agricultural technology adoption has been defined as the use or non-use of a technology by a farmer at a given point in time (RODGERS, 1983). Studies by ROGERS and SHOEMAKER (1971) and ROGERS (1983) describe the technology adoption process as a mental process that begins with the first knowledge of a new technology and ends with the decision to adopt or reject it. Therefore, knowledge and technology awareness are crucial components of the adoption process. This fact is more pronounced by DIAGNE and DEMONT (2007) who show that technology awareness is a prerequisite for its adoption. Certainly, a farmer must be aware of the existence of a new technology before he or she can use it. The term awareness is used in this paper to mean the mere knowledge of the existence of the NERICA technology and does not necessarily imply learning of its characteristics. When awareness is complete in a population, another important factor that can limit adoption is access: even if a farmer is aware of a particular technology, he or she cannot adopt it unless the technology is accessible. Thus, technology access[5] is defined in this paper to mean the availability of NERICA seeds within the reach of farmers who are aware of the NERICA technology. In this study, a farmer has access to NERICA seeds if he or she is aware of the existence of NERICA and if NERICA seeds can be obtained within or outside his or her village.

5 For simplicity, this study rules out all cases in which a farmer may unknowingly adopt or have access to the NERICA seeds without being aware of its existence. This is a necessary assumption because such data cannot be obtained.

2.2 Actual and Potential Adoption

Many studies assume that technology awareness and access are complete in a given population. For this reason, such studies only inform about actual or observed adoption of a technology rather than the desirability of a technology by the underlying population under incomplete awareness and access. Hence, actual adoption is defined in this paper as the adoption rate within the subpopulation of farmers who are aware of and have access to the NERICA technology. This is different from the adoption rate that would be realized if the entire population is aware of and has access to the NERICA seeds, which is defined in this study as the potential adoption of the NERICA technology. The difference between actual and potential adoption is defined in this paper as the adoption gap, which the study estimates by extending the ATE framework used by DIAGNE and DEMONT (2007) to appropriately control for both awareness and access in order to determine the adoption gap that can be attributed to lack of access to NERICA seeds.

2.3 Hypothesized Determinants of Adoption

There is extensive literature on the economic theory of adoption. Several factors have been found to influence decisions to adopt agricultural technologies. Traditionally, economic analyses of the adoption of agricultural technologies has focused on imperfect information, risk, uncertainty, institutional constraints, human capital, input availability, social capital, and infrastructure as factors that explain adoption decisions of farmers (FEDER et al., 1985; FOSTER and ROSENZWEIG, 1995). Due to data limitation, this study focuses on education, information, farm size, age, and technology cost as the most important factors influencing adoption of the NERICA. These factors are discussed in more detail below.

Education has been found by many adoption studies to significantly influence a farmer’s adoption decision (ROGERS, 1983; FEDER 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 for a given technology, thereby increasing the likelihood of adoption. The expected effect of education on NERICA adoption is thus positive.

CASWELL et al. (2001) highlights the importance of information in the technology adoption process, finding that more information about a technology reduces uncertainty about its performance. This can change an individual’s view of a technology over time from purely subjective to objective. FEDER and SLATE (1984) also find that more information enhances adoption particularly if a technology is profitable. The hypothesized effect of information acquisition on NERICA adoption, especially through contact with extension services, is positive.

Farm size has been identified by many adoption studies as one of the most important factors influencing adoption decisions (BOAHENE, SNIJDERS and FOLMER, 1999; DOSS and MORRIS, 2001, and DAKU, 2002). FEDER, JUST and ZILBERMAN (1985) note that if a technology requires a large amount of initial costs, only farmers with large farms will risk adopting the technology. FEDER et al. (1985) also make a distinction between divisible and indivisible technologies. They note that for divisible technologies, like NERICA, the adoption decision is determined by area allocation and the level of usage. This increases the likelihood of adoption among small holder farmers.

Age is also found to be an important determinant of technology adoption. ROGERS (1983) finds that the majority of early adopters are expected to be younger, more educated, venturesome, and willing to take risks. For this reason, age is hypothesized to negatively affect the adoption decision of technologies by farmers during the early stages of adoption. We, however, do not have data on individual risk preferences so we are unable to include risk aversion as a potential factor influencing adoption.

The cost of a technology is another important factor that can influence adoption. EL-OSTA and MOREHART (1999) indicate that technologies that are capital-intensive are only affordable by wealthier farmers, limiting their adoption to the more affluent group of the farming population. The fact that NERICA seeds are more expensive than other rice variety seeds, may limit their adoption to wealthier farmers. We hypothesized that farm size, a proxy for wealth, will positively affect farmers' decision to adopt the NERICA.

3 Sampling Procedure and Data

The study obtained a country-wide panel data in 2010 from rice growing villages and farmers who were initially sampled in 2006. The villages were selected through a multi-stage stratified random sampling procedure. In the first stage, villages were stratified into two strata across the six agricultural regions of the country: 1) villages where NERICA was disseminated (hereafter, NERICA villages) and 2) villages where NERICA was not disseminated (hereafter, non-NERICA villages). With the exception of the West Coast Region[6], five NERICA and five non-NERICA villages were

[6] The survey included ten NERICA and non-NERICA villages in West Coast Region. However, the sample size in each village was limited to only five households because 100 households were targeted in each agricultural region. For this reason, more households per village were selected in regions with fewer villages and vice versa.

randomly selected from each stratum for a total sample size of 70 rice growing villages. NERICA villages were first identified in each agricultural region, followed by a random selection of non-NERICA villages within a radius of 5-10 kilometers.

During the second stage, a list of all rice growing households in each selected village was obtained through interviews with key informants. Ten of these rice growing households were randomly selected from each village, resulting in a total sample size of 600. This sample sampling procedure was undertaken in 2006. Due to migration and other circumstances beyond the control of the survey team in 2010, the sample size was reduced to 515. However, this did not result in any serious systematic attrition bias. About 10-15 rice farmers were dropped from each of the agricultural regions selected for the survey. As a result, there was no region that had a significantly higher attrition rate than the others. Moreover, data were obtained on all cases for the variables used to compare the survey results from 2006 and 2010. This provides a balanced panel data for the study.

The 2010 survey team interviewed the person most knowledgeable and responsible for rice production in the household, about cropping systems, resource management, farm operations, post-harvest activities, cooking and organoleptic characteristics of rice varieties grown, and socio-economic and demographic characteristics including income and expenditure data. The following section explains the empirical framework for how adoption of NERICA is analyzed.

4 Empirical Framework

4.1 Sample Adoption Rate

To address biases resulting from non-exposure and poor access, a better estimate is to take the sample estimate within the sub-population of farmers who are exposed to the NERICA technology or those who have access to it as the true estimate of the population adoption rate. However, due to positive selection bias, the sample estimate within the sub-population of farmers who are exposed to the NERICA technology or those who have access to it is likely to overestimate the true population adoption rate. Positive selection bias arises from two sources. First, farmers self-select into exposure or access to the NERICA technology, reflecting the fact that farmers who are constantly searching for better technologies are likely to be exposed to or have access to them. Second, some progressive farmers and communities are targeted by research and extension. It is likely that the farmers and communities targeted for exposure of or access to NERICA seeds are precisely those who are more likely to adopt NERICA. Hence, the adoption rate in the targeted subpopulation is likely to overestimate the true population adoption rate (DIAGNE, 2006). For this reason, the sample adoption rate within the sub-population of farmers who are exposed to or have access to the NERICA technology is likely to be a biased estimate of the true population adoption rate.

4.2 Potential Outcome Framework and Evaluation Problem

Following DIAGNE and DEMONT (2007), this study uses the potential outcome framework to assess the effect of exposure of and access to NERICA seeds on the adoption of NERICA. Under this framework, treatments refer to exposure[7] and access to NERICA seeds by which every farmer has two potential outcomes for each treatment. With exposure as the treatment variable, every farmer has an outcome denoted as y_{1w} when exposed to NERICA and y_{0w} otherwise. Exposure is donated by w, whereby $w=1$ is exposure and $w=0$ otherwise. Thus, the observed outcome can be written as a function of the two potential outcomes:

$$y_w = wy_{1w} + (1-w)y_{0w} \qquad (1)$$

For any observational unit, the causal effect of NERICA exposure on its observed outcome is simply the difference of its two potential outcomes: $y_{1w} - y_{0w}$. However, since exposure is a necessary condition for adoption, we have $y_{0w} = 0$ for any farmer whether he or she is exposed to NERICA or not. For this reason, equation (1) can be simplified as follows:

$$y_w = wy_{1w} = y_{1w} \qquad (2)$$

Hence, the adoption impact for farmer i is given by y_{i1w} and the average impact is given by $E(y_{1w})$, which is the population Average Treatment Effect of exposure on NERICA adoption (ATE_w):

$$ATE_w = E(y_{1w}) \qquad (3)$$

The average treatment effect for the subpopulations of farmers aware $(ATE1_w)$ and unaware $(ATE0_w)$ of the NERICA can also be identified and estimated. They can be identified as follows:

$$ATE1_w = E(y_{1w} \mid w=1) \qquad (4)$$

[7] In this study, the word “exposure” is used strictly to mean awareness of the existence of the NERICA technology.

$$ATE0_w = E(y_{1w} | w = 0) \quad (5)$$

Equation (3) is a measure of the adoption rate that would be realized if the entire rice farming population had been aware of the NERICA technology. However, since adoption cannot take place unless there is access to NERICA seeds, this study extends the work of previous studies (DIAGNE and DEMONT, 2007; DIAGNE, 2010; DIBBA et al., 2012) to determine the adoption rate that would be realized if every rice farmer is aware of and has access to NERICA seeds. This is estimated with the use of an "access to seeds" as a second treatment variable. To create "access to seed" variable, farmers who knew about NERICA were asked whether they could obtain NERICA seeds within or outside their villages. A farmer who responded "yes" to this question is identified as having access to NERICA seeds.

Now, let y_{1s} denote the potential outcome when the farmer has access to NERICA seeds and y_{0s} otherwise. Letting s to stand for access to NERICA seeds, whereby $s = s_1 = 1$ represents access to NERICA seeds and $s = s_1 = 0$ otherwise. Thus, the observed outcome can be written as a function of the two potential outcomes:

$$y_s = sy_{1s} + (1 - s)y_{0s} \quad (6)$$

Since having access to seeds implies awareness, equation (6) can be modified as follows:

$$y_s = s_1 w y_{1s} + (1 - s_1 w) y_{0s} \quad (7)$$

However, since access to NERICA seeds is a prerequisite for adoption, $y_{0s} = 0$ for any farmer whether or not that farmer has access to NERICA seeds. Hence, the adoption impact of accessing NERICA seeds for a farmer i is given by y_{i1s} and the average treatment effect of access to NERICA seeds on adoption (ATE_s) for the entire population is given by:

$$ATE_s = E(y_{1s}) \quad (8)$$

The average treatment effect of access to NERICA seeds on adoption for the subpopulation of farmers with $(ATE1_s)$ and without $(ATE0_s)$ access to seeds can also be identified as follows:

$$ATE1_s = E(y_{1s} | s = 1) \quad (9)$$

$$ATE0_s = E(y_{1s} | s = 0) \tag{10}$$

Unfortunately, the values of y_{1w} and y_{1s} in equation (3) and (8) are observed only for farmers who have been exposed to and have had access to NERICA seeds, respectively. Hence, we cannot estimate the expected value of y_{1w} and y_{1s} by the sample average of a randomly drawn sample since some of y_{1w} and y_{1s} in the sample would be missing. This missing data problem makes it impossible to measure the effect of exposure or access to NERICA seeds on the observed outcomes without further assumptions. Section 4.4 provides a detailed explanation of the assumptions required to estimate the NERICA population adoption rate.

4.3 Population Adoption Gaps and Selection Bias

Under incomplete awareness and access of a technology, the observed adoption rate, which is defined as joint access and adoption (JAA)[8], could be significantly different from the population potential adoption rate. As a result, different population adoption gaps (GAP) can be identified that may be attributed to a lack of awareness of and/or lack of access to seeds. In this study, we identify the following adoption gaps:

$$GAP_w = E(y) - E(y_w) = JAA - ATE_w \tag{11}$$

$$GAP_{ws} = E(y) - E(y_s) = JAA - ATE_s \tag{12}$$

$$GAP_s = ATE_w - ATE_s = GAP_w - GAP_{ws} \tag{13}$$

Equation (11) is the adoption gap that can be attributed to lack of awareness, equation (12) is the gap that can be attributed to both a lack of awareness of and access to seeds, and equation (13) is the adoption gap that can be attributed to a lack of access to NERICA seeds.

Besides the identification of the population adoption gap, it is also important to determine whether the subpopulation of farmers who are aware of or those who have access to NERICA seeds have the same probability of adopting NERICA as compared to farmers who are not aware of or those who do not have access to NERICA. To determine this probability, it is imperative to identify any form of Population Selection Bias (PSB), which can be defined as follows:

[8] Joint Exposure and Adoption (JEA) and Joint Awareness Access and Adoption (JEAA) in previous studies (DIBBA et al., 2012; DONTSOP et al., 2013) are simplified in this study to Joint Access and Adoption (JAA). This is necessary because technology access implies awareness. Hence, JEA for the exposure model is equivalent to JAA in the access model.

$$PSB_w = ATE1_w - ATE_w = E(y_{1w} | w = 1) - E(y_{1w}) \quad (14)$$

$$PSB_s = ATE1_s - ATE_s = E(y_{1s} | s = 1) - E(y_{1s}) \quad (15)$$

Equation (14) and (15) are the expected population selection bias that would exist if the adoption outcome of the subpopulation of farmers who are aware of NERICA and those who have access to NERICA seeds are wrongly used to represent the true population adoption rate, respectively.

4.4 ATE Estimation of the Population Adoption Rate and its Underlying Assumptions

4.4.1 Assumptions of ATE Estimation

To correct for the bias associated with the sample adoption rate and to consistently estimate the potential adoption rate of NERICA, this study applies the ATE approach highlighted by DIAGNE and DEMONT (2007). As discussed in the previous section, the ATE approach is based on the potential outcome framework. The main problem associated with this framework is the inability to observe the counterfactual situation. That is, it is impossible to observe the potential adoption outcome of a farmer who is not aware or does not have access to NERICA without further assumptions. Hence, to consistently estimate the potential adoption rate of NERICA, this study relies on the validity of the conditional independence assumption (ROSENBAUM and RUBIN, 1983).

The conditional independence assumption identifies a set of variables X_i that influence an individual's decision to adopt a particular technology and a vector of covariates Z_i affecting exposure or access to NERICA. Conditional independence is define as:

$$Y_0 , Y_1 , \coprod D_i \mid X_i \quad (16)$$

where $\coprod$ denotes independence. This means that once observable differences between treated[9] and non-treated[10] farmers are controlled for, the outcome of the non-treated farmers would have the same distribution compared to the treated farmers had they not been treated (ROSENBAUM and RUBIN, 1983). If this assumption holds, the adoption outcome of the treated sub-population can be used to determine the counterfactual situation of the non-treaded sub-population and vice versa. In addition to the conditional independence assumption, the following assumptions are required for the identification of ATE (DIAGNE and DEMONT, 2007):

[9] Treated farmers are those who are exposed to or have access to NERICA seeds

[10] Non-treated farmers are those who are not exposed to or do not have access to NERICA seeds

i) potential adoption is independent from Z_i and conditional on X_i:
$P(y_1 = 1 | X, Z) = P(y_1 = 1 | X)$

ii) exposure or access is independent from X_i and conditional on Z_i:
$P(w_1 = 1 | X, Z) = P(w_1 = 1 | Z)$

iii) overlap for all values of the covariates between the treated and non-treated groups:
$0 < \Pr(D = 1 | Z) < 1$.

Assumption i) implies that the variables in Z_i, but not those in X_i must only have an indirect effect on adoption through the treatment variables (awareness and access). Assumption ii) holds by the fact that the variables in X_i are also found in Z_i. The variables to be included in X_i and Z_i should be pre-treatment variables, which can all be endogenous (see DIAGNE and DEMONT, 2007).

4.4.2 Parametric Estimation of ATE

This study relies on the validity of the conditional independence assumption to consistently estimate the population potential adoption rate of NERICA and its determinants using the ATE parametric approach. The approach uses observation from only the treated subpopulations to estimate the population adoption rate with the use of a parametric model, which can be specified as follows (see DIAGNE and DEMONT, 2007):

$$ATE(x) = E(y | x, d = 1) = (g, \beta) \qquad (17)$$

where d is the treatment[11] status and g is a known and possibly non-linear function of the vector of covariates x and the unknown parameter β which can be estimated using standard Least Squares (LS) or Maximum Likelihood Estimation (MLE) procedures using the observations (y_i, x_i) from the sub-samples of exposed or seed accessed farmers only, with y as the dependent variable and x the vector of explanatory variables. With an estimated parameter $\hat{\beta}$, the predicted values are computed for all the observations i in the sample (including the observations in the non-exposed and non-seed accessed sub-samples). The ATE is estimated by taking the average of the predicted $g(x_i, \beta) i = 1,...,n$ across the full sample and respective subsamples for ATE1 and ATE0:

[11] When awareness is the treatment variable $d = w$ and when access to seeds is the treatment variable $d = s$ in equation (17).

$$A\hat{T}E = \frac{1}{n}\sum_{i=1}^{n} g(x_i, \hat{\beta}) \tag{18}$$

$$A\hat{T}E1 = \frac{1}{n_1}\sum_{i=1}^{n} d_i g(x_i, \hat{\beta}) \tag{19}$$

$$A\hat{T}E0 = \frac{1}{n - n_1}\sum_{i=1}^{n} (1 - d_i) g(x_i, \hat{\beta}) \tag{20}$$

where n is the total sample size and n_1 is the number of treated farmers. The average treatment estimates (ATE, ATE1 and ATE0), the population adoption gaps (GAP_w, GAP_{ws}, and GAP_s), and the population selection bias (PSB_w and PSB_s) were all estimated in Stata using the Stata add-on *adoption* command developed by DIANGE and DEMONT (2007).

5 Results and Discussions

5.1 Socio-demographic Characteristics of Farmers

Table 1 compares 2006 survey results with those from 2010. With the exception of practice of lowland rice farming and farmer contact with the Department of Agriculture (DAS), there has been a significant increase in NERICA exposure and adoption rates, practice of upland rice farming, and farmer contact with the National Agricultural Research Institute (NARI) between the 2006 and 2010 surveys.

The percentage of farmers exposed to NERICA increased from 47% in 2006 to 88% in 2010, showing a significant difference of 41%. This may explain the significant increase (26%) in the adoption of NERICA prior to the 2010 survey (Table 1). The increase in the exposure rate was made possible through collaborative efforts between research and extension to disseminate NERICA to all the agricultural regions of The Gambia. As more rice farmers became aware of NERICA, the expected adoption rate increased accordingly.

The negative and positive change in the practice of lowland and upland rice farming, respectively, is not surprising. The NERICA disseminated thus far in The Gambia is upland rice. Therefore, we would expect upland farming to increase with the adoption of NERICA. The fact that NERICA fetches a higher price in the local markets compared to other rice varieties, could have made its production more attractive to rice farmers. As a result, many farmers increase their upland rice production. Furthermore, the dissemination of NERICA to farmers through research and extension outlets has resulted in increased farmer contact with the NARI. This increase could be attributed to the fact that NERICA seed dissemination activities are coordinated by the NARI. However, the insignificant change in farmer contact with the DAS from the 2006 to the 2010 survey could be explained by the fact that after the initial acquisition of NERICA seeds from extension agents, many other farmers may have acquired seeds through other farmers instead of through the DAS.

Table 1. Comparing 2006 and 2010 survey results on NERICA adoption and farming in The Gambia

Variable	**2006** (N=515)	**2010** (N=515)	**Difference** (T-test)
Exposure to NERICA	0.47 (0.02)	0.88 (0.01)	0.41 (0.02)***
Adoption within the NERICA exposed subpopulation	0.85 (0.03)	0.77 (0.03)	-0.08 (0.03)***
NERICA sample adoption	0.40 (0.02)	0.66 (0.02)	0.26 (0.03)***
Practice of upland rice production	0.53 (0.02)	0.78 (0.02)	0.25 (0.03)***
Practice of lowland rice production	0.80 (0.02)	0.43 (0.02)	- 0.36 (0.03)***
Farmer contact with the NARI	0.5 (0.01)	0.21 (0.02)	0.16 (0.02)***
Farmer contact with the DAS	0.31(0.02)	0.32 (0.02)	0.01(0.03)

NB: T-tests were used to test the difference between the 2006 and 2010 survey results. We used the mean value of each dummy to test the mean difference using the T-test.
NARI is the National Agricultural Research Institute. DAS is the Department of Agricultural Services. Robust standard errors are shown in parenthesis. ***Indicates that the difference is statistically significant at the 1% level.

Source: AfricaRice/NARI, Gambia Post Impact Assessment survey (2006/2010)

5.2 Actual and Potential Adoption Rates

Actual and potential adoption rates of NERICA are shown in Table 2 and Table 3, respectively. Within the agricultural regions, the lowest sample exposure rate is in the Central River South (CRS) (62%) and the highest is in the North Bank Region (NBD) (100%) and West Coast Region (99%). In the other regions, the sample exposure rate ranges from 86% to 95%. Among exposed farmers, access to seeds, a necessary condition for adoption, is very low in the CRS (38%) and relatively low in the Upper River Region (URR) (68%) and Central River Region (CRN) (71%).

The relatively low sample exposure rate and access to NERICA seeds in the CRS and CRN may be because some rice growing villages in these regions are located along a river, which restricts some farmers to adopt only lowland[12] tidal irrigated rice varieties instead of NERICA, which is an upland rice variety. For this reason, one would expect that the exposure rate and access to NERICA would be lower in these regions. The high exposure rate and access to NERICA seeds in other regions, especially the WCR and NBR, may be because NERICA was first introduced in these regions through PVS in 1998. These regions have, therefore, had a longer exposure time compared to others where NERICA was introduced several years later, between 2005 and 2010.

Table 2. Actual adoption of NERICA

Description	Regions						Total
	WCR	LRR	CRS	NBR	CRN	URR	
Total number of farmers	89	85	89	92	78	82	515
Farmers exposed to NERICA in 2010 (%)	99	95	62	100	86	89	88
Exposed farmers who had access to NERICA seeds in 2010 (%)	84	93	38	80	71	68	72
Farmers who adopted NERICA(%)							
2008	54	69	20	67	31	56	50
2009	65	79	29	67	59	72	61
2010	76	88	35	72	62	65	66

Notes: WCR = Western Coast Region, LRR=Lower River Region, CRS = Central River South, NBR = North Bank Region, CRN = Central River North, and URR = Upper River Region

Source: AfricaRice/NARI, Gambia Post Impact Assessment survey (2006/2010)

The actual or sample adoption rate is estimated to be 50% in 2008, 61% in 2009, and 66% in 2010. The agricultural region with the highest adoption rate is the Lower River Region (LRR) (69% in 2008, 79% in 2009 and 88% in 2010) and region with the lowest adoption rate is the CRS (20% in 2008, 29% in 2009 and 35% in 2010). With the exception of CRN, the sample adoption rate is above 50% in all the other regions (shown in Table 2). Since the sample estimate is likely to underestimate the true population adoption rate due to biases resulting from non-exposure and inaccessibility to NERICA, it is important to control for such biases in order to assess the full potential adoption rate of NERICA in The Gambia.

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[12] The villages selected along the river also have upland rice fields where farmers cultivate NERICA. Selecting only upland farmers in such villages would have created a positive selection bias that could have seriously overestimated the true adoption rate of the NERICA. This would have been the case because NERICA is the only upland rice variety cultivated in most of the villages located along the river Gambia.

The results of the potential NERICA adoption rate with ATE correction for non-exposure, non-access to seeds and selection biases are presented in Table 3. The ATE exposure model shows that if every rice farmer in The Gambia had been aware of the existence of NERICA prior to the 2010 survey, the adoption rate would have been 76% instead of 66%. This shows an adoption gap of 10 percentage points, which could be attributed to a lack of awareness. However, since awareness is a necessary, but not a sufficient condition for adoption, we should identify what the potential or population adoption rate would have been if every rice farmer had been aware of the existence of the NERICA and had had access to it. This is examined in the ATE access to seeds model.

Table 3. ATE parametric estimation of potential adoption rate

	ATE exposure model		**ATE access to seeds model**	
Population adoption rate	**ATE_W**	0.76 (0.29)***	**ATE_S**	0.92 (0.09)***
Adoption rate within treated farmers	**$ATE1_W$**	0.76 (0.34)**	**ATE_S**	0.92 (0.11)***
Adoption rate within non-treated farmers	**$ATE0_W$**	0.73 (0.11)***	**ATE_S**	0.89 (0.05)***
Sample adoption rate	**JEA**	0.66 (0.28)***	**JAA**	0.66 (0.08)***
Adoption gap	**GAP_W**	-0.10 (0.02)***	**GAP_{WS}**	-0.26 (0.01)***
Population selection bias	**PSB_W**	0.01 (0.05)	**PSB_S**	-0.01 (0.03)

Notes: ** $P<0.05$; and *** $P<0.01$. Robust standard errors are shown in parenthesis.

Source: AfricaRice/NARI, Gambia Post Impact Assessment survey (2006/2010)

The ATE access to seeds model shows that if every rice farmer in The Gambia had been aware of the existence of NERICA and had had access to NERICA seeds prior to the 2010 survey, the adoption rate would have been 92% rather than 66%. This shows an adoption gap of 26 percentage points, which is statistically different from zero at the 1% significant level. In addition, when the ATE access to seeds model estimate is compared with the ATE exposure model estimate, the results show an adoption gap of 16 percentage points, which arises due to lack of access to NERICA seeds.

The actual adoption rate within the sub-populations of those who had been exposed to $(ATE1_w)$ and those who had had access to NERICA seeds $(ATE1_s)$ are almost exactly the same estimates as the potential adoption rate in the full population. This indicates that there is no significant population selection bias, which means that the sub-samples of farmers who had been exposed to or had had access to NERICA seeds and the farmers who were not exposed to or did not have access to NERICA seeds have the same probability of adopting NERICA. This is confirmed by the results of the expected population selection bias when using the within NERICA-exposed or seed access sub-sample, which is not statistically different from zero.

5.3 Determinants of Access, Exposure and Adoption of NERICA

This subsection explores factors influencing exposure of, access to, and adoption of NERICA seeds. The probit model used to estimate the effect of factors influencing exposure of, access to, and adoption of NERICA included fifteen explanatory variables. Table 4 presents a description of the explanatory variables used in the model with their definitions and summary statistics. The corresponding marginal effects of the variables estimated in the probit model are presented in Table 5. The marginal effects indicate that the influencing factors significant at 5% significance level are: age squared, off-farm labor, gender, farmer contact with extension services, practice of upland rice farming, access to credit, and residence in West Coast Region (WCR). Off-farm labor and gender reduce the probability of exposure to NERICA by 51% and 7%, respectively, whereas, farmer contact with extension, practice of upland rice farming, and residing in WCR increase the probability of exposure to NERICA by 6%, 39%, and 10%, respectively. Moreover, farmer contact with extension and practice of upland rice farming increase the probability of accessing NERICA seeds by 17% and 26%, respectively. Furthermore, access to credit and farmer contact with extension increase the probability of adopting NERICA by 14% and 12% respectively. These results are explained in more details below.

Farmer contact with extension has a significant influence on exposure of, access to, and adoption of NERICA seeds. This is not surprising given that NERICA is disseminated to farmers through extension outlets. Hence, it is expected that farmers who have contact with extension agents should know, access, and adopt NERICA. Moreover, the finding is consistent with the previous adoption literature and theories discussed in Section 2, namely that farmer contact with extension is a major source of information and influential in the adoption process.

Table 4. Definition and summary statistics of the explanatory variables used in the probit model

Variable	Definition	Min	Max	Mean	Std. Deviation
Age	Age of the respondent	20	90	49.95	13.97
Age squared	Respondent's age squared	400	8,100	2,689	1,489
Experience with upland farming	Respondent's years of experience in upland rice farming	0	29	11.68	10.99
Education (dummy)	1 if the respondent has attained formal education	0	1	0.09	0.28
Household size	Total number of people residing in the household	1	35	9.52	4.18
Off-farm labor (dummy)	1 if respondent has an occupation other than farming	0	1	0.13	0.34
Woman (dummy)	1 if the respondent is female	0	1	0.93	0.25
Association membership (dummy)	1 if the respondent is a member of an association	0	1	0.83	0.38
Log of rice area	Log of the household's total cultivated rice area	16.1	1.09	-1.60	3.33
Extension services (dummy)	1 if the respondent has contact with extension services	0	1	0.32	0.47
Access to in-kind credit (dummy)	1 if the respondent has received rice seeds through in-kind credit	0	1	0.23	0.42
NARI (dummy)	1 if the respondent has contact with the National Agricultural Research Institute	0	1	0.22	0.41
Upland farming (dummy)	1 if the respondent practices upland rice farming	0	1	0.78	0.42
Lowland farming (dummy)	1 if the respondent practices lowland rice farming	0	1	0.43	0.49
WCR (dummy)	1if the household is located in the West Coast Region	0	1	0.17	0.39
NERICA village (dummy)	1 if the household is located in a village where NERICA was disseminated	0	1	0.49	0.50
Number of valid observations		515			

Source: AfricaRice/NARI, Gambia Post Impact Assessment Survey (2006/2010)

Table 5. Probit model marginal effects of the factors affecting exposure, access to seeds, and adoption

Variables	Exposure		Access to seeds		Adoption	
	Marginal effect	z-value	Marginal effect	z-value	Marginal effect	z-value
Age	0.00	1.14	0.00	0.26	0.07	1.80
Age squared	-0.00	-1.39	-0.00	-0.47	-0.00**	-2.02
Experience	0.00	1.15	0.01**	2.11	0.02**	2.00
Education	0.05*	1.77	0.02	0.27	0.37	1.09
Household size	0.01**	2.24	0.01	1.02	-0.02	-1.17
Off-farm labor	-0.52***	-2.72	-0.24*	-1.68	0.26	0.36
Woman	-0.06***	-3.24	0.01	0.09	0.24	0.80
Association membership	-0.01	-0.31	-0.09	-1.86	-0.29	-1.40
Log of rice area	-0.03**	-2.40	-0.00	-0.80	-0.02	0.70
Extension services	0.06**	2.40	0.17***	4.17	0.52***	2.93
Access to in-kind credit	-0.00	-0.05	0.11**	2.41	0.50**	2.31
NARI			0.11**	2.48		
Upland farming	0.37***	5.19	0.25***	4.37		
Lowland farming	-0.00	-0.20	0.02	0.39		
WRC	0.09***	4.02	0.08	1.48		
NERICA village	0.02	0.90	0.08**	1.94		
Number of observations	515		515		515	
Pseudo R^2	0.36		0.14		0.09	
LR chi^2	121.09***		86.07***		32.90***	
Log likelihood	-107.22		-262.15		-165.72	

Notes: *P<0.10, ** P<0.05 and *** P<0.01
Source: AfricaRice/NARI, Gambia Post Impact Assessment survey (2006/2010)

Access to credit[13] significantly influences NERICA adoption. The NERICA seeds were initially given to farmers by extension agents through in-kind credit, which is repaid at the end of the production season. Since access to seeds is a prerequisite for adoption, we would expect it to significantly influence farmers' decision to adopt NERICA. As discussed in the theoretical section, the cost of a new technology is one

13 Access to credit in this study simply refers to credit received in-kind. Since NERICA seeds are more expensive than other rice varieties most farmers can only afford it when it is given to them as credit in-kind, which is repaid after harvest. Hence, we measured the variable as a dummy. If a farmer received NERICA seeds on credit, it is indicated as 1 and 0 otherwise.

of the most important factors limiting its adoption. For this reason, it is important for farmers to access in-kind credit services to cover the cost of production. This further explains the significance of credit access in influencing the decision to adopt NERICA.

Residing in a NERICA village has a significance influence on access to NERICA seeds. At the initial phase of the NERICA seed dissemination project, only a few NERICA villages were selected as pilot areas for testing NERICA within various agricultural regions. These villages were then able to access NERICA seeds based on in-kind credit services from the project. The seeds provided by the project were initially tested on communal lands. For this reason, farmers living in NERICA villages are more likely to gain access to NERICA seeds. Moreover, the significance of age squared in the probit adoption model suggests a possible non-linear relationship between age and NERICA adoption. The results show that as farmers grow older, their probability of adopting NERICA decreases significantly. This is consistent with adoption theories discussed in Section 2, which found that younger farmers are more likely to adopt new technologies.

The practice of upland rice farming is a significant determinant of both exposure of and access to NERICA seeds. This is another expected result, because the NERICA varieties introduced to farmers in The Gambia are thus far only upland rice varieties. As a result, we would expect that farmers practicing upland rice cultivation to be more likely to gain knowledge of the existence of NERICA and more likely to have access to NERICA seeds. However, contrary to expectation, the years of experience with upland rice farming is not significant in determining the exposure to NERICA. Most of the rice growing villages that practice upland farming began upland rice farming with the introduction of NERICA. Since most of the farmers had no experience with upland rice cultivation before the introduction of NERICA, it should be understandable why the number of years of experience is not significant in determining exposure to NERICA. We also found that farmers from the WCR and those who have had contact with the NARI are more likely to be exposed to or have access to NERICA. This was expected because NERICA seed dissemination activities in The Gambia are coordinated by the NARI and its main station is in the WCR.

Contrary to expectations, farm size and off-farm labor have a negative influence on exposure to NERICA. As discussed in Section 2, new technologies come with additional cost, which means that they are more affordable to wealthier farmers. As a result, it was expected that farm size and income from off-farm labor would have a positive influence on exposure to and the adoption of NERICA. However, since most rice farmers practicing off-farm labor are more likely to take up rice farming as a secondary activity, they may be less likely to be aware of the existence of NERICA compared to farmers whose main activity is rice farming. Moreover, the fact that the majority of rice producers in The Gambia are smallholder farmers may result in the insignificant correlation between farm size and adoption.

The literature on adoption suggests that associations are a main source of information about new technologies for farmers (FEDER and SLATE, 1984; CASWELL et al., 2001). Despite the importance of associations in the adoption process, we found no correlation between association membership and our variables of interest. This is very surprising and contradicts KIJIMA and SSERUNKUUMA'S (2013) findings in Uganda. The majority of village associations in The Gambia are informal. Membership is open to all the villagers and there are no rules and regulations on how the associations are governed. Farmers do not meet on regular basis to share information. This could be a reason for the insignificant correlation found in this study. On the other hand, the significant effect of membership in farmers' groups on adoption found in Uganda may be attributed to the fact that farmers' groups are well-organized and membership is not open in Uganda.

Finally, the negative relationship between gender and awareness of NERICA found in the exposure model suggest possible form of gender bias in the way information about the NERICA technology has been disseminated in The Gambia. Upland NERICA is mainly cultivated in farmlands that were originally used by men to grow cash crops like groundnut and cotton. Therefore, most of the resources required for the cultivation of NERICA are under the control of men. As a results, when NERICA was introduced in The Gambia, men began to shift into rice cultivation, which was almost entirely an activity undertaken by women before the introduction of NERICA. Therefore, extension efforts to disseminate NERICA may have been biased against women by targeting men, who owned and controlled most of the resources required for the cultivation of NERICA. This finding is consistent with the observation made by CARNEY (1998) that there was a shift of resources from women to men with the development of pump-irrigated rice projects in The Gambia. This may have been facilitated by extension services who were responsible for the dissemination of project resources to target groups. Moreover, DIAGNE (2010) observes that the NERICA lines that were selected for release and seed multiplication in Guinea may have been those that satisfied mostly the varietal preferences of male Guinean rice farmers.

6 Conclusions

The sample adoption rate is not a consistent estimate of the population adoption rate when technology awareness and access are incomplete in a given population. Due to non-exposure and access biases, it excludes the adoption rate of non-adopting famers who may have adopted the technology provided that they had known about or had had access to the technology. Hence, the sample adoption rate is likely to underestimate the true population adoption rate. When the bias resulting from a lack of technology awareness is addressed, the results of the framework based on ATE indicate that the NERICA adoption rate could have been 76% instead of the observed 66% sample estimate provided that every rice farmer in The Gambia had been aware of the existence of NERICA varieties before the survey was conducted in 2010. However, given that awareness is not a sufficient condition for adoption, further investigation finds that if all the rice farmers in The Gambia had been aware of and had access to NERICA seeds, adoption would have been 92%. This indicates a population adoption gap of 26 percentage points revealing that if awareness had not been a constraint, 16% of the farmers would have failed to adopt NERICA due to lack of access to NERICA seeds.

Separate ATE parametric models identified influencing factors of exposure of, access to, and adoption of NERICA. Based on the significant relationship between these outcomes variables and farmer contact with extension, NARI and access to in-kind credit, we conclude that for NERICA to reach its full adoption potential, the important role of extension services cannot be neglected. Hence, concerted efforts should be undertaken to increase farmers' contact with extension, especially in the CRS which has been found to be the region with the least exposure and access to NERICA. To achieve greater adoption, any effort to increase farmer contact with extension should involve NARI, which is also a significant determinant of access to NERICA seeds. Involving NARI will also strengthen collaboration among research, extension, and farmers, which is vital for the successful dissemination and adoption of any agricultural technology. Moreover, the negative correlation between female gender and awareness of NERICA indicates the need to give women more access to upland resources.

The insignificant population selection bias is a striking finding. The finding contradicts the positive selection bias theory discussed in Section 4. However, it is consistent with past findings (DIAGNE, 2010; DIBBA et al., 2012; DIAGNE et al., 2012) on NERICA adoption. The finding means that targeting more villages within rice growing communities of The Gambia is likely to increase NERICA adoption rate. For this reason, more NERICA introduction villages can be created by disseminating seeds to farmer groups. Since farmer access to in-kind credit service is a significant determinant of access to and adoption of NERICA, efforts should be made to enhance farmers' access to credit as this will enhance access to NERICA seeds and the adoption thereof.

The policy implications of the research findings are to improve both awareness of and access to NERICA in order to significantly reduce the adoption gap. This is important given that rice is the main staple crop and thus improvements in its production through the adoption of high yielding rice varieties are necessary for the country to be food secure (WORLD BANK, 2007). Policies directed towards creating awareness will only close the adoption gap by 10 percentage points. This will leave a significant gap of 16% that can be addressed by policy measures to improve access to NERICA seeds throughout the country. Hence, there is a need to improve the capacity of extension services by either increasing the number of extension workers within rice growing communities and/or providing more motorbikes to allow greater mobility for the few extension workers posted in remote villages. Not only will this increase awareness but this will also enable extension workers to redistribute NERICA seeds from high production areas to places with low accessibility. Another major policy implication from this research is to expand in-kind credit services to rice farmers, especially among the rural poor, to enable them gain more access to NERICA seeds. Improving the conditions of roads that link remote villages to rural markets can also enable rice farmers to more easily acquire NERICA seeds.

Finally, as NERICA approches its full potentials adoption rate, the use of binary outcome indicators to measure the potential adoption rate will be less meaningful. The study by DIBBA et al. (2012) estimated a NERICA adoption gap of -43% between the sample adoption rate and the potential adoption rate in The Gambia. Similarly, DONTSOP et al. (2013) finds an adoption gap of -43% between the NERICA sample adoption rate and the potential adoption rate in Nigeria. However, our study reveals a much lower NERICA adoption gap of -26% between the sample adoption rate and the potential adoption rate in The Gambia. This indicates that as more farmers know the existence of NERICA and have access to NERICA seeds, the adoption gap will continue to reduce significantly. As a result, subsequent studies that try to determine the NERICA adoption gap may find an insignificant difference between the actual adoption rate and the potential adoption rate. Hence, a more meaningful measure of adoption would be the determination of the intensity of adoption, measured by the share of land area allocated to NERICA by farmers.

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Acknowledgements

The authors are grateful to the Global Rice Science Partnership (GRiSP) program and Africa Rice Center (AfricaRice) for their financial and technical support rendered for the successful implementation of this research project. The technical support provided by the University of Hohenheim is also highly acknowledged.

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