Estimation of Actual and Potential Adoption Rates and Determinants of NERICA Rice Varieties in Nigeria

Abstract

The article uses the Average Treatment Effect (ATE) to estimate the population potential adoption rates of New Rice for Africa (NERICA) varieties in Nigeria when awareness of the new varieties and access to their seed are not constrained to farmers. It thus extends previous works in the literature which have focused on estimating potential adoption rates when only awareness of the technology is not a constraint to farmers. The adoption gaps due to lack of awareness and access to seed, and the determinants of adoption are estimated as well. Results show that NERICA adoption rate in Nigeria would have been up to 54% if the whole population were aware and up to 62% if they had access to NERICA variety seed. The actually observed 19% adoption rate implies a population adoption gap of 35% and 43% due to lack of awareness and access to NERICA seed respectively. It is also inferred from these results that when awareness is not a constraint, about 8% of the population will fail to adopt NERICA because of lack of access to its seed. Also famers with secondary education and farmers with access to extension services are more likely to adopt NERICA than farmers without.

Keywords: Awareness, Access to seed, NERICA adoption, Average Treatment Effect, Nigeria

JL classification code: *C13, O33, Q12, Q16*

1. Introduction

Rice has become an important economic crop and the major staple food for millions of people in Sub-Saharan Africa in general, and Nigeria in particular (WARDA, 2006). As a major player in the international rice market, Africa accounted for 32 per cent of global imports in 2006, with a recorded quantity of nine million tonnes (Africa Rice Centre, 2008). Africa's emergence as a major rice importer is explained by the fact that during the last decade, rice has become the fastest growing food source in Sub-Saharan Africa (SSA) (Solh, 2005; Seck et al., 2010). Indeed, due to population growth (4% per annum), rising incomes, and a shift in consumer preferences in favor of rice, especially in urban areas (Balasubramanian et al., 2007), the relative growth in demand for rice is faster in this region than anywhere else in the world (Seck et al., 2010).

In Nigeria, the demand for rice has been increasing at a much faster rate than the rest of SSA since the mid-1970s. For instance, during the 1960s, Nigeria had the lowest per-capita annual consumption of rice in the West Africa sub-region (average of 3 kg). Since then, Nigeria's per-capita consumption levels have grown significantly at 7.3 per cent per annum. Consequently, during the 1980s, per-capita consumption averaged 18 kg, reached 22 kg in 1995-1999, and 27 kg by 2007. During this period, self-reliance decreased from 87.4 per cent to 71 per cent (NBS, 2007). Despite the increase in per-capita consumption, Nigeria's overall consumption is still lower than the rest of the sub-region (34 kg in 1995-1999). Estimated annual rice demand for Nigeria in 2009 was five million tonnes, while production averaged about 2.21 million tonnes. The national rice supply-demand gap of 2.79 million tonnes was expected to be bridged by importation (NRDS, 2009) which resulted in a serious drain on the nation's foreign exchange reserves.

Notwithstanding the above scenario, rice production in Nigeria has been expanding at a rate of 6 per cent per annum in the last few years. Of this increase, 70 per cent is mainly attributed to land expansion, and only 30 per cent to improvement in productivity (Falusi, 1997; Fagade, 2000; Okoruwa et al., 2007; WARDA, 2007; AfricaRice, 2008). Much of the expansion has been particularly in the upland and rainfed lowland systems that make up 95 per cent of rice land in Nigeria (Erenstein et al., 2003).

Yet, since area expansion and irrigation have already become a minimal source of output growth at a world scale, agricultural growth will increasingly depend on yield-increasing technological change (Hossain, 1989). The adoption of new agricultural technology, such as the High Yielding Varieties (HYV) 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 (World Bank, 2008). In this regard, in Bangladesh, Mendola (2007) had observed that the adoption of HYV had a positive effect on household wellbeing while Diagne, (2006b) showed that adoption of improved varieties such as NERICA increased farmers' productivity in Cote d'Ivoire.

To overcome the challenges facing by rice farmers in upland ecologies, AfricaRice (Ex-WARDA) developed the New Rice for Africa (NERICA) which is an interspecific hybrid between the local African rice (*Oryza glaberrima)* and the Asian rice (*Oryza sativa*). It offers new opportunities for upland rice farmers and was considered by some researchers as "Bred for woman rice farmers" (Diagne, 2006b). NERICA varieties have unique characteristics such as shorter duration (they mature between 30 and 50 days earlier than traditional varieties), higher yield, tolerance to major stress, higher protein content, and good taste compared to traditional rice varieties (Jones et al., 1997; Dingkuhn et al, 1998; Audebert et al, 1998; Johnson et al., 1998; Dingkuhn et al., 1999; Wopereis et al., 2008). NERICA varieties have also been reported to have stable yields under different management conditions, and their introduction into fields was considered as a first step towards the stabilization and sustainable intensification of Africa's fragile upland rice (Somado et al., 2008). NERICA varieties were officially introduced through PVS trials in all West African countries, including Nigeria and have been adopted by rice farmers since then (WARDA, 2005).

To further enhance the adoption of NERICA varieties, and increase the production level of rice, Nigeria adopted several development initiatives. These included the African Rice Initiative (ARI) which was established in 2002 to promote the dissemination of NERICA varieties in several SSA countries, and the Presidential Initiative on Increased Rice Production, Processing and Export launched in 2003 by the Federal Government of Nigeria[1]. After about 6 years of dissemination and implementation of the initiatives, not much is known about the level of awareness (knowledge), access to seed and adoption of NERICA varieties among rice farmers in Nigeria. Therefore, the empirical questions in this study are: (1) what are the actual and potential levels of adoption of NERICA varieties in Nigeria? (2) What are the factors affecting the adoption of NERICA varieties in Nigeria? and (3) what are the determinants of awareness and access to seed of NERICA varieties among rice farmers in Nigeria?

Most studies have assessed the adoption rate of new technology or programmes by simply computing the percentage of adopters from the sample (for example Sall et al., 2000, Ransom et al., 2003, Ajibola et al., 2005, Saka et al., 2005). This approach suffers either from what we

[1] See Figure 2 in the Appendix for stages in the dissemination and adoption of NERICA varieties in Nigeria.

call “non awareness” bias or from "selection bias. As a consequence, they generally yield biased and inconsistent estimates of population adoption rates even when based on a randomly selected sample. To solve this problem, Diagne (2006, 2010) and Diagne and Demont (2007) have used the Average Treatment Effect (ATE) framework of modern evaluation theory (Heckman and Vytlacil, 2005; Imbens and Wooldridge, 2009) to estimate the potential adoption rate when the population’s awareness of the technology is complete. However, as pointed out by Diagne (2010), the potential adoption rate based on awareness alone still underestimates the true potential adoption rate of a new technology. This is because being aware alone is not enough for adoption. One may be aware but have no access to the innovation -in our case, NERICA seed. Access to seed of the new variety thereby becomes an important factor for its adoption. This study extends the work of Diagne (2006, 2010) and Diagne and Demont (2007) on the problem of estimation of the true potential adoption rates by considering both lack of awareness and access as constraints to technology adoption. The study estimates the awareness and awareness-and-access-unrestricted potential adoption rates of NERICA varieties as well as the associated adoption gaps and the determinants of awareness, access to NERICA seeds and adoption.

2. Methodology

To consistently estimate the true NERICA population adoption rate and its determinants in Nigeria, we followed the approach of Diagne (2006, 2010) and Diagne and Demont (2007) and used the Average Treatment Effect (ATE) estimation framework (see for example Imbens, 2004 for a review). Classical approaches to the estimation of the determinants of adoption such as probit, logit and tobit models would yield biased and inconsistent estimates even when based on a randomly selected sample.

As pointed out by Diagne and Demont (2007) this approach is necessary because commonly used estimators of adoption rates suffer from either what is known as “non-awareness” bias or from “selection bias”, and yield based and inconsistent estimates of population adoption rates and effects of their determinants. The non-awareness bias makes observed sample adoption rates systematically underestimate the population potential adoption rates even if the sample is random. The biases do not vanish unless the full population is aware of the technology or awareness is distributed randomly in the population. Furthermore, the selection bias that results from the fact awareness is not likely to be randomly distributed in the population makes the sample adoption rate among the aware farmers to systematically overestimate or underestimate the true population potential adoption rates. Both types of biases render the coefficients of classical adoption models inconsistent. The true population adoption rate corresponds to what is defined in the treatment effect literature as the average treatment effect (ATE), which measures the effect of a "treatment" (NERICA varieties in this case) on a person randomly selected from the population (Diagne, 2006). Similarly, the adoption rate among the aware farmers corresponds to the average treatment effect on the treated (ATT) and the potential adoption rate among the non-aware-farmers to the average treatment effect on the untreated (ATU).

However, one can argue that apart from lack of awareness considered by Diagne (2006, 2010) and Diagne and Demont (2007), there is another constraint which is lack of access to seed. In fact, a farmer can be aware of NERICA varieties, but as long as s/he does not have access to NERICA seed, s/he cannot become an adopter. Awareness and access to seed are therefore both necessary conditions for adoption. Furthermore, while a farmer can be aware of NERICA varieties without having access to their seed, he or she cannot have access to NERICA seed without being aware of the existence of NERICA varieties (see figure 1).

It is important to note that access referred to here is the physical availability of the seed and not the acquisition availability. To obtain the access variable, information on all possible varieties present in the village was collected through the focus group discussion organized at the village level (stage 1 of figure 1). At the producers' level, farmers were first asked about all the varieties they knew from the village varieties' list including NERICA (stage 2 of figure 1). At the third stage, for those who reported having knowledge of NERICA (that is $w = 1$), the following specific question where asked: "Could you access the seed of NERICA within the village? Outside the village? And from where? (other farmers or relatives in the village, farmers or relatives of the other village, ADPs, NCRI, NGOs or farmers organization, and so forth)". If the farmer indicates that s/he could get seed from one of the sources mentioned, s/he was considered as having access to seed (that is $s = s_1 = 1$). Otherwise the farmer is considered as not having access to seed (that is $s = s_1 = 0$). Furthermore, when a farmer responded that s/he does not know about NERICA (that is $w = 0$), s/he was not asked the questions about access to seed. This means that for the farmers who are not aware we do not have information about their access to seed status. It is important to note, however, that some of these unaware farmers may actually have access to NERICA seed even though they are not aware of its existence. This can be the case for example when the variety is present in the village but the farmer is not aware or the variety is present in the same store where the farmers buy other varieties but s/he does not know. In addition, we cannot know the access to NERICA seed status of these unaware farmers even if we asked them that question as they would not have been able to tell us since they are not aware of their existence. However, for both aware and non-aware farmers we know the value of the product ws because even for non-aware farmers which we cannot know the value of s, $ws = 0$ since $w = 0$. Hence in summary, for all farmers we know the value of w and ws and it is only for aware famers that we know the value of s[2].

For these reasons, access to seed implies awareness, with the consequence that the awareness-and-access-unrestricted population potential adoption rate is always greater than or equal to the awareness-unrestricted one. In what follows, we extent the ATE adoption framework of Diagne (2006, 2010) and Diagne and Demont (2007) to estimate both the awareness-unrestricted and the awareness-access-unrestricted NERICA population potential adoption rates and the associated adoption gaps in Nigeria as well as the determinants of NERICA awareness, access and adoption.

Following Diagne and Demont, (2007), we use a potential outcome framework of Rubin (1974) in which every farmer in the population has theoretically four potential adoption outcomes: an outcome with awareness and access to seed say y_{11} (that is y_{11} is the outcome when $w = 1$ and $s = s_1 = 1$), an outcome when aware but do not have access y_{10} (that is y_{10} is the outcome when $w = 1$ and $s = s_1 = 0$), an outcome with no awareness but access y_{01} (that is y_{01} is the outcome when $w = 0$ and $s = s_0 = 1$) and an outcome with no awareness and no access y_{00} (that is y_{00} is the outcome when $w = 0$ and $s = s_0 = 0$). Hence the observed adoption outcome y can be expressed in terms of the four potential adoption outcomes as:

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[2] However, it is noteworthy to mention that in some cases awareness and access are not always sequential as they appear in the chart, but they are rather simultaneous (that is the farmer know about the variety at the moment s/he is obtaining its seed) and in some cases, the reverse sequence is the case (for example, the seed maybe at the reach of the farmer say in the same shop where s/he acquire other varieties but s/he does not know about its existence ($s = s_0 = 1$)). Hence access may precede awareness.

$$y = wsy_{11} + w(1-s)y_{10} + (1-w)sy_{01} + (1-w)(1-s)y_{00} \qquad (1)$$

Since awareness and adoption is a necessary condition for adoption, we have $y_{10} = y_{01} = y_{00} = 0$. Hence equation (1) simplifies to:

$$y = wsy_{11} \qquad (2)$$

Since the potential outcome is always 0 when the farmer is not aware or does not have access, the potential outcome y_{11} is the treatment effect of a given farmer when treatment is having the farmer both being aware and having access. The average treatment effect of awareness and access is then given by the expected value $E(y_{11})$.

Now, if we consider awareness as treatment and access to seed as outcome, every farmer has ex-ante two potential outcomes with respect to access to seed: when s/he is aware[3] of NERICA (s_1) and when s/he is not aware (s_0). Letting *w* be the binary variable which takes the value 1 if the farmer is aware of NERICA varieties and 0 otherwise, we can write the observed access to seed outcome *s* as function of awareness and the two access-to-seed potential outcomes as:

$$s = ws_1 + (1-w)s_0 \qquad (3)$$

Equation (3) implies that $ws = ws_1$ leading to $y = wsy_{11} = ws_1 y_{11}$.

Now let us define the awareness-unrestricted potential adoption status y_1^* as:

$$y_1^* = sy_{11} \qquad (4)$$

Similarly, the access-unrestricted potential adoption status y_1^{**} is defined as:

$$y_1^{**} = wy_{11} \qquad (5)$$

[3] The awareness variable in this article accounts only for the mere knowledge of the existence of the NERICA varieties. In other words, it only indicates whether or not the farmer is aware of the existence of the technology. This does not necessarily imply any knowledge of the characteristics of the technology. Hence, our definition of awareness is conceptually different from that of Dimara and Skuras (2003) and is closer to that of Saha *et al.* (1994) with the difference that we do not assume that awareness is the result of some optimization process of a potential adopter.

It is important to note that the average treatment effect of awareness and access as measured by the expected value $E(y_{11})$ is the potential adoption rate when the full population is aware and has access to NERICA seed and is different from the one defined and estimated in Diagne (2006, 2010) and Diagne and Demont (2007) which is the potential adoption rate when the full population is aware. It is easily seen that in this paper's notation, the latter population potential adoption rate is given by the parameter $E(y_1^*)$, which is the average treatment effect of awareness on adoption. These two population potential adoption rates are different from the population potential adoption rate when the full population has access (with some not necessary being aware) which is measured by the parameter $E(y_1^{**})$, which is the average treatment effect of access to seed on adoption. To distinguish the three population potential adoption rates, the parameter $E(y_{11})$ will be called awareness-access to seed-unconstrained population potential adoption rate while the $E(y_1^*)$ and $E(y_1^{**})$ will be called the awareness-unconstrained and access-unconstrained population potential adoption rates, respectively.

It is clear from equations (3)–(5) above that the observed population adoption rate $E(y)$ parameter (which is consistently estimated by the sample adoption rate computed from a random sample) is in fact a measure of the population joint awareness-access and adoption rate (which is the same as the population joint awareness, access to seed and adoption rate as $E(y) = E(wsy_{11})$) and not a measure of the population joint awareness and adoption $E(wy_{11})$ rate as argued in Diagne (2006, 2010) and Diagne and Demont (2007). Hence, in what follows we will use the notation JEAA (standing for joint awareness-access and adoption) for the observed population parameters $E(y)$ instead of the notation JEA (standing for joint exposure and adoption) used in Diagne (2006, 2010) and Diagne and Demont (2007). It is also clear from above that $E(y) \leq E(y_1^*) = E(sy_{11}) \leq E(y_{11})$ and $E(y) \leq E(y_1^{**}) = E(wy_{11}) \leq E(y_{11})$ (since *w* and *s* are binary), meaning that the awareness- unconstrained and access-unconstrained population potential adoption rates are both greater than the observed actual population adoption rate but always lower than the awareness-access to seed-unconstrained population potential adoption rate[4].

[4] However, we cannot theoretically determine which one between the *awareness- unconstrained* and the *access-unconstrained* population potential adoption rate is greater. This is an empirical question.

Diagne (2006, 2010) and Diagne and Demont (2007) have defined the adoption gap due to lack of awareness as the difference between the observed adoption rate and the population potential adoption rate. We can similarly define three adoption gaps with one due to lack of awareness and access to seed (equation 6), the others due to lack of awareness (equation 7) and lack of access to seed (equation 8) as follow:

$$GAP_{ws} = E(y) - E(y_{11}) = JEAA - ATE_{ws} \qquad (6)$$

$$GAP_{w} = E(y) - E(y_1^*) = JEAA - ATE_{w} \qquad (7)$$

$$GAP_{s} = E(y) - E(y_1^{**}) = JEAA - ATE_{s} \qquad (8)$$

Where ATE_{ws} (resp. ATE_w, ATE_s) is the average treatment effect parameter when awareness and access to seed (resp. awareness, access to seed) is the treatment variable. Because $ATE_w \leq ATE_{ws}$ and $ATE_s \leq ATE_{ws}$ as shown above, the adoption gap due to lack of awareness and access to seed is always smaller in absolute value than both the gap due to lack of awareness and the adoption gap due to lack of access to seed.

With the ATE estimation framework, the awareness-unrestricted, the access-unrestricted and the awareness-access-unrestricted potential adoption rates can be defined for various sub-populations defined by the values x in the support of some random variable X as the average treatment effects conditional on x, $E(y_{11}|X = x)$; $E(y_1^*|X = x)$ and $E(y_1^{**}|X = x)$ respectively (the conditional ATE parameters). In particular, the potential adoption rates in the sub-population with access to NERICA seed, in the subpopulation aware of NERICA and in the subpopulation aware and have access to NERICA seed correspond to the average treatment effect on the treated (ATT) parameters and they are given as follow:

$$ATT_s = E(y_1^{**}|s = 1) \qquad (9)$$

$$ATT_w = E(y_1^*|w = 1) \qquad (10)$$

$$ATT_{ws} = E(y_{11}|w = 1, s = s_1 = 1) \qquad (11)$$

Likewise, the potential adoption rates in the sub-population without access to NERICA seed, that is not aware of NERICA and the subpopulation not aware and not having access to seed are given by the respective average treatment effects on the untreated (ATU) as follow:

$$ATU_s = E(y_1^{**}|s = 0) \quad (12)$$

$$ATU_w = E(y_1^{*}|w = 0) \quad (13)$$

$$ATU_{ws} = E(y_{11}|w = 0, s = 0) \quad (14)$$

Furthermore, as in Diagne (2006, 2010) and Diagne and Demont (2007) we will define the awareness, access to seed and awareness-access to seed Population Selection Bias (PSB) parameters that measure the extent to which awareness and access to seed are not randomly distributed in the population as, respectively:

$$PSB_w = ATT_w - ATE_w = E(y_1^{*}|w = 1) - E(y_1^{*}) \quad (15)$$

$$PSB_s = ATT_s - ATE_s = E(y_1^{**}|s = 1) - E(y_1^{**}) \quad (16)$$

$$PSB_{ws} = ATT_{ws} - ATE_{ws} = E(y_{11}|w = 1, s = s_1 = 1) - E(y_{11}) \quad (17)$$

Following Diagne (2010) and Diagne and Demont (2007), we use the average treatment effect (ATE) estimation framework to provide consistent estimates of $E(y_1^{*})$ and $E(y_{11})$, the awareness-unrestricted and awareness-access-unrestricted population potential adoption rates, respectively. In fact, both parameters are identified and estimated exactly the same way except that for the case of $E(y_{11})$ we use the ws (awareness and access) variable instead of the *w* (awareness) variable. Undeniably, although the variable s is only observed for the aware farmers (that is for farmers with $w = 1$), the product ws is known for all farmers as shown above. For identification, we assume that the conditional independence assumption (also known as "selection on observables") holds in both cases. More precisely, it is assumed that the distributions of the treatment status variables *w* and *s* are independent each of the distribution of the potential outcome y_{11} conditional on a vector of covariates *x*. That is, using the standard notation for conditional independence: $w, s \perp y_{11} \,|\, x$ (A1)

By the propriety of conditional independence, assumption (A1) also implies that that

$$w \perp y_1^{*}|x$$

Therefore we can use the same identification results and estimation procedures as in Diagne (2006, 2010) and Diagne and Demont (2007) to identify and estimate the awareness-unrestricted and access-unrestricted population potential adoption parameters and their associated adoption gaps and population selection bias. Below we focus on the parametric estimation procedure of ATE.

2.1 Parametric estimation of ATE

The parametric estimation procedure of ATE is based on the following equation that identifies *ATE*(*x*), and holds under the conditional independence assumption (see Diagne and Demont 2007):

$$ATE\left(x\right) = E\left(y_1^* \middle| x\right) = E\left(y \middle| x, d = 1\right) \qquad (18)$$

Where $(d, y_1^*) = (s, y_1)$ when access to seed is the treatment variable and $(d, y_1^*) = (w, s_1 y_1)$ when awareness is the treatment variable. The parametric estimation proceeds by specifying a parametric model for the conditional expectation in the right hand side of the second equality of equation (12) which involves the observed variables *y, x, and d*:

$$E\left(y \middle| x, d = 1\right) = g\left(x, \quad\right) \qquad (19)$$

Where g is a known (possibly non-linear) 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 $\left(y_i, x_i\right)$ from the sub-sample of farmers that are aware and have access to seed only with *y* as the dependent variable and *x* as the vector of explanatory variables. With an estimated parameter $\hat{\ }$, the predicted values $g\left(x_i, \hat{\ }\right)$ are computed for all the observations *i* in the sample (including the observations in the non-access sub-sample). ATE, ATT and ATU are estimated by taking the average of the predicted $g\left(x_i, \hat{\ }\right) i = 1,\ldots,n$ across the full sample (for ATE) and respective sub-samples (for ATT and ATU):

$$A\hat{T}E = \frac{1}{n}\sum_{i=1}^{n} g\left(x_i, \hat{\ }\right) \qquad (20)$$

$$A\hat{T}T = \frac{1}{n_1}\sum_{i=1}^{n} d_i g\left(x_i, \hat{}\right) \quad (21)$$

$$A\hat{T}U = \frac{1}{n-n_1}\sum_{i=1}^{n}(1-d_i)\, g\left(x_i, \hat{}\right) \quad (22)$$

Where *n* is the sample size and $n_1 = \sum_{i=1}^{n} d_i$ is the sample number of treated. 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:

$$\frac{\partial E\left(y_1 | \bar{x}\right)}{\partial x_k} = \frac{\partial g\left(\bar{x}, \ \right)}{\partial x_k} \quad k = 1, ..., K \quad (23)$$

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

All the estimations were done using the statistical package Stata, with the Stata add-on *adoption* command developed by Diagne and Demont (2007) to automate the estimation of ATE adoption models and related statistical inference procedures. The adoption command is a Stata add-on command that works like standard Stata regression commands. It uses various Stata standard estimation commands internally to implement the estimation procedures described above and provides estimates of ATE, ATT, ATU, JAA, GAP and PSB. We also estimate using the same command the determinants of the probability of a farmer being aware of NERICA and the probability of s/he having access to its seed (the propensity scores).

2.2 Dissemination of new rice for Africa varieties in Nigeria

The NERICA varieties were first introduced to Nigerian rice farmers in 1999 through a three-year Participatory Varietal Selection (PVS) trials programme in both upland and lowland ecologies. During the first year, a centralised village plot was identified with local farmers where a rice garden was established by WARDA (now AfricaRice) with up to 60 rice varieties, including local/traditional, improved and interspecific varieties. After the site's selection, men and women rice farmers were invited to visit the plot as frequently as possible. However, official plant evaluations were held at three major stages of production. At the first stage (maximum tilling), the preferred plant architecture at vegetative stage was derived from farmers' interviews. At the second stage (grain filling), panicle type, plant height, cycle length and other agronomic and morphological traits were identified. At the final stage (post-harvest), the focus was on grain quality attributes, including size, shape, shattering, ease of threshing, and yield (Spencer et al., 2006).

During the three visits at different stages of production in the first year, varietal selections were recorded for each farmer and at the end of the season each farmer's choices were analysed. Based on the analysis, each farmer received in the second year up to 6 of the varieties s/he selected in the first year. At the end of the second year, farmer's evaluations of the ease of threshing and taste were elicited to provide a full view of the variety's strengths and weaknesses. In addition, they were asked to purchase any additional seed they required in the third year to provide an indication of their willingness to pay for seed of the new variety. During the third year, activities included the supply of small quantities of seed to local communities and seed companies for multiplication, publicity and training.

By 2002, a full set of upland PVS trials were conducted in 11 States of the Federation. Following this, independent evaluation of top varieties that had shown adaptability and acceptability across the country was carried out by the National Rice/Maize Centre of the Federal Ministry of Agriculture. For this exercise, five varieties[5] were evaluated in 21 States. Based on the results of this national field evaluation, the Ministry of Agriculture and the Centre recommended the official release of three varieties[6] to farmers in 2003. By 2004, WARDA upland rice variety dissemination work under the Gatsby Foundation project therefore covered a total of 21 most important rice growing states in Nigeria. NERICA 1 was officially released in 2003 and NERICA 2 in 2005.

Two major initiatives were undertaken after 2003 to accelerate the dissemination of NERICA in Nigeria. The first was the Presidential Initiative on Increased Rice Production, Processing and Export launched in 2003 by the Federal Government of Nigeria. The second was the Multinational NERICA Dissemination Project (MNDP) funded by the African Development

[5] WAB 450-1-B-P38-HB, WAB 450-11-1-B-P31-HB, WAB 450-1-B-P160-HB, WAB 189-B-B-B-8-HB and ITA 321.

[6] The varieties released included WAB 189-B-B-B-8-HB (FARO 54), WAB 450-1-B-P38-HB (NERICA 1), and ITA 321(FARO 53).

Bank and implemented under the African Rice Initiative (ARI) which started in 2005. A total of 328 NERI-Boxes[7] capable of planting 82 ha were distributed to rice farmers' groups in all participating states. Periodic monitoring visits were jointly undertaken by the Project Coordination Unit (PCU), the National Agricultural Seed Council (NASC), the National Cereals Research Institute (NCRI) and officials of the Rice Farmers Association of Nigeria (RIFAN) to guide the participating states on sound seed multiplication techniques, such as the maintenance of adequate isolation distance, rouging of off-types and good crop husbandry. Also, 71 rice farmers' groups were formed involving a total of 657 farmers, including 259 women farmers (FMARD, 2006). In terms of seed quality control, NCRI was involved in training the Agricultural Development Programmes (ADPs) staffs on seed production techniques that assure good NERICA seed quality production. Furthermore, several farmers' field days around the NERICA seed multiplication plots were organized at the states level. These were used to create informal contacts and learning for accelerated multiplier effect among farmers (FMARD, 2006).

However, it should be noted that despite these major initiatives to push NERICA adoption in Nigeria, many states were not covered by the PVS trials and the NERICA dissemination activities. Moreover, in states covered, only very few villages were involved in the trials and the project activities. However, farmer-to-farmer dissemination of NERICA varieties has occurred in many of the villages not covered by the PVS trials and other project activities.

Since its introduction many studies have been carried out to assess NERICA in Nigeria and elsewhere in Africa. Somado et al. (2008) reported that under farmer conditions, where minimal inputs are applied, the NERICA varieties have raised the yields of upland rice by more than 50 per cent. Specifically, NERICA varieties yield more than 1.5 metric tonnes per ha. The potential yield under farmers' conditions is more than 5.7 metric tonnes per ha, where fertilizer and other inputs are applied. Empirical studies carried out both in Nigeria and other countries in Africa have shown that NERICA adoption has positive impact on yield, income and poverty (Diagne, 2006; Adekambi et al., 2007; Kijima et al., 2008; Dontsop Nguezet et al., 2011).

[7] NERI-Box is a NERICA rice production technology pack designed with the needs of the rural farmer in mind. It bundles all the inputs a farmer requires to crop one quarter of a hectare.

3. Data and descriptive statistics

The data used in this study is based on a survey conducted in 2008/2009[8]. The survey covered the three rice ecologies in Nigeria where NERICA dissemination activities were being conducted: Rainfed upland, Rainfed lowland, and Irrigated. The states of Osun, Niger and Kano were purposely selected to represent respectively the three rice ecologies. Kano and Niger are located in the savannah Zone while Osun is located in the forest Zone. A multistage sampling approach was used to select the sample villages and farmers.

Six Local Government Areas (LGAs) were randomly selected from each of the sampled states (with the exception of Kano with five LGAs). A total of 48 villages (16, 17 and 15 villages from, Osun, Niger and Kano States, respectively) were selected. These included villages where NERICA varieties had been introduced (called "NERICA villages") and the neighbouring villages (5 to 15 kilometres away) where they were yet to be introduced. The survey was carried out at two levels. At the village level, focus group discussions were conducted with selected farmers and the village head to obtain prior information about the village in terms of its history, varieties grown, the state of infrastructure, constraints faced by rice farmers, and farm characteristics. Thereafter, the second level targeted individual farmers. An average of 7 farmers were selected from each village in Osun and Kano, and 20 farmers from each village in Niger based on probability, in proportion to the number of rice farmers in the state. The total sample consisted of 500 farmers. Data on their socio/demographic characteristics, knowledge, access to seed, and adoption of NERICA, farm size, and returns were collected.

Evidence from Table 1 reveals that the majority of respondents (93.1%) as well as those who adopted NERICA varieties (90%) were male. At the time of the survey, the average age of the farmers was 47 years. The average household size among respondents (both adopters and non-adopters) was 10. Eighty per cent of respondents were natives of their respective villages and have spent on average about 42 years in their villages. Most of the respondents (84.8%) stated agriculture as their major occupation, have an average cultivated land area of 2.91 ha,

[8] The first survey was carried out from December 2008 to February 2009 while the second survey, which collected data on household expenditure was, carried out during the second half of 2009.

and are aware of an average of 1.6 improved varieties of rice. About 30.7 per cent of farmers were aware of a least one NERICA variety while 25.5 per cent of them have access to its seed. It should be noted that all the adopters (100%) were both aware of, and have access to seed of NERICA varieties. This is because one cannot adopt a technology without being aware of, and have access to that technology. Only 4.9 per cent of the total sample has access to credit. The majority of both adopters (52.2%) and non-adopters (57.4%) have access to Information Communication Technology (ICT)[9]. Respondents walk an average of 4.3 km to reach the nearest seed market. The educational level of the heads of households is significantly different between adopters and non-adopters. About 69.1 per cent of the adopters had at least primary school level education compared to 42.8 per cent for non-adopters. There is also a significant difference between adopters and non-adopters in the attendance of vocational training, as well as in the type of experience in rice farming. Data on a set of institutional characteristics that is the percentage of farmers with access to extension services provided by NCRI and Agricultural Development Programmes (ADPs) was also collected. This revealed that 12.7 per cent and 8.5 per cent of NERICA adopters and non-adopters had contact with NCRI and ADPs. The test of difference between the socioeconomics/demographic characteristics of both adopters and non-adopters reveals that the two groups are significantly different from one to another that is they are heterogeneous. This expresses the presence of selectivity bias. Hence, the use of average treatment effect (ATE) framework for the estimation of adoption rates and their determinants in this study.

4. Results and discussion

Table 2 presents the results of the probit estimation of determinants of awareness and awareness-access to seed of NERICA varieties. The log likelihood of -166.17 and LRChi2 of 238.28 for awareness, and -152.84 and 218.93 for awareness-access to seed respectively were significant at one per cent level, showing that the two models were well fitted. Education, contact with extension agents, years of residence in the village, major occupation, vocational training, age of the farmer, number of local varieties known by the farmers and distance to the

[9] ICT was measured by access to New Technologies for communication (Radio, television and mobile telephone).

nearest market were statistically significant at different levels in explaining the two major constraints to adoption (awareness and access to seed of NERICA varieties).

Farmers with secondary level education tend to be more aware and have both awareness and access to NERICA varieties seed than those having only primary and no formal education. In addition, elderly farmers and those who know many local varieties have a higher probability of being aware and have both awareness and access to NERICA varieties seed than younger farmers and those who know only few local varieties. Farmers that have agriculture as their primary occupation or have received a vocational training in agriculture are more likely to be aware of, and have both awareness and access to seed of NERICA varieties than those that have agriculture as a secondary activity or do not have any vocational training. This can be explained by the fact that the typical farmer spends almost all his working time on farm activities. This increases his/her access to some information and, in some cases, increases his/her number of contacts with the extension services. The number of years spent by a farmer in the village negatively affects the probability of farmers being aware of, and having both awareness and access to seed of NERICA varieties. This means that the longer a farmer stays in the village, the less likely s/he can be aware of, and have both awareness and access to seed of NERICA varieties. Indeed, one more year spent in the village reduces the probability of awareness and have both awareness and access to seed of NERICA varieties by 0.01 respectively. This can be explained by the fact when a farmer spent more year in a village s/he is aware of many local and others improved varieties which can make s/he not to be aware or not to have both awareness and access to NERICA seed. Distance to nearest inputs market tends to reduce the probability of his/her being aware of new varieties, and consequently reduces the probability of having access to their seed. The marginal effect shows that distance to nearest inputs market is significantly inelastic to their probability to have both awareness and access to seed. Specifically, an increase in distance by one kilometer leads to only 0.004 decrease in the probability of having awareness and access to NERICA's seed.

The results of the ATE estimation of the different NERICA population awareness, access to seed, and adoption rates and gaps are presented in Table 3. Apart from the population selection bias (PBS) in the sub-population of the aware, all the parameters estimated were significant at 1 per cent level. The sample awareness rate of NERICA among rice farmers in Nigeria was estimated to be 30.1 per cent while the estimate of access to seed was 25.5 per cent in 2008. These figures reveal that not all the rice farmers who knew about NERICA varieties in 2008 have access to its seed. The joint awareness-access and adoption (JEAA) rate was 18.9 per cent. However, as demonstrated by Diagne (2010), because of the relatively incomplete diffusion of NERICA varieties and the relatively low level of awareness-access to NERICA seed in the country, the estimated joint awareness and adoption and joint awareness-access to seed and adoption rates significantly understate the population adoption rate[10] as of 2008.

The estimated population adoption rate of NERICA (ATE), which indicates the demand for NERICA varieties among the target population, was 54.4 per cent with awareness-unconstrained[11] and 62.3 per cent with awareness-access-unconstrained, which is the true population potential demand. This shows a potential adoption gap of 7.9 per cent in Table 3. This means that if the entire population of rice farmers were aware of NERICA varieties in 2008, the potential demand would have been 54.4 per cent. If, in addition to being aware, all the farmers had access to seed of NERICA varieties, the potential demand would have been 62.3 per cent. The 7.9 per cent gap can, therefore, be interpreted as the access to seed gap which is the potential demand loss due to non-access to seed. The estimated adoption rate within the awareness-unconstrained sub-population (ATTw) was 62.3 per cent compared to 75.3 per cent among the sub-population with awareness-access-unconstrained (ATTs). The gap of 13 per cent between the two rates may be explained by the fact that the sub-population of farmers who are aware and have access to seed is included in the sub-population of farmers who are aware of the variety.

The (potential) adoption rates among the sub-population of farmers who are not exposed (ATUw) and have no access to seed (ATUs) of NERICA varieties were 50.9 per cent and 58.0 per cent respectively. The corresponding estimates of the NERICA population adoption gap (the non-exposure bias (GAPw) and the access to seed bias (GAPs)) are -35.5 per cent and -43.4 per cent respectively. These adoption gap estimates imply that there is still a potential for significantly increasing NERICA adoption rates in Nigeria. The estimated population selection bias (PSB) was 7.9 per cent for the aware and 13 per cent for the aware and access

[10] The adoption rate that would be obtained if the whole population were exposed to NERICA varieties and have access to NERICA seed.
[11] This is what was estimated in Diagne *et al*. (2007) and Diagne (2006 and 2010).

to seed sub-populations. The PSB estimate was not statistically significant for the aware sub-population. We therefore accept the null hypothesis that the presently NERICA-aware sub-population is equally likely to adopt the NERICA varieties as the general population. However, the PSB was positive and statistically significant at 10 per cent level among the sub-population of farmers having access to seed. This implies that the probability of adoption by a farmer belonging to the sub-population of farmers that have access to seed is significantly different from that for any other farmer randomly selected from the general population. The positive sign of the PSB indicates that the farmers that have access to seed of NERICA varieties are significantly more likely to adopt at least one NERICA variety than any farmer randomly selected from the population.

It is also enlightening to compare adoption rates estimated in this study with estimates from other studies conducted in Nigeria and elsewhere in Africa. The actual adoption rates of 18.9 per cent is considerably higher than the 4 per cent reported by Diagne (2006) for Côte d'Ivoire; higher than the 18 per cent reported by Adegbola et al. (2005) for Benin. However, this rate is smaller than the 20 per cent obtained by Barry et al., (2009) in Guinea, also smaller than the 41 per cent obtained by Phillips (2008) for Nigeria in a comparative study with Côte d'Ivoire, smaller than the 30 per cent and 40 per cent reported for Ekiti and Kaduna states of Nigeria respectively by Spencer et al. (2006) who used the sample adoption rate and assumed full awareness and full access to seed of NERICA varieties by the farmers.

Compared across ecologies and states, table 4 shows that the incidence of these parameters was high in the upland ecology (78.4% for the potential adoption rate), follow by irrigated ecology (61.9%) and 55.2 per cent in the lowland ecology. Similarly, Osun state has the highest potential (67.0%) followed by Kano (60.1%) and Niger (49.8%) states. These statistics show that the upland ecology has the highest potential in terms of NERICA adoption. These results were expected since the first NERICA varieties developed and disseminated were more suitable for the upland ecology than any others ecology (Jones et al., 1997).

Table 5 presents the results of the ATE probit estimates of NERICA adoption among rice farmers in Nigeria. It is necessary to note that in practical estimation terms, the main difference between the ATE parametric adoption model and the "classic" adoption model lies in the fact that the "classic" model uses all the sample observations while the ATE parametric uses observations from the awareness-unconstrained or awareness-access-unconstrained sub-sample only. These two models point out differences in the magnitude of the coefficients, as well as their marginal effects. In general, as showed by Diagne (2006, 2010), the marginal effects of the ATE probit model are larger in absolute values than that of the classic "adoption" model. However, for the purpose of this study, only the ATE probit will be interpreted.

Table 5 shows a log pseudo likelihood of -55.55 and -40.55 and the Wald chi^2 of 67.31 and 47.43 for the awareness-unconstrained and the awareness-access-unconstrained subpopulation respectively. These were significant at 1 per cent level each, showing that the models were well fitted. The probability of adopting NERICA varieties increases significantly with farmers who have contact with extension services, have received a vocational training or have more than primary school education level. More years of education and/or experience and increase in contact with extension officers are often hypothesized to increase the probability of adoption. This is because of factors inherent in the aging process or the lowered likelihood of payoff from a shortened planning horizon over which accepted benefits can accrue (Fernandez-Cornejo et al., 1994; Barry et al., 1995; Batte and Johnson, 1993). Another reason is that in agriculture, technological innovations are perceived to be more risky than in other traditional practices. Some researchers have argued that the perception of increased risk inhibits adoption (Feder et al., 1985). When an innovation first appears, potential users are generally uncertain of its effectiveness and tend to view its use as experimental (Mansfield, 1966). Hiebert (1974) and Feder and O'Mara (1981, 1982) show that uncertainty declines with learning and experience, thus inducing more risk-averse farmers to adopt an innovation, provided it is profitable. Similar results were reported by previous studies on improved technology adoption (Gockowski et al., 2004, Shiferaw et al., 2006). Regular contacts with the extension service make farmers aware of new technologies and improve their knowledge on how they can be applied. In addition, the number of year the farmer has spent in the village positively affect the probability of adopting NERICA as its increase by one year leads to increase in the probability of adoption by 0.01. Many years in the village helps the farmers to have a good knowledge of the major production aspects and systems that can be practiced in the village; to have a sound knowledge of agronomic practices and to locate the major sources of production inputs such as seed, fertilizer and even land at affordable price. Finally, respondents that have agriculture as their major occupation tend to adopt NERICA more than those who use agriculture as secondary occupation. Although some of these variables are not significant, their signs are nevertheless in line with findings of previous studies (Adesina and Baidu-Forson, 1995, Saka et al., 2005, Okoedo-Okojie et al. 2009, Odoemenen and Obinne, 2010 and Namwata et al., 2010).

4. Conclusions and recommendations

In a world of perfect access to information, producers would be aware of, have access to, and would adopt new technologies that raise profits or well-being more generally. Without information and access to seed, the adoption decision would only depend on profitability. However, if there is information constraint, adoption may also depend on awareness and access to seed. This latter point is what is tested in this paper by extending the work of Diagne (2006, 2010) and Diagne and Demont (2007) on the problem of estimation of the true potential adoption rates by considering both lack of awareness and access as constraints to technology adoption. The questions asked are - Are there farm operators in Nigeria for whom the technology is profitable, but who are not aware of its existence? And, are there farm operators for whom the technology is profitable, and are aware of its existence, but do not have access to the seed?

After controlling for producers' profitability, and allowing for the facts that awareness and access to seed precede adoption, the study used the ATE methodology to assess the true potential adoption rate of NERICA varieties in Nigeria and estimate the lack of seed gap of NERICA adoption. NERICA awareness and access to seed are found to be major factors influencing NERICA adoption in Nigeria. However, the study discovered that basing the adoption estimates only on awareness, as in previous studies (Diagne et al., 2007, 2009, and Diagne, 2006, 2010), underestimates the potential adoption rates. Specifically, this study found that the NERICA adoption rate in Nigeria would have been up to 54.4 per cent in 2008 if the whole population were aware of NERICA varieties and up to 62.3 per cent if in addition the whole population had access to seed of NERICA varieties instead of the actually observed 18.9 per cent joint awareness-access and adoption rate. The lack of seed adoption gap was estimated at 7.9 per cent and the population adoption gaps were -35.5 per cent and -43.4 per cent for the awareness-unconstrained and the awareness-access-unconstraint sub-populations respectively.

Bridging these gaps is essential in increasing the productivity of smallholders' upland rice farmers in Nigeria and there are several reasons why government should invest more resources in filling these adoption gaps. Firstly, the upland ecosystem in Nigeria is cultivated by small holder farmers who use little (or no) fertilizer, face many stresses such as drought, weed, pest, and so forth. According to ADF report (2003), this has led to low yield in this ecology (on average 0.5 metric tonnes per ha) compared to the rain fed low land and irrigated ecology. Secondly, traditional upland rice varieties mature in 150 to 170 days while NERICA varieties mature in 90 to 100 days. No wonder that Diagne et al. (2009) suggest the reason why farmers might prefer NERICA varieties to traditional varieties with similar yields has to do with the shorter growing season for NERICAs. They added that this characteristic reduces the risks associated with terminal droughts, saves on labour and sometimes allows for a second rice crop. Finally, NERICA varieties possess good agronomic traits such as disease and pest resistance, intermediate to tall stature and lodging resistance. With these characteristics, NERICA varieties therefore offer an opportunity for sustainable intensification of upland rice production systems.

Knowing these advantages of NERICA, more investment in their dissemination and in making their seed available to farmers is a necessary policy, considering that the 62.3 per cent adoption rate is bound to increase significantly in the future as farmers learn more about the characteristics of NERICA varieties, become comfortable with their performance and have access to their seed. To improve dissemination/diffusion, the farmer access to extension services was an important factor explaining NERICA adoption from the estimation. Access to extension services would enables farmers to learn about the characteristics and relative performances of NERICA compare to other varieties after they are made aware of their existence. Government should therefore invest further in the dissemination of NERICA by enabling extension services and NGO's to reach more rice farmers and provide them with relevant information about these varieties in order to bridge not only the existing adoption gap but also to shove further the potential adoption rate of NERICA. Likewise, Government could make seed available by developing road and market infrastructures, given one-off loans to a small number of traders and/or farmers enabling them to buy appropriate seed in distant markets or by distributing appropriate seeds to farmer from time to time. Also, ensure the local availability of seed by providing access to chemical seed treatment (with instructions for use) to reduce storage losses. Ensure that the poorest farmers have access to locally available seed through seed vouchers and seed fairs to allow the poorest farmers to buy seeds.

This paper has dealt with the gaps between actual and potential adoption created by lack of awareness and lack of access to seed. However, in our methodology, we assume that while farmer can be aware of a variety without having access to his seed, s/he cannot have access to its seed without being aware. Hence, awareness precedes access to the seed of the variety. Nevertheless, in some cases awareness and access do not follow that sequence, but they are rather simultaneous and in some cases, the reverse of the sequence is the case. Thus, the same methodology can be used to investigate such situations when such information is collected.

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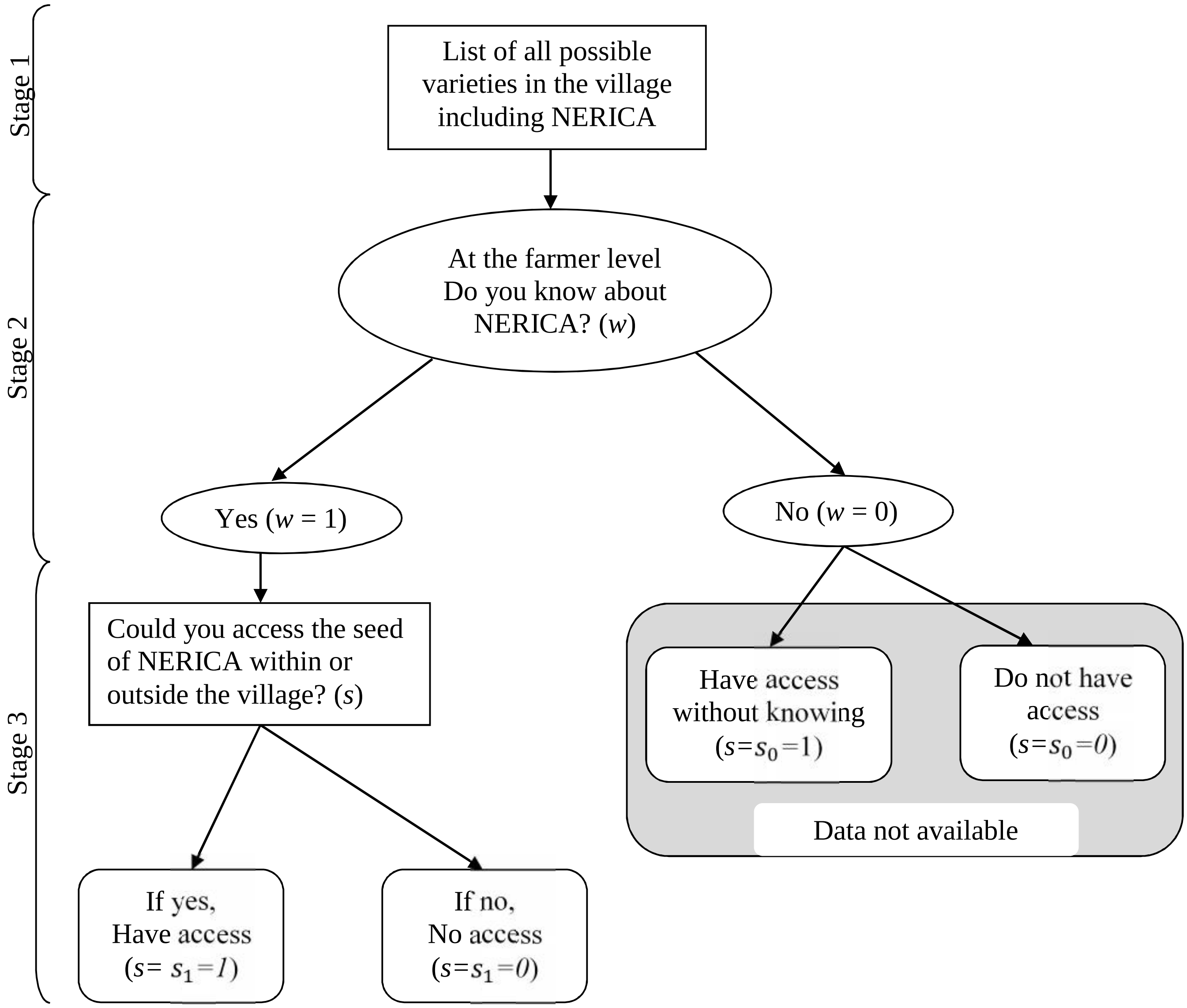

Figure 1: Flowing chart showing the construction of access to seed variable

Table 1: Household socioeconomic characteristics by adoption status

Characteristic	Non-Adopters (n=380)	Adopters (n=101)	Total (n=481)	Difference Test
Socio-demographic factors				
Proportion of male farmers (%)	93.8	90.0	93.1	0.04
Proportion of female farmers (%)	6.2	10.0	6.9	0.04
Age (average)	45	49	47	3.4***
Household size (average)	10	10	10	0.14
% Born in the village	63.6	16.4	80.0	0.02
Number of years of residence in the village (average)	42	43	42	1.08
%aware of NERICA varities	14.1	100	30.7	-0.86***
% having access to seed	7.8	100	25.5	-0.92***
% having access to credit	4.5	6.5	4.9	-0.02
% having agriculture as major occupation	94.3	45.7	84.8	0.48***
% having access to ICT	57.9	52.2	56.8	0.06
Distance to the nearest seed market (average)	3.7	5.8	4.3	-2.03**
Land area (ha) cultivated (average)	3.4	1.8	2.9	1.57***
Number of improved varieties known by the farmer	1.7	1.4	1.6	0.31*
Education and experience in rice farming				
% with no formal education	57.2	30.1	50.1	0.25***
% with primary education	20.5	39.8	25.6	0.14***
% with secondary education	17.3	28.5	20.2	0.14***
% with post-secondary school education	5.0	1.6	4.1	0.02
Proportion of farmers that receive vocational training (%)	5.8	5.8	11.6	0.20***
Proportion of farmers with experience in lowland rice farming (%)	53.6	0.62	54.2	0.65***
Proportion of farmers with experience in upland rice farming (%)	10.8	17.9	28.7	0.71***
Proportion of farmers with experience in mangrove rice farming (%)	15.0	1.5	16.4	0.12***
Institutional factors				
Proportion of farmers in contact with NCRI (%)	1.7	11.0	12.7	0.06*
Proportion of farmers in contact with ADPs (%)	0.2	8.3	8.5	0.10***

NB: The T-test was used to test for differences in socioeconomic/demographic characteristics between adopters and non-adopters.

Legend: * significant at 10 per cent; ** significant at 5 per cent and *** significant at 1 per cent

Source: AfricaRice/NCRI Baseline and priority setting survey 2008/2009

Table 2: Probit estimates of the determinants of awareness and access to seed of NERICA varieties

	Awareness model		Awareness-access to seed model	
	Coefficients	Marginal effect	Coefficients	Marginal effect
Secondary education dummy=1 if the farmer has secondary school level and 0 if otherwise	0.428** (2.150)	0.141** (2.040)	0.440** (2.150)	0.125** (1.980)
Extension = 1 if farmer has contact with extension service and 0 if otherwise	-0.676*** (-3.030)	-0.177*** (-3.730)	-0.654*** (-2.670)	-0.139*** (-3.370)
Number of years of residence in the village	-0.035*** (-4.120)	-0.011*** (-4.140)	-0.019*** (-2.110)	-0.005*** (-2.120)
Household size (number of people in the household)	0.013 (0.600)	0.004 (0.600)	0.013 (0.610)	0.003 (0.610)
Farnatv = 1 if the farmer is a native of the village and 0 if otherwise	0.235 (0.920)	0.068 (0.980)	0.149 (0.570)	0.036 (0.600)
Farmdummy = 1 if primary occupation is farming and 0 if otherwise	1.051*** (4.810)	0.378*** (4.590)	1.273*** (5.800)	0.428*** (5.250)
voctrain = 1 if had vocational training and 0 if otherwise	0.322 (1.360)	0.107 (1.270)	0.489** (2.040)	0.146* (1.790)
Age of the farmer in years	0.030* (3.150)	0.009 (3.140)	0.019* (1.910)	0.005* (1.910)
Number of local rice varieties known by the farmer	0.081*** (9.720)	0.025*** (9.050)	0.071*** (8.800)	0.018*** (8.130)
Number of improved rice varieties known by the farmer	-0.040 (-0.460)	-0.012 (-0.460)	-0.127 (-1.270)	-0.033 (-1.270)
Number of years of experience in upland system	0.007 (0.160)	0.002 (0.160)	-0.025 (-0.480)	-0.006 (-0.480)
Distance to the nearest seed market (in kilometer)	-0.012* (-1.750)	-0.004* (1.-750)	-0.004 (-0.640)	-0.001 (-0.640)
Constant	-0.462 (-1.030)		-0.464 (-1.000)	
Number of observations	465		465	
Log likelihood	-166.17366		-152.843	
LR chi2	238.28***		218.93***	
Df	12		12	
Pseudo R2	0.4176		0.417	

Legend: * p<0.10; ** p<0.05; *** p<0.01

The figures in parenthesis represent the standard error

Source: AfricaRice/NCRI Baseline and priority setting survey 2008/2009

Table 3: ATE parametric (Probit) estimation of population adoption incidence rates

	Parameter With Awareness-unconstrained		Parameter With awareness-access-unconstrained	
Population potential adoption rate:	**ATEw**	0.544*** (7.91)	**ATEs**	0.623*** (7.51)
Adoption rate among exposed and access to seed:	**ATTw**	0.623*** (20.50)	**ATTs**	0.753*** (24.47)
Adoption rate among non-exposed:	**ATUw**	0.509*** (5.60)	**ATUs**	0.580*** (5.53)
Actual adoption rate:	**JAA**	0.189*** (20.50)	**JAA**	0.189*** (24.47)
Adoption Gap: **JAA – ATE**	**GAPw**	-0.355*** (-5.60)	**GAPs**	-0.434*** (-5.53)
Population selection bias	**PSBw**	0.079 (1.44)	**PSBs**	0.130* (1.90)
Number of obs (N)		465		465

Legend: * p<0.10; ** p<0.05; *** p<0.01
The figures in parenthesis represent the robust standard error
Source: AfricaRice/NCRI Baseline and priority setting survey 2008/2009

Table 4: ATE parametric (Probit) estimation of population adoption incidence rates across ecologies with seed-unconstrained

Adoption	Lowland ecology	Upland ecology	Irrigated ecology	Niger State	Osun State	Kano State
Population potential adoption rate: **ATEs**	0.552*** (4.40)	0.784*** (20.93)	0.619*** (5.89)	0.498*** (6.61)	0.670*** (6.58)	0.601*** (5.45)
Adoption rate among exposed and access to seed: **ATTs**	0.449*** (7.01)	0.831*** (28.90)	0.464*** (4.98)	0.471*** (7.5)	0.833*** (27.11)	0.392*** (4.17)
Adoption rate among non-exposed: **ATUs**	0.557*** (4.27)	0.626*** (7.33)	0.635*** (5.92)	0.504*** (6.14)	0.595*** (4.14)	0.629*** (5.49)
Actual adoption rate (adoption, exposure & access): **JAA**	0.022*** (7.01)	0.633*** (28.90)	0.040*** (4.98)	0.083*** (750)	0.262*** (27.11)	0.044*** (4.17)
Adoption Gap: **JAA – ATEs**	-0.529*** (-4.27)	-0.151*** (-7.40)	-0.579*** (-5.91)	-0.416*** (-6.14)	-0.407*** (-4.14)	-0.558*** (-5.47)
Population selection bias **PSBs**	-0.103 (-0.95)	0.048*** (2.73)	-0.155*** (-3.32)	-0.027 (-0.53)	0.164* (1.74)	-0.209*** (-3.34)
Number of obs (N)	113	240	95	305	97	73

Legend: * p<0.10; ** p<0.05; *** p<0.01
The figures in parenthesis represent the robust standard error
Source: AfricaRice/NCRI Baseline and priority setting survey 2008/2009

Table 5: ATE Probit (restricted to awareness and access to seed sub-sample)

	ATE-probit with Awareness-unconstrained		ATE-probit with awareness-access-unconstrained	
	Coefficients	Marginal effect	Coefficients	Marginal effect
Secondary education dummy=1 if the farmer has secondary school level and 0 if otherwise	0.610 (1.640)	0.237* (1.70)	0.497 (1.11)	0.187 (1.10)
Number of years of experience in the upland system	0.016 (1.080)	0.006 (1.10)	0.031 (1.51)	0.012 (1.35)
Extension = 1 if farmer has contact with extension service and 0 if otherwise	0.456 (1.000)	0.179 (1.00)	1.320* (1.85)	0.466** (2.29)
Number of years of residence in the village	0.028*** (2.680)	0.011** (2.55)	0.018 (1.41)	0.007 (1.54)
Farmdummy = 1 if primary occupation is Farming and 0 if otherwise	2.404*** (6.020)	0.573*** (5.29)	2.195*** (5.50)	0.388** (2.56)
voctrain = 1 if had vocational training and 0 if otherwise	0.646 (1.580)	0.251* (1.68)	0.505 (1.08)	0.171 (1.15)
Age of the farmer in years	0.012 (0.680)	0.005 (0.69)	0.020 (0.97)	0.008 (0.93)
Distance to the nearest seed market in kilometer	-0.044 (-1.440)	-0.017 (-1.44)	-0.028 (-0.38)	-0.011 (-0.38)
Constant	0.651 (0.700)		0.465 (0.41)	
Number of observations	141	73	117	73
Log pseudolikelihood	-55.551		-40.553	
Wald chi2	67.31***		47.43***	
Df	8		8	
Pseudo R2	0.4049		0.3810	

Legend: * p<0.10; ** p<0.05; *** p<0.01. The figures in parenthesis represent the robust standard error

Source: AfricaRice/NCRI Baseline and priority setting survey 2008/2009

Appendix

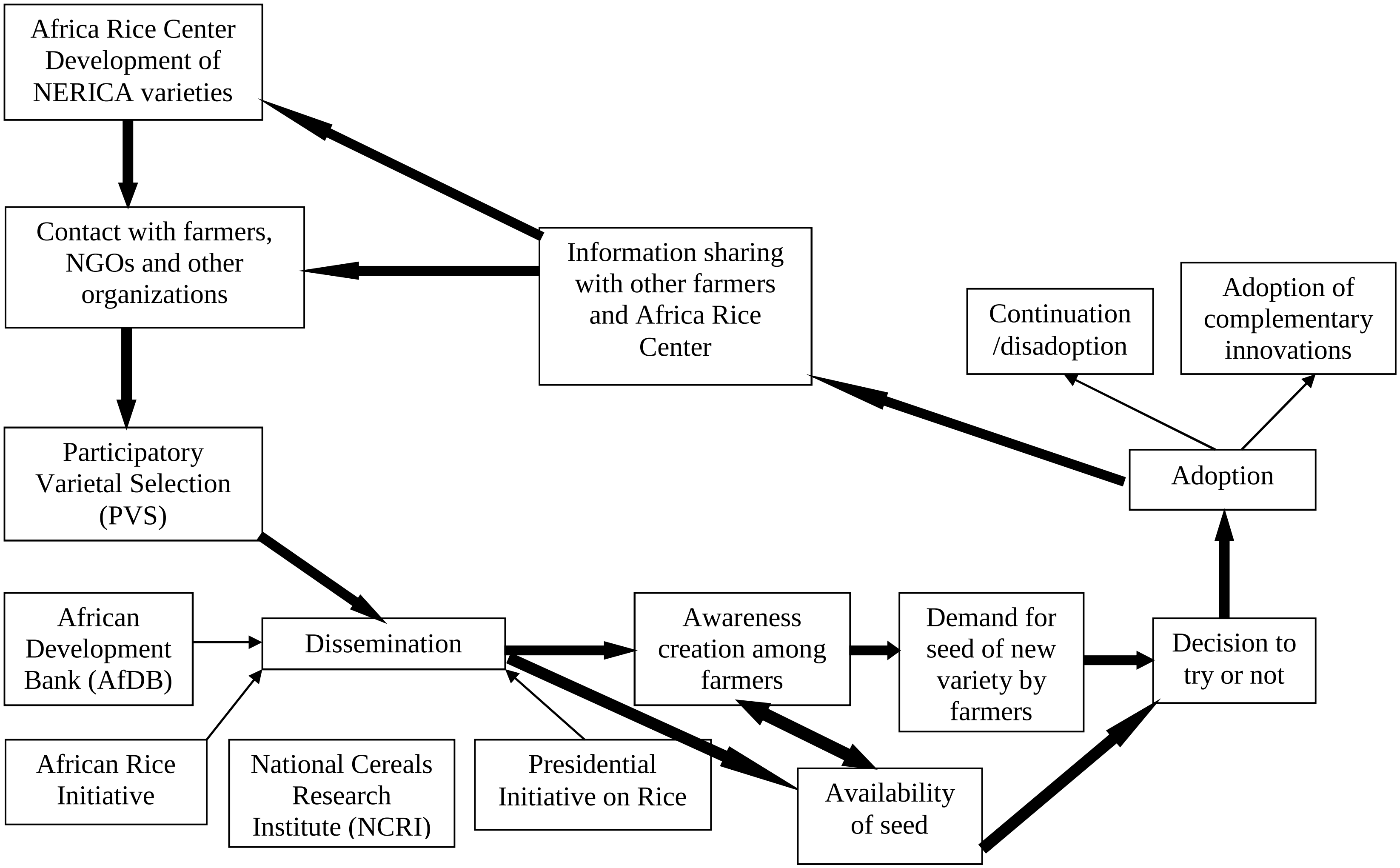

Figure 2: Stages in NERICA dissemination and adoption in Nigeria