Impact of NERICA Adoption on Productivity and Income in Benin: Is There Gender Difference

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Abstract

This paper examines the gender differential impact of NERICA adoption on rice yield and farmers' annual household income using data from 342 rice farmers from Benin. NERICA varieties have been one of the most significant advances in crop improvement in Africa. They have been developed through AfricaRice's interspecific hybridization breeding program which won their creator Monty Jones the 2004 World Food Prize. They are widely believed to offer hope for Africa's Green Revolution because of their ability to grow under multiple stresses as well as their high response rate to inorganic fertilizers and other inputs. This paper applies the counterfactual outcomes framework of modern evaluation theory to estimate the Local Average Treatment Effect (LATE) of NERICA adoption on farmers' yield and income. The evidence from the results shows that NERICA adoption has a positive and significant impact on farmers' yield and household per capita income. The impacts of NERICA adoption are not homogeneous across farmer gender and are higher for female farmers than male farmers. Women potential adopters of NERICA produce 866 kg more paddy per hectare and have an additional per capita household income of 43,715 FCFA (US$101) compared to men potential adopters who produce 392 kg more paddy per hectare and have an additional per capita household income of 11,027 FCFA (US$23) per capita. The findings suggest that targeting women with NERICA can increase rice productivity, total production and income significantly more than if the NERICA are targeted at men.

Keywords: *Impact assessment, LATE, productivity, Income, NERICA, Rice, West Africa*
JEL classification codes: *C13, O33, Q12, Q16*

1- Introduction

Agriculture remains one of the pillars of Africa's economic, social and rural development. About 70% of Africans and roughly 80% of the continent's poor live in rural areas and depend mainly on agriculture for their livelihood (Maxwell, 2001). Rice is the most important food crop for millions of people in West Africa. The social crisis in many West African countries during the 2008 food crisis revealed that rice is the most strategic crop in these countries. Despite the double digit increase in rice production in 2008 and 2009 in West Africa as a result of the policies implemented by many countries to respond to the food crisis, West Africa's rice import is estimated to have risen to close to 9 million MT amounting to a total import bill of 3.16 billion US dollars (FAO, 2009). According to FAO (2013), rice imports have decreased, but are still high in West Africa and are estimated at about 7.1 million MT in 2013. In Benin, despite the increase of rice production, thanks to the implementation of new rice policies, rice imports were still high in 2013 with an estimated 200,000 MT. Hence, there is an urgent need to accelerate the growth in domestic rice production in West Africa to reduce its unsustainable and risky dependency on rice imports. One of the main ways to increase rice production is the adoption of improved rice technologies by smallholders. One of the most significant technologies in rice production in Africa is the New Rice for Africa (NERICA) varieties, which won its creator Monty Jones the 2004 World Food Price.

Indeed, NERICA rice varieties, one of the most significant advances in crop improvement in Africa in recent years, developed by AfricaRice and its National Agricultural Research Systems (NARS) partners in the mid-1990s, are interspecific hybrids between local African rice (*Oryza glaberrima*) and Asian rice (*Oryza sativa*). They offer new opportunities for upland rice farmers (Diagne *et al*., 2013; Akakpo and Assigbè, 2005; WARDA, 2001). NERICA varieties were introduced in Benin in 1998 through the participatory varietal selection (PVS) approach. In addition, the Multinational NERICA Rice Dissemination Project (MNRDP), funded by the African Development Bank (AfDB), widely disseminated NERICA varieties in Benin from 2006 to 2010. According to Diagne *et al.* (2013) and Adegbola *et al.* (2005), these varieties have been widely adopted by rice farmers.

Furthermore, the Association of Women's Rights in Development (AWID) (2004), Jacoby (1991) and von Braun and Patrick (1989) argued that any change in farm systems affects men and women differently. According to Kokki and Bantilan (1997), this is partly due to the differences in perception regarding technology that exist between women and men in farm households. Women perceive technology in terms of its workability and drudgery, while men are mostly concerned with financial viability. Several international institutions, such as IFAD, FAO, CGIAR, UNICEF and IFPRI, were more precise on this issue when, considering the important role of women and problems related to their active involvement in economic development and rice production, emphasized that "targeting women in agricultural technologies dissemination can have a greater impact on poverty reduction and food security than targeting men" (IFPRI, 2005)

Indeed, during the last three decades, a large and growing literature has been developed on gender-based distributional issues and the economic activities of rural women. Many studies clearly show that women play a vital role in agricultural production in general and rice production in particular (FAO, 2006; CTA, 2002; Quisumbing, 1996; Carney and Watts, 1990, 1991; Aredo, 1995; FAO, 1984; Guyer, 1984). Nonetheless, women lack influence over the agricultural research and development agenda and seek accountability for their concerns. Women often have little access to or have been discriminated against in the distribution of production factors (Kinkingninhoun-Mêdagbé *et al.,* 2008; Basile, 2001; Dey Abbass, 1997; Saito *et al.,* 1994; Kanbur and Haddad, 1994; Carney, 1993; Bindlish and Evenson, 1993; Morris and Meyer, 1993). They are systematically denied access to land, credit, extension services and technology (ILO, 1984). Women's position with regard to resource control and decision making is a gender relationship whuch is reinforced by legal and educational systems as well as the media. These situations affect the productivity, efficiency, income generation and hence the welfare of men and women differently (Basile, 2001; Dey Abbass, 1997; Strauss and Thomas, 1995; Saito *et al*., 1994; Jacoby, 1991 ; von Braun and Patrick, 1989).

Since the adoption of NERICA rice varieties introduces changes in rice farming systems because of their specific characteristics, such as input requirement and productivity, it may affect male farmers and female farmers differently.

Therefore, this paper aims to assess the impact of NERICA adoption on yield and farmers' households income after the implementation of the MNRDP, and test the hypothesis that, although the NERICA varieties are being widely adopted by both male and female farmers, the impact is not homogenous across gender.

2. *New Rice for Africa (NERICA) varieties and their dissemination in Benin*

The New Rice for Africa (NERICA) are the result of interspecific crosses between *Oryza sativa,* the high yielding Asian rice species, and *Oryza glaberrima,* the locally adapted and multiple-stress resistant African rice species. Developed by AfricaRice in the mid-90s, NERICA varieties have some desirable traits (high yield potential and adaptability to African conditions) that offer opportunities for increasing rice productivity similar to that achieved during the Asian Green Revolution, such that it raises hope for Africa's Green Revolution[1].Many of the NERICA varieties mature between 50 and 80 days earlier than traditional varieties. In particular, NERICA varieties are well known to have a much shorter growth cycle (up to 30 days shorter) than most farmers' varieties and this attribute is almost always the first one cited by farmers when they are

[1] The NERICA (New Rice for Africa) rice varieties won its creator Monty Jones the 2004 World Food Prize and his inclusion in the 2007 Time magazine's list of the 100 most influential people in the world.

asked about what they like about NERICA. The good cooking and eating attributes of some of the NERICA varieties have also been documented by Watanabe *et al*. (1999b). They are also said to be much richer in protein and more resistant to disease, drought, acid soils and most of the ravaging insects of West Africa as well as weeds (Jones *et al*., 1997; Dingkuhn *et al*, 1998; Audebert *et al*, 1998; Johnson *et al*., 1998; Dingkuhn *et al*., 1999; Wopereis *et al*., 2008). Several rice development initiatives have attempted to boost rice production, including the African Rice Initiative (ARI), which was established in 2002 to promote the dissemination of NERICA varieties in several sub-Saharan African (SSA) countries including Benin. However, there is no published analysis of the impact of NERICA adoption on productivity and income in most of the West African countries where NERICA varieties have been adopted.

NERICA rice varieties were introduced in Benin by the "*Institut national des recherches agricoles du Bénin*" (INRAB) [2] in 1998 through Participatory Varietal Selection (PVS). This first introduction of NERICA was followed by a set of PVS trials in Central and Northern Benin. In addition, these varieties were widely disseminated by the Multinational NERICA Rice Dissemination project from 2006 to 2010. During the implementation of this project, PVS trials were conducted from 2006 to 2008 in five communes: Dassa-Zoumè and Glazoue in Central Benin and Materi, Cobly and Tanguieta in Northern Benin, involving about 1,000 rice farmers. Among the 10 rice varieties selected by farmers at the end of the process (field trials, organoleptic tests, etc.), five upland NERICA varieties - NERICA1, NERICA2 et NERICA4, NERICA8 and NERICA18 - were disseminated through field days, seed distribution, etc.. The objective was to improve farmers' livelihood through the adoption of high-yielding varieties. In a study conducted in 2004, Adégbola *et al.* (2005) found a NERICA adoption rate of 18% and an estimated potential adoption rate of 50%, which suggests a high potential demand for NERICA varieties. Moreover, in an early impact study in 2005, Diagne *et al.* (2013) found a positive and significant impact of NERICA adoption on rice yield.

3. Methodology

3.1. Theoretical framework of impact evaluation

The assessment of the impact of the adoption of NERICA varieties on household productivity and income is based on the agricultural household model framework. Any agricultural household makes its production and consumption choices to maximize the utility of consumption subject to some constraints on available resources and technologies.[3] We assume that rice farming households choose among *J* rice varieties (including NERICA and other traditional and improved varieties) to produce rice and maximize the utility of consumption of food and non-food items subject to a budget constraint:

[2] Benin's National Agricultural Research Institute.
[3] See, for example, Just, Hueth and Schmitz (2004), Chapter 7, appendix 7G for a very general formulation of the agricultural household model.

$$\max_{(c,b_1,..,b_J)\in R^M} U(c,z_u)$$
$$s.t. \quad p^c \cdot c = m + p_\tau \tau + \sum_{j=1}^{J} p_j^r f(b_j, z_j) - \sum_{k=1}^{K} \sum_{j=1}^{J} p_{jk} b_{jk} \quad \textbf{(1)}$$

where $U(.)$ is the agricultural household's utility function (here utility), R^M is the Euclidean space of dimension M, c is the consumption vector of food (including rice) and non-food commodities (including leisure) with p^c the corresponding price vector, z_u is a vector of household socio-demographic variables that affect utility, m is the income available to the household prior to making its production choices (including transfer and rental income on fixed owned factors), τ is the household total labor endowment valued at the market wage rate p_τ, p_j^r is the price of rice produced using variety j, f is a production function, $b_j = (b_{jk})_{k=1,..,K}$ with b_{jk} being the quantity of the variable input k used in producing rice using variety j with p_{jk} the corresponding unit price and with seed corresponding to k=1 (i.e. b_{j1} stands for the quantity of seed of variety j and p_{j1} its unit price) and z_j is a vector of exogenous technological and environmental variables conditioning the production of rice using variety j (variety characteristics, plot soil characteristics, weather, etc.). Also included in the z_j vector are the quantities of the fixed inputs used in the production of rice with variety j.

The left hand side of the budget constraint equality in equation (1) is the total household consumption expenditure. The right hand side contains in its last two terms the household net crop income, which is the total value of production minus total variable cost. It is important to note that the household net crop income does not include total fixed costs (i.e. the total cost of the fixed inputs) and is therefore different from the household profit. The assumption that the household grows only rice is for simplicity and notational ease only and is without loss of generality as the above formulation can be easily extended to include other crops and non-farm income generating activities by simply adding to b_{jk}, z_j and p_k another subscript for crop and non-farm income generating activities and adding the relevant terms for the different crops in the budget constraints. Therefore we will view the right hand side of the budget constraint as the total household net disposable income in coherence with the empirical analysis.

To further simplify the notation we will put $b = (b_1,...b_J) = (b_{jk})_{k=1,..,K\,;\,j=1,...,J}$ $a = (b,c)$, $p^r = (p_j^r)_{j=1,...,J}$, $p^I = (p_{jk})_{k=1,..,K;\,j=1,...,J}$, $z^I = (z_j)_{j=1,...,J}$, $z = (z^u, z^I, m, \tau, p^c, p^r, p^I)$ and $S(z) = \{(b,c) \in R^M : p^c \cdot c = m + p_\tau \tau + \sum_{j=1}^{J} p_j^r f(b_j, z_j)) - \sum_{k=1}^{K} \sum_{j=1}^{J} p_{jk} b_{jk}\}$. With these notations, the agricultural household optimal vector of inputs and consumption choices $a^* = (b^*, c^*)$, solution of the optimization problem (1), is a function of the conditioning vector z:

$$a^* \equiv \delta(z) = \arg\max_{a\in S(z)} \{U(c,z)\} \quad \textbf{(2)}$$

The vector *z* is usually called a parameter in the general optimization literature (see, for example, Topkis, 1998; Milgrom *et al.*, 1994). But here we will call it a conditioning variable to differentiate it from what we call a parameter in the econometric section below. What is important here is that *z* is a vector of non-choice variables over which the household does not maximize. These non-choice variables may be exogenously given to the household (as in the case of age, gender, prices, rainfall and other market, community infrastructure and environmental variables) or they may be variables whose values are directly or indirectly determined (even partially) by some of the household choice variables in the vector *a* (as in the case of health and nutritional status, soil fertility, etc.). The subset of z variables that fall in the latter case are said to be *endogenously* determined even if their values still depend on the values of other variables exogenously given to the household. Thus, for the purpose of the analysis below, we can distinguish between two types of variables making up the z vector: 1) the subset of *z* variables that are exogenously given to the household which we define as *exogenous* variables and which is noted by z_x, and 2) the subset of *z* variables that are endogenously determined which we define as endogenous variables denoted by z_e. The choice variables in the vector *a* are also trivially defined to be endogenous. Hence, in summary, we have $z=(z_x,z_e)$ with z_x being the set of exogenous variables and (a,z_e) being the set of endogenous variables.

As we define the adoption of a variety by the use of its seed to produce rice, in what follows we will use the generic form of the household maximization problem (2) to make explicit how the rice output and factor demand and productivity outcomes depend directly on the quantity of NERICA seed used and indirectly through the dependence of its optimal choices of the quantities for the other input and consumption commodities on that same quantity of NERICA seed used. To proceed, first let $a_{\dot{N}} = b_{\dot{N}1}$ stands for the quantity of NERICA seed choice variable and let $a_{(\dot{N})}$ be the vector of other inputs and consumption variables (i.e. *a* without its component $a_{\dot{N}}$). We will also use a similar notation for the corresponding optimal input and consumption choice functions (i.e. the demand functions): $a^*_{\dot{N}} = \delta_{\dot{N}}(z)$ and $a^*_{(\dot{N})} = \delta_{(\dot{N})}(z)$. Second, we note that when the quantity of NERICA seed used by the household is fixed exogenously at some level $a_{\dot{N}}$ (not necessarily equal to $a^*_{\dot{N}}$), then the optimal demand for the other inputs and consumption bundles $a^*_{(\dot{N})}$ will in general be a function of $a_{\dot{N}}$ in addition to the conditioning vector z. Consequently, we can write the expression of the factor productivity for the k^{th} input other than seed (*k*=2,..,*K*) as a function of $a_{\dot{N}}$ and *z* as follows:

$$\psi^*_k = \psi_k(a_{\dot{N}}, z) = \frac{q^*}{b^*_k} = \frac{q(a_{\dot{N}}, b^*_{(\dot{N})}, z)}{b^*_k} \quad \textbf{(3)}$$

Where $b_k^* = \sum_{j=1}^{J} b_{jk}^*$ and $q^* \equiv q(a_{\dot{N}}, b_{(\dot{N})}^*, z) = \sum_{j=1}^{J} f(a_{\dot{N}}, b_{(\dot{N})}^*, z)$ are, respectively, the total optimal quantity of input *k* used in rice production and the total quantity of rice produced when the quantity of NERCA seed used in rice production is fixed at the value $a_{\dot{N}}$.

In the above functions for the optimal choices and the outcomes in equation (3), we have kept the *z* argument to be the same. But this is only for simplicity in the notation. In general, the *z* argument is different for each function and is made of a subset of the overall vector *z* defined earlier, with possibly the different subsets having common elements. In what follows, we use the variable *y* and the function *g* as generic notations for the outcome variables and the functions in the left-hand and right-hand sides of equation (3) and the output and factor demand expressions, respectively. In other words, the outcome equation above will be represented by the following generic outcome equation:

$$y = g(a_{\dot{N}}, z) \quad \textbf{(4)}$$

By definition, adoption of NERICA takes place when the value of the variable $a_{\dot{N}}$ changes from zero to some strictly positive value $a_{\dot{N}}^1 > 0$. Hence, the causal effect of NERICA adoption on any outcome $y = g(a_{\dot{N}}, z)$ is measured by the difference $g(a_{\dot{N}}^1, z) - g(0, z)$.

3.2. Analytical framework of impact evaluation

To assess the impact of the adoption of NERICA varieties on productivity and income, the potential outcomes framework is used in a statistically robust fashion with a minimal set of assumptions compared to other available methods such as the structural econometric approach (Diagne *et al.*, 2013; Diagne, 2006). The potential outcome framework is increasingly becoming the standard for assessing the impact of programs or policy interventions (see, for example, Imbens and Wooldridge, 2009 for a review).

Under the potential outcome framework, each population unit with an observed outcome *y* has *ex-ante* two potential outcomes: an outcome when receiving a treatment and an outcome when not receiving a treatment. Here, the treatment is adoption of at least an NERICA variety *j*. Let D_j be the binary variable indicating the adoption of NERICA variety *j* with $D_j = 1$ indicating adoption (i.e. $d_j = d_j^1$) and $D_j = 0$ indicating non adoption by a population unit (i.e. $d_j = 0$). Also, let $y_1 \equiv g(d_j^1, z)$ and $y_0 \equiv g(0, z)$ be the potential outcomes corresponding to the two mutually exclusive states of adoption and non-adoption, respectively. For any population unit, the causal effect of adopting an improved variety on the outcome y is defined as: $y_1 - y_0$. However, the two potential outcomes cannot be observed at the same time. With the observed outcome y given by $y = D_j y_1 + (1 - D_j) y_0$, we can only observe either y_1 or y_0 depending on whether D_j equals 1 or 0., thus making it impossible to measure $y_1 - y_0$ for any population unit. However, the average causal effect of adoption within a specific population can be determined: $E(y_1 - y_0)$, with E as the mathematical expectation. Such a population parameter is called the average treatment effect (ATE) in the literature (Heckman and Vytlacyl, 2005; Wooldridge, 2002; Heckman, 1996; Angrist *et al.,* 1996). One can also estimate the mean effect of adoption on the sub-population of adopters: $E(y_1 - y_0 \mid D_j = 1)$, which is called the average treatment effect on the treated and is usually denoted by ATT. The average treatment effect on the *untreated*: $E(y_1 - y_0 \mid D_j = 0)$ denoted by ATU is also another population parameter that can be defined and estimated. However, in the case of an endogenous treatment like what we have here with adoption, ATE, ATT and ATU are often not identified and therefore cannot be estimated (Imbens and Wooldridge, 2009). In this case, one can identify the *local average treatment effect* (LATE) introduced by Imbens and Angrist (1994). LATE assumes the existence of at least one instrumental variable V that explains treatment status but is redundant in explaining the outcomes and is defined as the mean impact in the subpopulation of "compliers" who are defined as the population units who were induced to change treatment status by the instrument v: *LATE*= $E(y_1 - y_0 \mid C(v))$, where $C(v)$ is the complier subpopulation with respect to (Heckman and Vytlacil, 2005; Imbens, 2004; Abadie, 2003; Imbens and Angrist, 1994). We should note that in the case where the population unit of impact analysis is the village and y is the village poverty headcount index, ATE is the mean reduction in the percentage of poor people in the village. Similarly for ATT, ATU and LATE.

Identification and estimation of ATE, ATT, ATU and LATE under alternative assumptions.

The population means impact parameters ATE, ATT, ATU and LATE can generally be identified under some statistical independence assumptions between the population distributions of the treatment status variable D_j and the two potential outcomes $y_1 = g(d_j^1, z)$ and $y_0 = g(0, z)$ (possibly conditional on some observed component z' of z), without making any functional form assumption about the (structural) relationship $y = g(d, z)$. Two alternative statistical independence assumptions are made to identify ATE, ATT and ATU (see, for example Imbens and Wooldrige [2009]).[4] The *unconditional independence* assumption and the *conditional independence* assumption are also called "selection on observables".

When one of the two independence assumptions cannot be made, we are under the case of "selection on unobservables" and ATE, ATT and ATU cannot be identified without making

[4] These independence assumptions are accompanied by some regularity conditions on the support of the conditional and unconditional distribution of D_j (see Imbens and Wooldridge, 2009)

additional functional form assumptions (Heckman and Vytlacil, 2005). Under all circumstances (unconditional independence, "selection on observables" or "selection on unobservables") the LATE parameter can be identified using instrumental variables methods and estimated by: 1) the wald estimator; 2 Stage least squares estimators; or 3) the Abadie (2003) local average response function (LARF) and weighing least squares or maximum likelihood estimator (Angrist and Pischke, 2009; Imbens and Angrist, 1994; Abadie, 2003). Depending on the outcome in question, valid instruments can be found among variables in the observed component z using exclusion restrictions implied by the agricultural household maximization and knowledge of the institutional context in which the NERICA varieties were disseminated and made accessible to farmers.

In this paper, since the adoption variable is endogenous, the LATE parameter is estimated with the combined variable of awareness and access to seed of a NERICA variety as instrumental variable. With this non-random instrumental variable in the target population, the OLS with interaction local average response function (LARF) is used to estimate the LATE parameter for the impact of NERICA varieties adoption on rice yield and household income.

3.3. Study site, sampling and data

The study was carried out in five Communes[5] in Benin, the pilot sites of the MNRDP: Dassa-Zoumè and Glazoué in central Benin, and Tanguieta, Matéri and Cobly in Northern Benin. Rice production in Benin was 150,604 tonnes of paddy in 2010 on 40,274 hectares. Moreover, the Central and Northern regions are the two major upland rice growing areas, providing 58% of the total rice production in Benin .

In accordance with the recommendation of statisticians, as revealed by Khandker *et al.* (2010), this study adopted a two-step stratification approach to improve the internal and external validity. In the first step, villages were selected from Communes and, in the second stage, famers from villages. Only one rice farmer was selected per household. This allowed us to collect household-level information. The importance of rice and the accessibility of the village were the main criteria used for the village selection. Villages were randomly selected from each group of villages based on the importance of each group. In total, 35 villages were selected: 22 in the central region and 13 in the northern region. On average, 10 rice producing households were randomly selected from each village and 361 such households were surveyed for the *ex-post* impact assessment study. However, due to problems with the quality of data, only 342 households were used.

Data were collected at village and producer levels. The data collected are related to community infrastructures, community-based evaluation of rice varieties, prices of major commodities, most popular non-agricultural activities in the village, plot sizes, areas and yield by variety, type of rice variety planted, farmer knowledge and use of rice varieties, inputs use, mode of access to

[5] The term "Commune" is a territorial unit in Benin regrouping many villages.

seed and their management, production and agricultural income, non-farm income and assets food intake, children's schooling and health, etc.

4-Results and discussion

4.1. Descriptive statistics by treatment status

Evidence from Table 1 shows that 64.61% of the interviewed farmers are female. Only 44.74% of rice farmers, including 58.17% of female farmers, have adopted NERICA. This reveals that female farmers have adopted NERICA more than male farmers. The NERICA adopters are, on average, 47 years old compared to 46 years for the non-adopters. There is no significant difference in farmers' age either over adoption status or farmers' gender. Concerning the education level of rice farmers, there is a significant difference between NERICA adopters and NERICA non-adopters. Adopters have, on average, two years of formal education compared to one year for the non-adopters. This reveals that NERICA adopters are better educated than non-adopters. The analysis across gender shows male farmers with a higher educational level than female farmers. As regards the farmers' marital status, 81.57% of farmers are married. The comparison over gender reveals that more male rice farmers are married than female rice farmers. On average, there are six persons per household and the difference in the size of households is significantly different between genders and NERICA adoption status. Households headed by male farmers are larger than those headed by female famers and the adopting households are larger than those of non-adopters.

Agriculture is the principal activity for 95% of surveyed farmers. Rice is one of the major crops grown and is an important source of income for the farmers; it represents 44% of their annual agricultural income and is an important component of their diet. About half (52.92%) of rice farmers were trained in agriculture; the proportion of men trained in agriculture is higher than that of women and more adopters have been trained than non-adopters. Most (76.90%) of the farmers belong to one association or the other and 43.27% of them are in contact with the CeRPA (public extension service). Being in contact with the agricultural extension services is supposed to facilitate a better awareness and access to agricultural technologies. It should be noted that there are more men belonging to an association and being in contact with the CeRPA than women. In addition,71.07% of men have access to seed of NERICA varieties against 61.1% for women, with an access rate of 64.6% for the whole sample.

Table 2 shows that adopters and non-adopters differ significantly in terms of their rice farm size and labor use. NERICA adopters use more land and less labor for rice than the NERICA non-adopters. In addition, there is no significant difference in the use of seeds, fertilizers and pesticides over adoption status. Male farmers use more land and less labor than female farmers. This shows that land issue is still a problem between male and female farmers. Indeed, in most of the regions in Benin, women do not inherit land; this could explain the smaller size of land used by women for rice cultivation.

The average rice yield was 1889 kg per hectare (Table 3) and yield was not affected by adoption status or farmers' gender. This can be explained by the fact that farmers who did not adopt NERICA varieties may adopt other high-yielding improved varieties, which may increase their overall rice yield. Rice farmers gained an average of 75,507 FCFA (US$ 168) per capita per year; the gain was higher for NERICA adopters (92,095 FCFA or US$ 205) than NERICA non-adopters' (62,079 FCFA or US$ 138). Male-headed households gained significantly more per capita income (difference of 21,774 FCFA or US$ 48) than women-headed households. This might be explained by the fact that men had larger farms and adopted NERICA varieties more than women. However, as already explained above, the mean differences of outcomes between NERICA adopters and NERICA non-adopters cannot give the causal effect of NERICA adoption.

4.2. Impact of NERICA adoption on farmers' yield

The impact of NERICA adoption on rice yield was estimated using the Local Average Response Function (LARF) OLS regression model with interaction with the adoption variable. Evidence from Table 4 shows that the gender of farmers and contact with the public extension service positively affect yield while training in agriculture and being from the Central region negatively affect the rice yield. The interaction between age of farmers, being in the lowland ecology and being from the Central region of Benin positively affect farmers' rice yield. Contact with rice extension services give farmers access to information on farm operations management skills, technical assistance training and advice.

Table 5 presents the values of local average treatment effect (LATE) for the whole sample, male farmers and female farmers. LATE values are positive and statistically different from zero for all the categories, suggesting that NERICA adoption has a positive impact on farmers' yield. Farmers obtained an additional yield of 678 kg per hectare by adopting NERICA rice varieties. This impact value is lower than that reported by Adégbola *et al.* (2006). Indeed their study indicated a positive impact of NERICA adoption on yield of 1586 kg of paddy per hectare among potential adopters in 2003. Our findings are also in contrast to those from a similar study in Côte d'Ivoire (Diagne, 2007) that found a negative impact of NERICA adoption on yield - NERICA adopting farmers harvested 250 kg of paddy per hectare less than non-adopters (statistically different from zero at the 1% level). However, our finding is higher than those reported in the same year in Mali, Gambia and Nigeria by Diagne *et al*. (2013) where the additional yields were 554 kg per hectare, 440 kg per hectare and 203 kg per hectare, respectively. All these findings confirm the fact that NERICA rice varieties can really enhance the productivity of African rice farmers, and by extrapolation rice production in Africa, and therefore reduce rice importation by African countries.

In this study, the impact of NERICA adoption was higher for women than for men – women adopters increased their yield by 866 kg of paddy per hectare compared to 391 kg of paddy per hectare for male adopters This indicate an overall significant degree of heterogeneity in the impact of NERICA adoption in the subpopulation of potential and actual adopters. This could be explained by the fact that, before adopting NERICA varieties, most of the female upland rice farmers obtained low yield with the traditional varieties and the adoption of the high-yielding NERICA varieties, significantly increased their total rice output per hectare. The same tendency was reported by Diagne *et al. (*2012) in Mali and Nigeria, confirming that female rice farmers benefit more than men from adopting NERICA rice varieties.

4.3. Impact of NERICA adoption on farmers' income

The results of LARF OLS regression with interaction model for farmers' household income are summarized in Table 6, which shows that NERICA adoption, age of farmer, living in a PVS village and lowland ecology determine household income per capita. The significant positive value of the NERICA adoption variable indicates that the adoption of NERICA has a positive impact on farmers' household income per capita. The influence of "age of farmer" and "living in a PVS village" on household income per capita is positive while that of "lowland rice" is negative. This means that income increases with the farmer's age, farmers who live in a PVS village earns a better income than those who live in a non-PVS village, while farmers lowland rice farmers have a lower income increase than their upland counterparts.

Table 7 shows the impact of NERICA adoption on per capita annual household income and disaggregated by gender. The values of LATE are positive and statistically different from zero, thus confirming that the adoption of NERICA have a positive and significant impact on farmers' per capita household income. The LATE value of 35,250 FCFA (US$ 72) per capita for the whole sample indicates that potential NERICA adopters gain an additional 35,259 FCFA (US$ 72) per capita. In others words, the adoption of NERICA induced on average US$ 72 on rice farmers per capita household income. This impact is lower than that reported by Diagne et al (2012) in a similar study in the same year in Ghana and by Dontsop Nguezet *et al.* (2011) in Nigeria but higher than those found in the same study by Diagne *et al.* (2012) in Mali and Nigeria. Nevertheless, the findings in all of these countries studies show a positive and significant impact of NERICA adoption on per capita annual household income, indicating that NERICA rice varieties can effectively improve farmers' livelihood in Africa.

Table 7 also reveals that the additional per capita household income for women (49715 FCFA (US$ 101) is higher than for male farmers (11027 FCFA (US$ 23). This suggests that female rice farmers gain more than men from the adoption of NERICA varieties.

5. Conclusion

NERICA varieties were developed to boost rice production by improving the productivity and income of the poor upland rice farmers in sub-Saharan Africa. To ensure the efficiency and performance of this new technology, it was important to assess the impact of its adoption on the target population. This paper assessed the gender differential impact of NERICA adoption on farmers' productivity and income. Findings show that NERICA adoption has a positive and significant impact on farmers' production and income. Potential adopters of NERICA increased their yield by 678 kg of paddy per hectare and their per capita income by 35250 FCFA (US$ 72). These results were explained by the higher potentialities of NERICA varieties compared with the existing upland rice varieties. Thus NERICA have the potential to enhance farmers' productivity and income, thereby increasing rice production and farmers' household welfare if they are cultivated in the appropriate conditions. Furthermore, we found that the impact of NERICA varieties is higher for women than for men, probably because male farmers previously had substantial income from improved varieties and were reluctant to adopt the new NERICA varieties while female farmers, with low income from their marginal land and resources, were more keen to adopt the new varieties. This highlights the importance of checking for the heterogeneity of impacts in impact assessment studies for group-targeted policy implications. The findings suggest that it would be more profitable to target women in NERICA upland dissemination. Extending the diffusion of NERICA varieties to the other rice growing areas of Benin can effectively increase rice production, improve farmers' household livelihood, and therefore reduce poverty among rice farmers. As noted by Morris *et al.* (1999), improved technology is certainly a requirement for changing farming practices, but elements such as effective extension services, improved access to land, an efficient input distribution system and appropriate economic incentives must also be added.

Tables

Table 1 : Farmers' socioeconomic characteristics by gender and adoption status

	Male			Female			Total		
	Adopter	**Non-adopter**	**All**	**Adopter**	**Non-adopter**	**All**	**Adopter**	**Non-adopter**	**All**
Number of observations	**64**	**57**	**121**	**89**	**132**	**221**	**153**	**189**	**342**
Proportion of farmers (%)	52.9	47.1	35.4	40.3	59.7	64.6	44.7	55.3	100
Age (years)	45	49	47	46	45	46	46	46	46
Household size	7	6	7	6	5	5	6	5	6
Percentage of married	96.9	96.5	96.7	68.2	80.9	73.3	87.6	76.7	81.6
Percentage that have access to NERICA varieties	100	38.6***	71.07	100	34.8***	61.1	100	36***	64.6
Land area cultivated (ha)	1.30	0.55***	0.95	0.71	0.42***	0.54	0.96	0.46***	0.68
From ethnic « Idatcha »	40.6	36.8	38.8	52.8	39.4*	44.8	47.7	38.6*	42.7
Number of years of residency in the village	3	3	3	1	1***	1	2	1***	1.52
Primary education (%)	54.7	49.1	52.1	9.8	21.3**	14.5	21.7	35.3***	27.8
Secondary education (%)	14.6	12.3	13.2	3.4	1.5	2.3	7.8	4.8	6.1
Agriculture as major activity (%)	96.9	100	98.35	95.5	94.7	95.5	96.1	96.3	96.2
Having mobile phone (%)	64.1	40.3***	52.9	39.3	26.5**	31.7	49.7	30.7***	39.2
Watching TV (%)	23.4	8.8**	16.5	18	9.1**	12.7	20.3	9***	14.0
Listening to radio (%)	87.5	75.4*	81.8	62.9	53.0	57.0	73.2	59.8***	65.8
Receiving agricultural training (%)	71.9	54.4**	63.6	60.7	37.9***	47.1	65.4	42.9***	52.9
Practicing upland (%)	50	8.8***	30.6	39.3	7.6***	20.4	43.8	7.9***	24
Practicing lowland (%)	85.9	93	89.3	86.5	90.1	88.7	86.3	91	88.9
Membership in association (%)	90.6	70.0***	81	79.8	71.2	74.7	84.3	70.9***	76.9
Contact with CeRPA (%)	62.5	40.3**	52.1	55.0	27.3***	38.5	58.2	31.2***	43.3

NB: T-test was used to test for differences in socioeconomics characteristics between adopters and non-adopters.
*Legend: * significant at 10%; ** significant at 5% and *** significant at 1%.*
Source: AfricaRice/PAPA 2010, NERICA impact assessment survey.

Table 2: Inputs utilization level for all improved and NERICA varieties by male and female farmers.

Average of:	Men *n=121*	Women *n=221*	Adopters *n=153*	Non-adopters *n=189*	All *n=342*
Land area (ha)	0.95 (0.09)***	0.54 (0.05)	0.96 (0.09)***	0.46 (0.03)	0.68 (0.05)
Seeds (kg/ha)	61.83 (2.39)	60.78 (2.37)	61.83 (2.39)	60.78 (2.37)	61.25 (1.69)
Fertilizer (kg/ha)	275.74 (40.23)	220.51 (20.44)	235.54 (31.22)	218.10 (24.39)	225.90 (19.39)

Herbicides (l/ha)	1.05 (0.83)	1.41 (0.80)	1.05 (0.66)	1.47 (0.93)	1.28 (0.59)
Labor (man. days/ha)	213.72 (25.85)***	339.55 (26.27)	199.16 (17.28)***	372.64 (31.39)	295.03 (19.53)

Robust standard errors in parentheses

******=Significant at 1%, **= significant at 5%, *=significant at 10%.***

Table 3: Comparison of yield and average income by farmers' adoption status and gender

	Adopter (153)	Non-adopter (189)	Male (121)	Female (221)	All (342)
Yield (kg/ha)	1905.41 (1146.25)	1876.202 (1126.08)	1969.20 (1089.05)	1845.51 (1157.30)	1889.27 (1133.57)
Income (FCFA/ capita)	92094.55*** (130577.55)	62079.41 (77261.11)	89577.54* (136988.41)	67803.58 (82602.70)	75507.24 (105425.74)

Robust standard deviation in parentheses

****=Significant at 1%, **= significant at 5%, *=significant at 10%.*

Table 4: Results of LARF OLS regression model of rice farmers' yield

	Rice yield with Awareness and access to NERICA
NERICA adoption in 2009 dummy	-3505.53***
Age of farmer	-13.28
Gender of farmer dummy	862.4**
Contact with CeRPA	937.06***
Having secondary activity dummy	-74.44
Being in lowland ecology dummy	-623.03
Receiving training in agriculture	-697.53**
Being from Collines region dummy	-612.57**
Household size	-136.13
age X adoption	10.46***
Gender of farmer X adoption	-1326.15
Secondary activity X adoption	175.7663
Lowland ecology X adoption	1867.57***
Training in agriculture X adoption	1615.98***
Being from Collines X adoption	

Household size_adoption	293.45***
Number of observations	159
R-squared	0.5202
Adj R-squared	0.4709
Wald test for the joint significance of all coefficients	F(15,143) =10.36***
Wald test for the coefficients of the non-interacted terms	F(2,143) = 7.8e+10***
Wald test for the coefficients of the interacted terms	F(1,143) = 1.9e+10***

Robust standard errors in parentheses

****=Significant at 1%, **= significant at 5%, *=significant at 10%.*

Table 5: Local Average treatment effect (LATE) for farmers' rice yield

	LATE for yield (kg/ha)
Male farmers	391***
Female farmers	866***
All farmers	678***

Robust standard errors in parentheses

****=Significant at 1%,*

Table 6: Results of LARF OLS regression model for farmers household' income

Variables	Equation for NERICA	
Adoption of NERICA	163625.4* (86279.25)	
Age	3115.329** (1326.447)	
Second activity	-18790.92 (33223.21)	
Education level	43483.03 (28849.45)	
Have training in agriculture	29179.98 (33653.16)	
Living in PVS village	-11398.51 (63854.71)	
Lowland rice	-182731.3*** (54269.8)	
Age X adoption	-5930.046*** (1575.54)	
Second activity X adoption	17654.15 (37722.54)	
Education level X adoption	-53737.97* (30610.77)	
Have training in agriculture X adoption	-22924.98 (38196.57)	
Live in PVS village X Adoption	-522.6188 (66213.58)	
Lowland rice X adoption	191718.7*** (59083.85)	
Number of observations	*178*	*178*
F(13, 164) / (13, 164)	*3.23*	*5.62*
Prob > F	*0.0002*	*0.0000*

R-squared	*0.2037*	*0.3081*
Adj R-squared	*0.1406*	*0.2533*
Root MSE	*94440*	*89195*

Robust standard errors in parentheses

****=Significant at 1%, **= significant at 5%, *=significant at 10%.*

Table 7: Local average treatment effect (LATE) for farmers' household per capita income

	LATE for per capita household income (FCFA)
Male	11027*** (3507)
Female	49537*** (6087)
All	35250*** (5050)

Robust standard errors in parentheses;

****=Significant at 1%, **= significant at 5%, *=significant at 10%.*

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