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

By Kinkingninhoun-Medagbe Florent Mahoukede1, Diagne Aliou[2] and Agboh-Noameshie Rita A. [1],

1: Africa Rice Center, Benin; 2: University of Gaston Berger, Senegal

This paper analyzes the gender differential impact of NERICA adoption on rice yield and farmers' annual household income using data from 342 rice farmers in Benin. NERICA varieties have been developed by AfricaRice which won its creator Monty Jones the 2004 World Food Prize. The paper applies the potential outcomes framework to estimate the Local Average Treatment Effect (LATE). The results show that NERICA adoption has positive and significant impact on farmers' yield and household per capita income. The impacts of NERICA adoption are not homogeneous across farmers' categories and are higher for female farmers than male farmers. The findings suggest the widely dissemination of NERICA varieties, mainly upland NERICA, with a focus on women, in order to increase rice productivity and consequently total production and income.

***Keywords**: Impact, LATE, productivity, Income, NERICA, Rice, Benin, West Africa*

***JEL classification codes:** C13, O33, Q12, Q16*

1. Introduction

NERICA (New Rice for Africa) 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, is an interspecific hybrid between local African rice (Oryza glaberrima) and Asian rice (Oryza sativa). It offers new opportunities for upland rice farmers (Diagne *et al*., 2013; Akakpo and Assigbè, 2005; WARDA, 2001). NERICA varieties have been introduced in Benin in 1998 through participatory varietal selection (PVS) approach. In addition, the African Development Bank (AfDB) funded project, Multinational NERICA Rice Dissemination Project (MNRDP), had 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, male and female.

The Association of Women's Rights in Development (AWID) (2004), Jacoby (1991) and von Braun et al (1989) argued that any change in farm systems affects men and women differently. According to Kokki (1997), this is partly due to the differences in perception regarding technology that exist between women and men in farm households. Women not only perceive technology in terms of its workability aspect but also consider aspects of 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, they emphasized that "*targeting women in agricultural technologies dissemination, can have a greater impact on poverty reduction and food security than targeting men*" (IFPRI, 2005)

During the last three decades, a large and growing literature has been developed with 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, in 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 or have been discriminated against in distribution of production resources (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 position with regard to resources control and decision making is a gender relationship and 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 *et al.,* 1989).

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

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

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

The New Rice for Africa (NERICA) are the result of the inter-specific 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, the NERICA 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 is well known to have a much shorter growth cycle than most farmer varieties (up to 30 days shorter) and this attribute is almost always the first one cited by farmers when they are 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 been formed to boost rice production, including the African Rice Initiative (ARI) which was established in 2002 to promote the dissemination of the NERICA in several 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 "*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 in the Central and Northern Benin. In addition, these varieties have been widely disseminated by the Multinational NERICA Rice Dissemination project from 2006 to 2010. During the implementation of this project, the PVS trials were conducted from 2006 to 2008 in 5 communes: Dassa-Zoumè and Glazoue in Central

[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.
[2] Benin's National Agricultural Research Institute.

Benin and Materi, Cobly and Tanguieta in Northern Benin involving about a thousand of rice farmers. Among the ten rice varieties finally selected by farmers at the end of the process (field trials, organoleptic test, etc.), five NERICA varieties were disseminated through field days, seed distribution, etc. The five NERICA varieties selected by farmers are NERICA1, NERICA2, NERICA4, NERICA8 and NERICA18. All these varieties are upland rice varieties. The objective was to disseminate NERICA rice varieties in Benin in order to improve farmers' livelihood through the adoption of high-yielding varieties. In a study conducted in 2004, Adégbola *et al.* (2005) found 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 adoption of NERICA varieties on household productivity and income is based on the agricultural household model framework. Any agricultural household make 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:

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

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

[3] See, for example, Just, Hueth and Schmitz (2004), Chapter 7, appendix 7G for a very general formulation of the Agricultural household model.

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 and Milgrom *et al.*, 1994). But here we will call it a conditioning variable to differentiate it with 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, sex, 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 and which is noted 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 function of $a_{\dot{N}}$ in addition to the conditioning vector z. Consequently, we can write the expression of the factor productivity for the kth input other than seed (k=2,..,K) as a function of $a_{\dot{N}}$ and z are given similarly:

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

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 is 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 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 sides 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 $a^1_{\dot{N}} > 0$. Hence, the causal effect of NERICA adoption on any outcome $y = g(a_{\dot{N}}, z)$ is measured by the difference $g(a^1_{\dot{N}}, z) - g(0, z)$.

3.2. Analytical framework of impact evaluation

The impact of NERICA adoption is analyzed through the Sustainable Livelihood Framework (SLF) developed by DFID and its collaborators (Solesbury, 2003; DFID, 2001). As in every society, individual households in Benin are endowed with human capital (households' members' skills, aptitudes, knowledge, etc.), natural capital (the quality and quantity of natural resources available like land, water, etc.), physical capital (infrastructure (road, electricity, markets, etc.), technologies such as NERICA varieties, tools, and equipment used for increasing productivity), social capital (networks for cooperation, mutual trust, and support, etc.) and financial capital (savings and regular inflows of money including credit), which constitute the resource constraint based on which they maximize their livelihood. Bringing new rice varieties such as NERICA (change in physical capital) to farmers and making them aware of these varieties affects the rice farmers' knowledge, skills, perception, beliefs expectations and preferences (change in human capital). This is because, based on the characteristics of NERICA varieties and possibility to get their seeds to cultivate, farmers believe that cultivating these new varieties would increase their yield and therefore they anticipate strong benefit. Therefore, household decision to adopt NERICA varieties constitutes the farmers' behavioral outcomes, which will affect their productivity and income, and finally their livelihood (livelihood outcomes).

To assess the impact of 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 state 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 equal 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. The 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 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, then 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).[4] The *unconditional independence* assumption and the *conditional independence* assumption also called "selection on observables".

When one of the two independence assumptions cannot be made then we are under the case of "selection on unobservable" and ATE, ATT and ATU cannot be identified without making additional functional form assumptions (Heckman and Vytlacil, 2005). Under all circumstances (unconditional independence, "selection on observables" or selection on unobservable") the LATE parameter can be identified using instrumental variables methods and estimated by 1) the wald estimator, 2 Stage least squares estimators or 3) by use of the Abadie (2003) local average

[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)

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 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 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. The rice production in Benin was 150.604 tons of paddy in 2010 on 40.274 hectares. Moreover, the Central and Northern regions are found to be the two major upland rice growing area in Benin providing 58 % of the total rice production of the country.

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 randomly selected from the list of rice producing villages in Communes, and in a second stage the famers were randomly selected from the list of rice farmers in each selected village. The importance of rice, the accessibility to the area and the participation of the village to participatory varietal selection (PVS) activities were the main

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

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 villages in the central region and 13 villages in the northern region. Ten household on average were randomly selected from each village among all the rice farmers in the village. In total, 361 rice producers' households were surveyed for the ex-post impact assessment study. However, 342 households' data were validated and used for this study.

Data were collected at village and producer levels. 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, plots size, areas and yield by variety, type of rice variety planted, farmer knowledge and use of rice varieties, inputs use, mode of access to 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 more adopted NERICA than male farmers. The NERICA adopters are, on average, 47 years old while the non-adopters are on average 46 years old. There is no significant difference in farmers' age either over adoption status or farmers' gender. Concerning rice farmers' attendance to primary school, there is a significant difference between NERICA adopters and NERICA non-adopters. Adopters have in average, 2 years of formal education while the non-adopters have just one year. This reveals that NERICA adopters are better educated than non-adopters.. The analysis across gender shows male farmers with higher educational level than female farmers. As regards the farmers' marital status, 81.57% of farmers are married. The comparison over sex reveals that more male rice farmers are married than female rice farmers. The average size of the households is 6 persons and significantly different not only according to the gender of farmers, but also to NERICA adoption status. The households with male farmers have higher size than those with female famers and the adopting households have higher size than those of non-adopters. As regards the economic activities, for the 95% of surveyed farmers, agriculture is the principal activity. Rice is one the major crops grown and is an important source of income for the producers. It represents 44% of their annual agricultural income and it is an important component of their diet. 52.92% of rice farmers were trained in agriculture. The proportion of men trained in agriculture is higher than women. It is the same when considering the adoption status. 76.90% of producers belong to an association 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. 71.07% of men have access to NERICA seeds against 61.1% for women, or 64.6% for all producers. There is a difference in access to seeds, between sex and between adoption status.

Table 2 shows that there is a significant difference on rice area cultivated and labor use between adopters and non-adopters. NERICA adopters use more land for rice and less labor than the NERICA non-adopters. In addition, there is no significant difference in seeds, fertilizers and pesticides use over adoption status. As regards the comparison over gender, 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, what could explain the small size of land women are using for rice cultivation.

Furthermore, the comparison of rice yield by adoption status and gender of farmer in Table 3 shows an average rice yield of 1889 kg per hectare. However, there is no significant difference in rice yields over the adoption status or over farmers' gender. This can be explained by the fact that the farmers who did not adopt the NERICA varieties may adopt other high-yielding improved varieties, which may increase their overall rice yield. Furthermore, the rice farmers gained, on an average 75,507 FCFA (US$ 168) per capita per year. The comparison over the status of adoption reveals that NERICA adopters' households got higher annual per capita income (92,095 FCFA (US$ 205)) than NERICA non-adopters' households (62,079 FCFA (US$ 138). There is also a significant difference of 21,774 FCFA (US$ 48) per capita between male and female farmers revealing that male farmers' households gained more per year from rice cultivation than female farmers' households. This might be explained not only by the difference between men and women in land using, but also the adoption of NERICA varieties. However, as we 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 sexual category of farmers and contact with the public extension service

are positively affecting the yield while receiving training in agriculture and being from the Central region are negatively affecting the rice yield. As regards the interaction terms, age of farmers, being in lowland ecology and being from the Central region of Benin interaction terms are positively affecting farmers' rice yield. The farmers' contact with rice extension services allows them to have information on farm operations management skills, and 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. The LATE values are positive and statistically different from zero for all the categories suggesting that NERICA adoption has positive impact on farmers' yield. Farmers are getting on average 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 an impact of NERICA adoption on yield of 1586 kg of paddy per hectare among potential adopters in 2003. In 2004, the These findings are also in contrast to those from a similar study in Côte d'Ivoire (Diagne, 2007) that gave negative impact of NERICA adoption on yield. NERICA adopting farmers got the lower rice yield and the difference was 250 kg of paddy per hectare (statistically different from zero at the 1% level). However, this impact finding is higher than those found 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 then the rice production in Africa, and therefore reduce rice importation in African countries.

The gender analysis of the impact gives higher impact for women compared to men. NERICA adoption increases the female potential adopters' rice yield by 866 kg of paddy per hectare while the yield increases is 391 kg of paddy per hectare for male potential adopters. This reveals that female farmers gained more in them of yield by adopting NERICA rice varieties. 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, most of the female rice farmers producing rice in upland ecology, were experiencing lower yield with the

traditional varieties in this ecology. So, the adoption of NERICA varieties, which are high-yielding varieties, significantly increases their total rice output per hectare. The same tendency is found by Diagne *et al. (*2012) in Mali and Nigeria confirming that female rice farmers are benefiting more from NERICA rice varieties

4.3. Impact of NERICA adoption on farmers' income

The results of LARF OLS regression with interaction model farmers household' income are summarized in Table 6. It came out that the factors determining household income per capita are NERICA adoption, age of farmer, living in PVS village and lowland ecology. The significance and positive value of 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 PVS village" on household income per capita is positive while that of "lowland rice" is negative. This means that more the farmers are elder, more the income increases. Similarly, if a farmer lives in a PVS village, his income is better than another farmer who lives in a non-PVS village. Regarding the type of rice ecology practiced, farmers who grow rice in lowland ecology have lower income increase than those who are growing rice in upland ecology.

Table 7 gives the impact of NERICA adoption on per capita annual household income and their comparison across the gender of farmer. The values of LATE are positive and statistically different from zero confirming that the adoption of NERICA have a positive and significant impact on farmers' per capita household income. The LATE value is 35,250 FCFA (US$ 72) per capita for the whole sample. This indicates that the potential adopters of NERICA have on average an additional gain of 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 finding is lower than the impact found by Diagne et al (2012) in a similar study in the same year in Ghana and Dontsop Nguezet *et al.* (2011) in another study in Nigeria. However, the impact result is higher than those found in the same study by Diagne *et al.* (2012) in Mali and Nigeria.

This study reports in all the target countries a positive and significant impact of NERICA adoption on per capita annual household income. This indicates that NERICA rice varieties can effectively improve farmers' livelihood in Africa.

As regards the comparison across sexual categories, Table 7 brings out that the additional per capita household income is higher within female farmers than within male farmers. Potential women adopters got 49715 FCFA (US$ 101) per capita while potential men adopters obtained 11027 FCFA (US$ 23) per capita. This suggests that female rice farmers are gaining more from the adoption of NERICA varieties than male rice farmers.

It clearly came out from the study that female rice farmers are benefiting more from NERICA varieties adoption than male rice farmers The findings suggest that targeting women with NERICA can significantly increase rice productivity and consequently total production and income, more, than if the NERICA are targeted at men.

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 assure the efficiency and performance of this new technology after it was developed and released, 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 positive and significant impact on farmers' production and income. The potential adopters of NERICA had a surplus of production of 678 kg of paddy per hectare and had on average an additional gain of 35250 FCFA (US$ 72) per capita. These results were explained by the higher potentialities of NERICA varieties compared with the existing upland

rice varieties. This reveals that NERICA could really enhance farmers' productivity and farmers' income, and therefore increase rice production and farmers' household welfare if they were widely promoted, disseminated and adopted by African rice farmers, and if they are cultivated in the appropriate conditions. Furthermore, we found that NERICA varieties benefit male and female farmers differently. The impacts are higher for female farmers than for male farmers. Female potential adopters of NERICA have a surplus of production of 866 kg of paddy per hectare and an additional gain of US$ 101 per capita while male potential adopters of NERICA have a surplus of production of 392 kg of paddy per hectare and an additional gain of US$ 23 per capita. This can be explained by the fact that male farmers were having substantial income from improved varieties and were reluctant to quickly adopt other varieties. In opposite, the female farmers with low income from their marginal land and resources were more keen to adopt the new varieties. This reveals the importance to check 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 NERICA varieties diffusion to the other rice growing area in Benin can effectively increase rice production, improve farmers' households' 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.

List of Tables and Figures

Table 1 : Farmers socioeconomic characteristics by sexual category and adoption status

	Male			**Female**			**Total**		
	Adopter	**Non-adopter**	**All**	**Adopter**	**Non-adopter**	**All**	**Adopter**	**Non-adopter**	**All**
Number of observation	**64**	**57**	**121**	**89**	**132**	**221**	**153**	**189**	**342**
Proportion of producers (%)	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 have accessed NERICA varieties	100	38.6***	71.07	100	34.8***	61.1	100	36***	64.6
Land area cultivation (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 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: le T-test was used to test for differences in socioeconomics characteristic between adopters and non-adopters.

*Legend: * significatif à 10%; ** significatif à 5% and *** significatif a 1%.*

Source: AfricaRice/PAPA 2010, NERICA impact assessment survey.

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

Average of:	Men	Women	Adopters	Non-adopters	All
	n=121	*n=221*	*n=153*	*n=189*	*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. day/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 parenthesis

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

Table 3: Comparison of yield and average income by adoption status and sexual category of the famer

	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 parenthesis

****=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_ adoption	10.46***
Gender of farmer _adoption	-1326.15
Secondary activity_adoption	175.7663
Lowland ecology_adoption	1867.57***
Training in agriculture_adoption	1615.98***
Being from Collines_adoption	
Household size_adoption	293.45***
Number of observation	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 parenthesis

****=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 parenthesis

******=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 dummy	-18790.92 (33223.21)
Attending primary school dummy	43483.03 (28849.45)
Have training in agriculture dummy	29179.98 (33653.16)
Living in PVS village dummy	-11398.51 (63854.71)
Lowland rice dummy	-182731.3*** (54269.8)
Age _adoption	-5930.046*** (1575.54)
Second activity_adoption	17654.15 (37722.54)
Attending primary school_adoption	-53737.97* (30610.77)
Have training in agriculture _	-22924.98 (38196.57)

adoption		
Live in PVS village_ Adoption	-522.6188 (66213.58)	
Lowland rice_adoption	191718.7*** (59083.85)	
Number of observation	*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 parenthesis

****=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 parenthesis;

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

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