133- WHO BENEFITS MORE FROM NERICA VARIETIES? GENDER DIFFERENTIAL IMPACT ON YIELD AND INCOME IN BENIN

Kinkingninhoun-Medagbe, F.M[1] Diagne, A.[2], Agboh-Noameshie, R. A[3] and Lokossou, J. C

1. Research Assistant, Agricultural Economist, Africa Rice Center (AfricaRice), 01 BP 2031 Cotonou, Benin, Tel: (229) 64 18 13 13; *E-mail: f.medagbe@cgiar.org (Corresponding author).*
2. Program leader, Policy, Innovation Systems and Impact Assessment, Africa Rice Center , 01 B. P. 2031 Cotonou, Benin Tel: (229) 64 18 13 13;*6 E-mail: A.Diagne@cgiar.org*
3. Gender Task Force Coordinator, Africa Rice Center (AfricaRice) , Cotonou, Benin, Tel: (229) 64 18 13 13; *E-mail: a.agboh-noameshie@cgiar.org*
4. Agricultural Economist, Faculty of agronomic sciences, University of Abomey-Calavi Benin; E-mail: lokjour@yahoo.fr

A Paper prepared for the 4th International Conference of the African Association of Agricultural Economists

Abstract

The NERICA varieties are modern rice varieties developed by AfricaRice which won its 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 examines the gender differential impact of NERICA adoption on the yield and farmers' household annual income using data from 342 rice farmers from Benin. It applies the potential outcomes framework to estimate the Local Average Treatment Effect (LATE) of NERICA adoption on farmers' rice yield and households' income. Evidence from the results shows that NERICA adoption has positive and significant impact on farmers' yield and per capita annual households' income. The impacts of NERICA adoption are not homogeneous across farmer gender and geographical area. The impact on rice yield is higher for female farmers potential adopters while the impact on per capita annual household income is higher for male farmers potential adopters. Concerning the geographical area, the impact on rice yield is higher for potential adopters from Central Benin while the impact on per capita annual household income is higher for potential adopters from Northern Benin. The findings suggest to impact assessment specialists to estimate not only the impact of technologies for the whole target population, but also for the different social groups inside the population. This will allow them to better understand the benefit of the technology to each group.

Keywords: *Impact, gender, LATE, productivity, Income, NERICA, Rice, Benin*

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

1- Introduction

In their effort to support rural populations in developing countries in poverty reduction and food security, financial institutions such as The World Bank put a special emphasis on rice intensification in Sub-Saharan African countries. This statement is more true when we consider the recent world rice crisis with the drastic increase in rice price these last years in these countries. To achieve this intensification, many agricultural technologies have been developed and released to farmers. These technologies aim to improve farmers' productivity, income and livelihood through some changes in farm systems. One of these technologies is new rice varieties such as the NERICA (New Rice for Africa), which were developed by the Africa Rice Center in collaboration with the national agricultural research systems (NARS)..

Indeed, the NERICA varieties are the result of interspecific crosses between *Oryza sativa* high yielding rice species from Asia and the locally adapted and multiple-stress resistant *Oryza glaberrima* African rice species. With their high yield potential and their adaptability to African conditions, NERICA varieties provide a great hope for African agriculture in general and for upland rice farming in particular (Akakpo and Assigbè, 2005; WARDA, 2001). In Benin, the first experimental field tests on NERICA began in 1998 with "participatory varietal selection" (PVS) approach in Glazoué's Commune (Collines' Department). Since their introduction in Benin, just as in many other African countries, the NERICA have been widely adopted (Adégbola *et al.*, 2005).

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, conscious of 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)

Indeed, 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 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 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 is an attempt to test the hypothesis that although the NERICA varieties are being widely adopted by both male and female farmers, the impact is not homogenous.

The objective of this study is to test the homogeneity of the impact of NERICA adoption across gender in Benin. The impact factors targeted by the paper are rice yield and household income. The paper is organized as follows: After the introduction section, section 2 outlines the theoretical approach of impact assessment and a description of the data used. Section 3 presents the results and discussion on assess the contribution of NERICA adoption to of male and female rice farmers, while conclusions and policy implications are presented in section 4.

2. Methodology

2.1. 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 to the farming communities 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 Central (Department of Collines) and North (Department of Atacora) started from 2005 in the framework of the Multinational NERICA Rice Dissemination project. Indeed, the PVS trials were conducted between 2005 and 2008 in 5 communes, Dassa-Zounme and Glazoue in Central Benin and Materi, Cobly and Tanguieta in North 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 et NERICA4, NERICA8 and NERICA18. The objective was of the introduction and dissemination of NERICA rice varieties is to improved farmers' livelihood through the adoption of high-yielding varieties. The subsequent adoption studies conducted in Central Benin by INRAB in

[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.

2004 show a NERICA sample adoption rate of 18% and an estimated potential adoption rate of 50% (Adégbola *et al*., 2005), which suggests a high potential demand for NERICA.

2.2. Theoretical framework of impact evaluation

To assess rigorously the gendered impact of adoption of NERICA varieties on productivity and income, the potential outcomes approach 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 variable *y* is used generically to designate any one of the outcome variables defined above. In what follows the population unit of impact analysis can be either the household or the village. Taking the village as the population unit of impact analysis is not only more appropriate for outcome such as poverty, it also allows one to take into account within village interactions and general equilibrium effects (Miguel and Kremer, 2004). Such interactions (among households) and general equilibrium effects are very relevant in the case of adoption in particular as non-adopting farmers are affected the price changes that result from a significant number of farmers adopting an improved variety. However, they are ruled out by the standard stable unit value assumption (SUTVA) made in the potential outcome framework when the household is the unit of impact analysis.

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).[3] 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 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 a

[3] 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)

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.

2.3. Study site, sampling and data

The study was conducted in the framework of assessing the ex-post impact of the Multinational NERICA Rice Dissemination project coordinated by Africa Rice Center. It focused on five Communes[4] in Benin: Dassa-Zoumè and Glazoué in central Benin (Collines' region), and Tanguieta, Matéri and Cobly in Northern Benin (Atacora' region). Production statistics show that 150.604 tons of paddy were produced in Benin in 2010 on 40.274 hectares. Moreover, Zou/Collines' region and Atacora/Donga regions are found to be the two major growing area of upland and lowland rice in Benin with 58 % of the total rice production of the country.

Concerning the sampling, the method used is a two-stages stratification sampling method.. Village was considered as the first stratification level and household the second stratification level. The importance of rice, the accessibility to the area and the participation of the village to participatory varietal selection (PVS) activities 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 villages in Collines Department (central Benin) and 13 villages in Atacora Department (North Benin). 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 through two levels surveys: village and household 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, 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. They were entered in ACCESS and analyzed with Stata software.

Table 1 presents the socio-demographic characteristics of the interviewed rice farmers and their households. The results indicate 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

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

the education level of rice farmers, 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 men with higher educational level than women. As regards the farmers' marital status, 81.57% of the households studied are married. The comparison over gender reveals that more male rice farmers are married that 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 are belong to an association and 43.27% of them are in contact with the public extension service (CeRPA). 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 public extension service (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.

3-Results and discussion

3.1. Land, inputs use comparison

Table 2 compares input use between adopters and non-adopters of NERICA and between male and female farmers. High significant differences are found in 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, Table 2 reveals that 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.

3.2. Rice yield and household income comparison

Comparison of rice yield by adoption status and gender of farmer is presented in Table 3. The results show an average rice yield of 1889 kg per hectare in the surveyed sample. However, there is no significant difference in rice yields neither over the adoption status nor 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.

Table 3 also compares the per capita annual household income by adoption status and by farmers' gender. The rice farmers interviewed 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 men and women, which reveals that male farmers' households gained more per year from rice cultivation than female farmers' households. This could be explained not only by the difference between men and women in land using, but also the adoption of NERICA varieties.

3.3. 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. Table 4 indicate that having reached junior high school dummy variable and having access to credit significantly explain the change in farmers' rice yield. The coefficients of their interacted terms were also statistically significant. These results show that the these two variables are keys socio-demographic factors explaining

farmers' rice yield. Moreover, the impact of NERICA adoption is heterogeneous across these factors.

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 55.37 kg per hectare by adopting NERICA rice varieties. This impact value is too low compared to the one found in Benin in 2003 (+1586 kg of paddy per hectare) by Adégbola *et al.* (2006) and the one found in 2005 (+1272 kg per hectare) by Diagne *et al*. (2013). This comparison show a decrease over years of the value of the impact of NERICA adoption on yield. Furthermore, the impact estimates in 2006 by Diagne *et al*. (2013) in Cote d'Ivoire, Gambia and Guinea show higher estimate in Gambia (134 kg/ha), but lower estimates in Cote d'Ivoire and Guinea. 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 female farmers compared to male farmers. NERICA adoption increases the female potential adopters' rice yield by 67.97 kg of paddy per hectare while the yield increases is 30.12 kg of paddy per hectare for male potential adopters. This reveals that female farmers gained more in term of yield in 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 in these countries.

Concerning the impact analysis over geographical area of farmers, Table 5 shows that NERICA adoption is more profitable for the farmers from central region in terms of productivity increase. The potential adopters from this region have an additional yield of 80.84 kg per hectare while the potential adoption from the Northern region have an additional yield of a 22.50.

3.4. 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, apart from the change in technology used (NERICA adoption), the gender of the farmer is one of the main socio-demographic variables which significantly explain the change in per capita annual household income. The coefficients of the interacted terms of other variables were also statistically significant. These variables are being married, having the commerce as secondary activity and the number of year of experience in rice

farming. 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. Furthermore, the impact of NERICA adoption on yield is also heterogeneous regarding this socio-demographic characteristics of farmers.

Table 7 gives the LATE estimates for the per capita annual household income and their comparison across the farmer gender and geographical area. The values of LATE are all positive and statistically different from zero confirming that the adoption of NERICA have a positive and significant impact on farmers' per capita annual household income. The LATE value is 40,194 FCFA (US$ 110.26) per capita per year for the whole sample. This indicates that the potential adopters of NERICA have on average an additional gain of 40,194 FCFA (US$ 110.26) per capita per year. In other words, the adoption of NERICA induced on average US$ 72 on rice farmers per capita annual household income. This finding is lower than the impact found by Diagne et al (2011) in a similar study in the same year in Ghana and Dontsop Nguezet et al. (2012) 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. These studies report in all the target countries a positive and significant impact of NERICA adoption on per capita household annual income. This indicates that the adoption of NERICA rice varieties can effectively improve farmers livelihood, not only in Benin, but also in other African countries.

Concerning the impact comparison across gender and geographical area , Table 7 bring out that the additional per capita annual household income is higher within male farmers than within female farmers. Potential male adopters got 55261.95 F CFA (US$110.26) per capita per year while potential female adopters obtained 32691.68 F CFA (US$ 65.23) per capita per year. This suggests that male rice farmers are gaining more from the adoption of NERICA varieties than female rice farmers in term of per capita annual household income. The fact that an opposite finding is obtained for yield could be explained by the fact that the additional revenue obtained by male farmers from NERICA adoption, even smaller, would allow them to invest in a secondary activity such as commerce which would have provided to their households more income for the whole year. Furthermore, Table 7 also show a higher LATE estimate for farmers from the Northern region of Benin. They gained 44093.71 F CFA (US$87.97) while the fromers from the Central region obtained 37197.28 F CFA (US$74.21). The same reason mentioned above for the gender comparison finding could explain this result.

4. Conclusion

NERICA varieties were developed to significantly improve 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 necessary to evaluate its impact on the target population in comparison with the expected results. This study that evaluated the gender impact of NERICA adoption on farmers' productivity and income showed that technology benefit farmers differently according to their gender and their geographical area. Indeed, it came out that NERICA adoption have a positive and significant impact on farmers' production and income. The potential adopters of NERICA had a surplus of production of 55.37 kg of paddy per hectare and had on average an additional gain of 40194.93 FCFA (US$ 80.20) per capita per year. 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. The study had also brought out that the impacts of NERICA adoption are not homogeneous across farmers' gender and geographical area. The impact on rice yield is higher for female farmers potential adopters while the impact on per capita annual household income is higher for male farmers potential adopters. Concerning the geographical area, the impact on rice yield is higher for potential adopters from Central Benin while the impact on per capita annual household income is higher for potential adopters from Northern Benin. Thus, NERICA adoption is benefiting male rice farmers and female rice farmers differently, and also farmers from Central region and farmers from northern region differently.

Considering these outcomes, it would be necessary to extend NERICA diffusion to the other rice growing area in Benin to effectively rice production and improve farmers' households livelihood. Introducing and diffusing NERICA varieties in other African countries where they are not yet introduced could really boost rice production in Africa and a constitute a good tool to improve farmers' livelihood and reduce poverty in Africa. The findings also suggest to impact assessment specialists to assess not only the impact for the whole target population, but also for the different social groups inside the population. This will allow them to better understand the benefit of the technology to each group and the impact pathway.

List of 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 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***	71.0 7	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	98.3 5	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 *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	60.78	61.83	60.78	61.25
	(2.39)	(2.37)	(2.39)	(2.37)	(1.69)
Fertilizer	275.74	220.51	235.54	218.10	225.90
(kg/ha)	(40.23)	(20.44)	(31.22)	(24.39)	(19.39)
Herbicides	1.05	1.41	1.05	1.47	1.28
(L/ha)	(0.83)	(0.80)	(0.66)	(0.93)	(0.59)
Labor (man.	213.72	339.55	199.16	372.64	295.03
day/ha)	(25.85)***	(26.27)	(17.28)***	(31.39)	(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 gender of the famer

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

Robust standard deviation in parenthesis

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

Table 4: Estimated coefficient of the OLS local average response function (LARF) for farmers' rice yield

	Coefficient and significance	**Standard error**
NERICA adoption in 2009 dummy	460.70	556.86
Sex of the farmer	101.79	192.21
Having reached junior high school dummy	1088.88***	392.69
Having secondary activity dummy	-93.26	167.63
Having contact with any institution working on rice dummy	195.82	171.29
Number of year of experience in rice farming	116.54	107.68
Having contact with research institute dummy	-1380.71	1132.64
Having access to credit dummy	343.04*	206.75
Sex of the farmer_Adoption	23.59	291.22
Having reached junior high school_Adoption dummy	-1121.11**	565.01
Having secondary activity_Adoption dummy	-30.51	278.66

Having contact with any institution working on rice_Adoption dummy	-402.39	327.18
Number of year of experience in rice farming	38.86	164.71
Having contact with research institute_Adoption dummy	1323.24	1254.24
Having access to credit_Adoption dummy	-649.24**	307.33
Constance variable	1317.79***	337.21

Number of observation	303
R-squared	0.0728
Adj R-squared	0.0264
Wald test for the joint significance of all coefficients	F(15, 287) =1.51 ***
Wald test for the coefficients of the non-interacted terms	F(1, 287) = 1.4e+09 ***
Wald test for the coefficients of the interacted terms	F(1, 287) = 3.0e+07 ***

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

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

		LATE for yield (kg/ha)
Gender	Male farmers	30.12***
	Female farmers	67.97***
Geographical zone	Central Benin	80.84***
	Northern Benin	22.50***
	All farmers	55.37***

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

Table 6: Estimated coefficient of the OLS local average response function (LARF) for per capita annual household income

	Coefficient and significance	**Standard error**
NERICA adoption in 2009 dummy	240445.5***	62180.43
Sex of the farmer	34261.97*	18361.12
Being married dummy	-7808.147	18866.69
Having reached junior high school dummy	-9068.713	37641.12
Having secondary activity dummy	-8884.633	18141.89
Having reached senior high school dummy	-53667.3	108043.4
Having the commerce as secondary activity dummy	29374.01	22141.62
Having contact with any institution working on rice dummy	-12997.79	15621.1
Number of year of experience in rice farming	9176.674	9801.149
Having access to credit dummy	11701.05	18825.35
Sex of the farmer_Adoption	22749.07	28158.49

Being married_Adoption dummy	-129012***	35389.44
Having reached junior high school_Adoption dummy	62052.67	53817.17
Having secondary activity_Adoption dummy	46064.16	29336.33
Having reached senior high school_Adoption dummy	12737.68	153428.5
Having the commerce as secondary activity_Adoption dummy	-79187.99**	34218.23
Having contact with any institution working on rice_Adoption dummy	-11220.07	29833.19
Number of year of experience in rice farming_Adoption	-36854.14**	15169.02
Having access to credit_Adoption dummy	-31397.97	27705.41
Constance variable	37340.75	34575.29
Number of observation	303	
R-squared	0.1642	
Adj R-squared	0.1100	
Wald test for the joint significance of all coefficients	F(19, 283) = 2.93***	
Wald test for the coefficients of the non-interacted terms	F(1, 283) = 4.6e+26 ***	
Wald test for the coefficients of the interacted terms	F(4, 283) = 8.2e+26 ***	

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

Table 7: Local Average treatment effect (LATE) estimates for per capita annual household income

		LATE values for per capita annual household income (FCFA and USD)
Gender	Male farmers	55261.95 (110.26)***
	Female farmers	32691.68 (65.23) ***
Geographical zone	Central Benin	37197.28 (74.21) ***
	Northern Benin	44093.71 (87.97)***
	All farmers	40194.93 (80.20)***

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

The number in brackets are the equivalent number in US dollars with the conversion rate of 1USD=501.2133 FCFA (12/04/2013)

References

Abadie, A. 'Semiparametric instrumental variable estimation of treatment response models', *Journal of econometrics, Elsevier,* vol. 113(2), (2003) pp 231-263.

Adégbola, P., Arouna, A. Diagne, A and Adékambi, S.A. *Déterminants socio-économiques et taux d'adoption et d'intensité d'adoption des nouvelles variétés de riz NERICA au Centre du Bénin*, Paper in publishing, (2005), pp 1-22.

Adégbola, P. Y. , Arouna, A., A. Diagne and S.A Adékambi. *Evaluation de l'impact économique des nouvelles variétés de riz NERICA au NERICA au Bénin : Une évidence avec les modèles basés sur l'approche « contre factuel »*, Paper in publishing, (2006).

Akakpo, C. et Assigbè, P. *Les outils d'intervention développés par la recherche agricole pour améliorer les conditions techniques de production de riz au Bénin*. Rapport, (2005),pp 1-12.

Angrist, J.D. and J.S. Pischke, *Mostly Harmless Econometrics: An Empiricist's Companion*, Princeton University Press(2009).

Angrist, J.D., G.W. Imbens, and D.B. Rubin. 'Identification and Causal Effects Using Instrumental Variables', *Journal of The American Statistical Association*, vol. 91, Nº434, (1996), pp 444-455.

Aredo, D. 'The Gender Division of Labor in Ethiopian Agriculture: A Study of Time Allocation Among People in Private and Co-Operative Farms in Two Villages.' Addis Ababa: Organization for Social Science Research in Eastern and Southern Africa. December, (1995), pp 1-56.

Audebert, Alain; Michael Dingkuhn; Jones P. Monty; and David E. Johnson. "Physiological Mechanisms for Vegetative Vigor of Interspecific Upland Rices— Implications for Weed Competitiveness." Japanese Journal of Crop Science 67, no. 2, (1998): 358–59.

Association for Women's Rights in Development (AWID). *Gender Equality and New Technologies: Why New Technology is a Women's Rights Issue?*, Toronto, Ontario (CANADA), (2004) http://www.awid.org

Basile, E. *Women, poverty and resources in Sub-Saharan Africa*. Paper for the Rural Poverty Report, IFAD, (2001).

Bindlish, V., and R. Evenson. 'Evaluation of the performance of T&V extension in Kenya'. World Bank Technical Paper 208, Africa Technical Department Series. Washington, D.C.: World Bank, (1993).

Carney, J., and M. Watts. 'Manufacturing dissent: Work, gender, and the Politics of meaning in a peasant society'. *Africa* Vol. 60, Nº2, (1990), pp 207-241.

Carney, J., and M. Watts. 'Disciplining women? Rice, mechanization, and the evolution of Mandinka gender relations in Senegambia', *Journal of Women in Culture and Society* Vol.16, Nº4, (1991), pp 651-680.

Carney, J. 'Women's land rights in Gambian irrigated rice schemes: Constraints and opportunities', *Economic Geography,* Vol.69, Nº4, (1993), pp 329–349.

CTA. *Comprendre les questions transversales grâce à une approche Plurithématique : le genre et l'agriculture dans la société de l'information*. Annual report, (2002), pp 27-31

Dey Abbas J. 'Gender Asymmetries in Intrahousehold Resource Allocation in Sub-Saharan Africa: Some Policy Implication for Land and Labor Productivity', in *Intrahousehold Resource Allocation in Developing Countries: Models, Methods and Policy*. Edited by L. Haddad, J. Hoddinost and H. Alderman, International Food Policy Research Institute, John Hopkins P., Baltimore, (1997).

Diagne, A., Kinkingninhoun-Medagbe, F. M. and P. M. Dontsop_Nguezet. Enhancing productivity, income and consumption spending among smallholder-farmers in West Africa: the impact of NERICA rice varieties. Prepared for IAAE Conference, August 18-24, 2012 in Foz do Iguaçu, Brazil, (2012)

Diagne, A. *Taking a New look at Empirical Models of Adoption: Average Treatment Effect estimation of Adoption rate and its Determinants*. Contributed paper presented at the 26 Conference of the International Association of Agricultural Economists, August 12-18, 2006 and at the Joint meeting the European Economic Association and the Econometric Society, August 24-28, 2006 Vienna

Dingkuhn, Michael; David E. Johnson; Abdoulaye Sow; and Alain Y. Audebert. "Relationships between Upland Rice Canopy Characteristics and Weed Competitiveness." Field Crops Research 61 no. 1, (1999): 79–95.

Dingkuhn, Michael; Monty P. Jones; David E. Johnson; and Abdoulaye Sow. "Growth and Yield Potential of Oryza Sativa and O. Glaberrima Upland Rice Cultivars and Their Interspecific Progenies." Field Crops Research 57, no. 1, (1998): 57–69.

Dontsop Nguezet, P.M., Diagne, A., Okoruwa, V.O. and Ojehomon, V.T.. Impact of Improved Rice Technology (NERICA varieties) on Income and Poverty among Rice Farming Households in Nigeria: a Local Average Treatment Effect (LATE) Approach. *Quarterly Journal of International Agriculture 50, No. 3* (2011); Pp. 267-292. DLG-Verlag Frankfurt/M.

FAO. 'Le rôle des femmes dans la riziculture. Point de mire : Afrique au sud du Sahara". Les femmes dans l'agriculture, Vol. 92, N°2, (1984), pp 1-92.

FAO. *FAOSTAT database*, (2004). http://**faostat**.**fao**.org

FAO. Gender and food security: Division of labour. From http://www.fao.org/gender/en/lab-e.htm. On 08 January (2006)

Guyer, J. 'Family and farm in southern Cameroon'. African Research Studies 15. Boston, Mass., U.S.A.: Boston University African Studies Center, (1984).

Heckman, J. 'Randomization and social program evaluation as an instrument variable', *Review of Economics and statistics*. Vol. 77, Nº2, (1996), pp 336-341.

Heckman, J. and E. Vytlacil. 'Structural Equations, Treatment Effects, and Econometric Policy Evaluation,', *Econometrica,* Vol.73, (2005), pp 669-738.

IFPRI. *Women: still the key to food and nutrition security,*. http://www.ifpri.org/pubs/ib/ib33.pdf. On 08 December (2006).

Imbens, G.W. 'Nonparametric Estimation of Average Treatment Effects under Exogeneity: A Review', *The Review of Economics and Statistics*, Vol. 86, (2004), Issue 1.

Imbens, G.W., and J.D. Angrist. 'Identification and Estimation of Local Average Treatment Effects', *Econometrica*, Vol. 62, (1994), pp 467-476.

Imbens, Guido W., and Jeffrey M. Wooldridge. "Recent Developments in the Econometrics of Program Evaluation." *Journal of Economic Literature*, (2009) 47(1): 5–86, ~~(2009)~~.

Imbens, G.W., Rubin, D.B. 'Estimating Outcome Distributions for Compliers in Instrumental Variable Models'. *Review of Economic Studies*, Vol.l64, (1997) 555-574.

Jacoby, Hanan G. 'Productivity of men and women and the sexual division of labor in peasant agriculture of the Peruvian Sierra'. *Journal of Development Economics*, Elsevier, vol. 37(1-2), November, (1991), pp 265-287.

Johnson, D.E., Dingkuhn, M., Jones, M.P. and Mahamane, M.C., The influence of rice plant type on the effect of weed competition on *Oryza sativa* and *Oryza glaberrima*, *Weed Research* 38, (1998): Pp. 207–216.

Jones M. P., Dingkuhn, M., Johnson, D. E. and Sam O. Fagade. Interspecific hybridization: progress and prospects. Proceedings of the workshop: Africa/ Asia Joint Research, Interspecific Hybridization between African and Asian Rice Species ed. (*Oryza glaberrima* and *Oryza sativa*). Bouaké, (1997): WARDA.

Kanbur, R., and L. Haddad. 'Are better-off households more or less unequal? A bargaining theoretic approach to `Kuznets effects' at the micro level'. *Oxford Economic Papers, Vol.* 46, Nº3, (1994), pp 445-458.

Kinkingninhoun-Medagbé, F. M., Diagne, A., Simtowe, F., Agboh-Noameshie, A. R. *and* P. Y. Adégbola.. 'Gender discrimination and its impact on income, productivity and technical efficiency: Evidence from Benin', *Agriculture and Human Values, Springer* Netherlands, (2008)

Kokki, R. D and Cynthia Bantilan. 'Gender-related Impacts of Improved Agricultural Technologies: Identification of Indicators from a Case Study', *Gender, Technology and Development*, Vol. 1, Nº.3, (1997), pp 371-393, SAGE Publications.

Miguel, Edward and Michael Kremer. Worms: Identifying Impacts on Education and Health in the Presence of Treatment Externalities. Econometrica, (2004), 72 (1), 159-217

Morris, G., and R. Meyer. *Women and financial services in developing countries: A review of the literature.* Department of Economics, Pennsylvania State, University, University Park, Pa., U.S.A. Mimeo, (1993).

Quisumbing, A. R. 'Male-female differences in agricultural productivity: Methodological issues and empirical evidence'. *World Development, Vol.* 24, Nº10, (1996), pp 1579–1595.

Saito, K., H. Mekonnen, and D. Spurling. 'Raising the productivity of women farmers in Sub-Saharan Africa', World Bank Africa Technical Department Series 230. Washington, D.C.: World Bank, (1994).

Strauss, J., and D. Thomas. 'Human resources: Empirical modeling of household and family decisions'. In *Handbook of development economics*, Vol. 3, ed. J. Behrman and T. N. Srinivasan. Amsterdam: North-Holland/Elsevier Science, (1995), Publishing Co.

von Braun, Joachim and J. R Patrick. 'The Impact of New Crop Technology on the Agricultural Division of Labor in a West African Setting', *Economic Development and Cultural Change*, Vol. 37, Nº3, Apr., (1989), pp. 513-534 Published by: The University of Chicago Press.

WARDA. 'New Rice for Africa: NERICA—Rice for Life'. *WARDA/CGIAR*. Bouaké, Cote-d'Ivoire. (2001)

Wooldridge, J. 'Econometric analysis of cross section and panel data'. The MIT press, Cambridge, Massachusetts , (2002), USA.

Wopereis, M.C.S., Diagne, A., Rodenburg, J., Sié, M. and Somado, E.A. "Why NERICA is a successful innovation for African farmers: a response to Orr et al. from the Africa Rice Center" *Outlook on Agriculture*, Vol. 37, No. 3, (2008) Pp. 169-176.