Agricultural technology adoption and rice varietal diversity: A Local Average Treatment Effect (LATE) Approach for rural Benin

Authors: BONOU Alice [1*], DIAGNE Aliou[2] and BIAOU Gauthier[3]

Affiliations :

[1] WASCAL / Faculté des Sciences Economiques et de Gestion / Université Cheikh Anta Diop, Dakar, Sénégal, 01 BP : 5996 Cotonou, Benin, alice.bonou@gmail.com

[2] AfricaRice, BP 2031, 01 Cotonou, Bénin, a.diagne@cgiar.org

[3]Faculté des Sciences Agronomiques / Université d'Abomey-Calavi, 01 BP 526 Cotonou, Benin, gbiaou@yahoo.fr

[*]Corresponding author: alice.bonou@gmail.com

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Abstract

The aim of this study was to assess the impact of adoption of new high-yielding varieties (NERICA) of rice on its varietal diversity in Benin. The database was from Impact Assessment unit of AfricaRice and concerns 304 producers of rice. Overall the study covered twenty-four villages over three districts: Dassa-Zounmè, Glazoué and Savalou. Data analysis was carried out using the econometric approach based on the Local Average Effect of Treatment (LATE) framework. Overall, estimation of impact showed that at village level the indexes of *in-situ* (on farm) conservation of varietal diversity of rice are the same in NERICA and Non-NERICA villages. Moreover, at farmer level, the average impact of NERICA adoption on number of modern rice varieties of the sub-population of NERICA potential adopters is 0.8. NERICA's rice varieties had positively impacted the *in situ* conservation of varietal diversity. Our findings indicated that it is worth extending diffusion of NERICA varieties in Benin.

Key words*: Adoption, LATE, NERICA, varietal diversity, rice*.

Introduction

In order to relieve the burden of African countries' rice importation, research organizations have initiated the creation of new high-yielding varieties. The latest rice varieties developed by AfricaRice is the so-called NERICA: NEw RICe for Africa. In Benin, the potential adoption rate of varieties NERICAs has increased of 23% in five years, from 3% in 1997 to 26% in 2001 and reached 68% in 2004 (Adegbola 2005). If the adoption of NERICAs is an important factor in improving food security, however it raises the question, whether the strong growth of this adoption would not have a negative impact on the conservation of varietal diversity of rice?

For supporters of the Green Revolution, the progress and achievement of agricultural development in traditional agro ecosystems inevitably require replacement of local varieties by improved varieties (Tripp 1996; Wilkes & Wilkes 1972; Agbodoli 1999). Thus farm conservation of native species diversity is considered as the opposite of Agricultural Development (Brush 2000).

According to FAO (1996), the erosion of genetic diversity due to the adoption of improved varieties may limit the success of rice breeding for higher yields, better quality and greater resistance to drought and insects. Hence, biodiversity is a real asset to the breeding of rice

(IRRI 2004). According to Brush (2000), genetic erosion leads to a loss of local species. However, it can be slowed and even reversed by *in-situ* conservation activities in order to preserve not only the local species and wild relatives but also the relationships agro-ecological and cultural underpinning the evolution and crop management in specific communities. Clearly, the replacement of traditional or primitive or old varieties also represents a loss of cultural diversity, because many varieties play an important role in religious ceremonies such as marriage, and a threat to the stability of agro-ecosystems. These traditional varieties were generally regarded by Western companies and organizations as part of the common heritage of mankind (Cleveland & Murray 1997).

Although several authors argue that modern varieties are responsible for the erosion of traditional varieties, others say they are an important and essential component of varietal diversity. Witcombe (1999a) found that in areas that are already growing modern varieties, improvement of plants does not necessarily have a negative impact on genetic diversity. Barry (2008) and Nour Ahmadi *et al.* (2010), in a study of the recent evolution of the diversity of rice cultivars in Guinea found that the adoption of NERICAs has a positive effect on varietal diversity because they induced increase of varieties used without significantly reducing the number of traditional varieties.

Therefore, it raises the question of whether the conservation status of varieties observed in Guinea can be generalized to all African countries where NERICA varieties are diffusing. Thus, does the adoption of NERICA in cropping systems contribute to preserve the varietal diversity of rice in Benin? This research aimed specifically first to measure the varietal diversity of rice, secondly to assess the impact of the introduction of NERICAs on varietal diversity at community level and then to assess the impact of the adoption of NERICAs on modern varieties used by farmers.

Impact evaluation framework

Ex post Impact Evaluation (IE) seeks to measure the impact of NERICA adoption on an outcome of interest only due to the program. IE is basically a causal inference issue. It tries to relate observed changes in an outcome to the intervention. Formally its value is:

$$\boldsymbol{Gi = (Yi|Ti = 1) - (Yi|Ti = 0)} \qquad \textbf{(1)}$$

Where Gi is the impact of NERICA adoption on household (i), Yi is the outcome of household (i), here the outcome is the number of modern rice varieties used by household (i). Ti is a dummy variable equal to 1 when household (i) adopts NERICA and 0 otherwise.

Comparing the same household with and without NERICA adoption eliminates the effect of other factors. Then, Gi is due only to NERICA adoption. But there is a problem of missing data because the realization of the two outcomes above is mutually exclusive for any household (Rubin 1977; Diagne 2003; Khandker *et al.* 2010). Without information on the counterfactual, we need to estimate it by finding a comparison group which mimics the counterfactual of NERICA adoption group. If there is any systematic difference between the 2 groups, the estimated impact will be biased. The basic objective of a sound impact assessment is then to find ways to get rid of selection bias (B = 0) or to find ways to account for it.

Two broad approaches help to do that:

(1) Modify the targeting strategy of the program itself to wipe out differences that would have existed between the treated and non-treated groups before comparing outcomes across the two groups (experimental methods or randomized evaluation);

(2) Create a comparator group through a statistical design (quasi experimental methods) (Rosenbaum & Rubin 1983; Khandker *et al.* 2010). That includes: Propensity score matching methods, Double-difference methods in the context of panel data, which relax some of the assumptions on the potential sources of selection bias, Instrumental variable methods which further relaxes assumptions self-selection, Regression discontinuity design and pipeline methods which exploit the design of the program itself as potential sources of identification of program impacts.

Randomized evaluation is the best method because it avoids the problem of selection bias from unobserved characteristics (Linnemayr *et al.* 2011). However it is difficult to use it because it may not always be feasible. Beside treatment assignment is not often random because of the following factors: (a) purposive program placement and (b) self-selection into the program. That is, programs are placed according to the need of the communities and individuals, who in turn self-select given program design and placement. Self-selection could be based on observed characteristics, unobserved factors, or both. Finally often the problems of compliance, spill overs, and unobserved sample bias (hidden bias) hamper clean identification of program effects from randomization. So in such cases, researchers then turn to so-called non experimental methods based on assumptions in order to avoid bias. Then, Propensity Score Matching methods (PSM) deal with the self-selection bias problem (Mendola 2007) but assume that selection bias is based only on observed characteristics and unobserved characteristics do not have a significant effect on treatment. However, the PSM method fails to deal appropriately with the selection on unobservable problem which may be handled by the Double-difference methods (DD). Regarding Double-difference methods

(Khandker *et al.* 2010), they allow for unobserved heterogeneity between groups but assume that its effect is time-invariant over the course of the evaluation. However, like PSM, they do not deal appropriately with the problem of non-compliance. Concerning Instrumental Variable methods (IV), they allow for endogeneity in individual participation, program placement, or both (Abadie 2003; Dontsop Nguez *et al.* 2011; Adekambi *et al.* 2009). They can be applied to cross-section or panel data, and in the latter case they allow selection bias on unobserved characteristics to vary with time. Instrumental variable (IV)-based methods (Heckman & Vytlacil 1999, Heckman & Vytlacil 2005; Heckman & Robb 1985; Manski & Pepper 2000; Imbens 2004; Abadie 2003; Imbens & Angrist 1994) are used in order to remove both overt and hidden biases and deal with the problem of endogenous treatment. The IV-based methods assume the existence of at least one variable z called instrument that explains treatment status but is redundant in explaining the outcomes y_1 and y_0 , once the effects of the covariates X are controlled for. Different IV-based estimators are available, depending on functional form assumptions and assumptions regarding the instrument and the unobserved heterogeneities. Finally, Regression discontinuity and pipeline methods are extensions of instrumental variable and experimental methods. All these non-experimental methods have their own strengths and weaknesses and hence are potentially subject to bias for various reasons. In reality, no single assignment or evaluation method may be perfect, and verifying the findings with alternative methods is wise. This study uses the new methodological issue ‘the non-parametric Local Average Treatment Effect (LATE).

Description of the intervention and its implementation

Rice varieties “New Rice for Africa” (NERICA) are the result of the inter-specific crosses between *Oryza sativa*, the high yielding rice species from Asia, and *Oryza glaberrima*, the locally adapted and multiple-stress resistant African rice species. Developed by AfricaRice (ex WARDA) in the mid-1990s, the NERICAs 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.

Many of the NERICA varieties mature between 30 and 50 days earlier than traditional varieties. 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; Johnson *et al*. 1998; Dingkuhn *et al*. 1999; Wopereis *et al.* 2008). Several rice development initiatives have been formed to boost rice production, to promote the dissemination of the NERICAs in several Sub-Sahara Africa (SSA) countries including Benin. In Benin, the “Institut National des Recherches Agricoles du Bénin” (INRAB) introduced the NERICA rice varieties to the farming communities in 1998 through Participatory Variety Selection (PVS). The PVS which was used to disseminate NERICA varieties in Benin was implemented only in a few selected states and villages (Adégbola *et al*. 2005). This means that the overall population of Benin rice farmers was not equally exposed to the new varieties (that is the treatment was not randomly assigned). On the other hand, rice farmers exposed to the new variety had full control over their decision to adopt or not to adopt (the receipt of the treatment is endogenous). Following the impact assessment literatures, the most plausible assumption in this case is that of selection on unobservable characteristics (Imbens & Wooldridge 2009; Adekambi *et al.* 2009). This is because farmers decide to adopt NERICA varieties based on the anticipated benefit they would derive by adopting NERICA. However this anticipated benefit cannot be observed, hence the need for an instrument which will be independent of productivity, income and poverty but could affect them only through the adoption.

Methodology

Study area

This study was based on data collected through a household survey conducted in 2005 from three rural districts in the department of Collines (Republic of Benin) by AfricaRice in collaboration with Université d’Abomey-Calavi (UAC). The districts included Dassa-Zounmè, Glazoué and Savalou. The study area covers 931 km² and is bordered by the Federal Republic of Nigeria in the East, and the Republic of Togo in the West. It encompasses 12 villages where the National Institute of Agricultural Researches (*Institut National de Recherche Agricole du Benin, INRAB*) had been conducting on-farm trials and PVS activities on NERICA varieties since 1997, and 12 non-NERICA villages within 5 to 10 km radius from the villages hosting the PVS trials. 13 households were randomly selected in each village on average, leading to a total sample size of 304 farmers. In the three districts, agriculture remains the mainstay of the local economy. It occupies at least 94% of the population. The dominant crops are food crops such as maize, cowpea, rice, soybeans, sorghum, yams, and cassava. Rice is practiced in pure culture in both lowlands and on plateaus. However, some producers from Fulani ethnic group often sow the traditional rice variety Gambiaca in combination with yam. In terms of total area covered, the most cultivated variety is the traditional variety Gambiaca. It occupies about 47% of the total rice area. Varieties introduced by INRAB occupy the second place, accounting for about 35% of the total rice area. NERICA varieties come in the third position followed by intraspecific WARDA varieties.

Data collection

A structured questionnaire individual was used to collect data on the cropping seasons 2000 to 2004. 304 rice farmers selected following a stratified random sampling from 24 villages participated in the survey. In addition, data on biodiversity of rice cultivar at village level was collected by free listing using group interviews. The group interview was done by gathering on average 10 farmers per village and they were asked open questions relative to the topic. The data used in this research are of two types. Quantitative data on socio-economic and cultural characteristics of producers (gender, age, ethnicity, origin, household size, farm labour, level of education, number of years of experience in production of rice), characteristics of individual farms (rice varieties that the household knows, rice varieties grown by the household, source and year of the exposure to the variety of rice, the first year of cultivation of a given recorded variety, the unit of decision making on the choice of rice varieties grown in the household, the decision-making unit of production and purchase of seeds rice in the household). Qualitative data concerned management of rice seeds at village level, criteria for choosing varieties grown in the village, number of varieties known/grown in the village and seed sources.

Data analysis

Data were analysed using two approaches: estimation of varietal diversity indexes of rice and estimation of impact of adoption on indicator of varietal diversity.

Estimation of varietal diversity indexes

Estimation of varietal diversity indexes was made on the basis of the improved Simpson indexes of biodiversity (Diagne *et al*. 2005; Simpson 1947; Magurran 1988). Considering the estimation of varietal diversity indexes we used the following formulas:

$$B_0 = \sum_{j=1}^{J_k} 1_{[P_j > 0]}$$

B_0 is the total number of varieties grown in the village. J_K is the number of morphologically distinct varieties known by the population and P_j the proportion of farmers who is cultivating variety j and $1_{[Pj\ >\ 0]}$ is an indicative function that takes the value 1 when $P_j > 0$ and zero otherwise.

$$B_1 = J_k - \sum_{j=1}^{J_k}(1-P_j) = \sum_{j=1}^{J_k} P_j$$

B_1 is the average number of varieties cultivated by farmers. B_1 is the result of a weighted count of distinct varieties grown in the community, with each variety grown weighted by the proportion of farmers cultivating it. B_1 can discriminate two villages which cultivate the same set of distinct varieties (i.e., having the same B_0) but with different proportions of farmers cultivating each variety. It measures the level of varietal biodiversity conservation *in situ*.

$$B_S = \sum_{j=1}^{J_k} P_j(1-P_j) = B_1 - \sum_{j=1}^{J_k} P_j^2 \text{ and}$$

B_s measures homogeneity in the distribution of proportions of farmers who grow all the varieties grown in the village. It measures the degree of varietal biodiversity conservation *in situ*.

$$B_2 = J_k - \sum_{j=1}^{J_k}(1-P_j)^2 = B_1 + B_s.$$

B_2 is the sum of B_1 and B_s.

Indexes B_0, B_1 and B_2 satisfy the criterion of decomposability of varieties and they can be calculated for different types of rice. Only the index B_1 satisfies the criterion of decomposability of space.

Impact Evaluation Technique: The Local Average Treatment Effect (LATE)

One observation is that farmer's exposure status to the NERICA varieties (i.e. his awareness of the existence of the NERICA varieties) is a "natural" instrument for the NERICA adoption status variable (which is the treatment variable here). Indeed, firstly one cannot adopt a NERICA variety without being aware of it and we do observe some farmers adopting NERICA (i.e. awareness does cause adoption). Secondly, it is natural to assume that exposure to NERICA affects the overall household varietal diversity outcome only through adoption (i.e. the mere awareness of the existence of a NERICA variety without adopting it does not affect the diversity outcome of a farmer). Hence, the two requirements for the NERICA exposure status variable to be a valid instrument for the NERICA adoption status variable are met. Now, let z be a binary outcome variable taking the value 1 when a farmer is exposed to the NERICA (village NERICA) and the value 0 otherwise (village non-NERICA). Let d_1 and d_0 be the binary variables designating the two potential adoption status of the farmer with and without exposure to the NERICA varieties, respectively (with 1 indicating adoption and 0 otherwise). Because one cannot adopt a NERICA variety without being exposed to it, we have $d_0 = 0$ for all farmers and the observed adoption outcome is given by $d = zd_1$. Thus, the sub-population of potential adopters is described by the condition $d_1 = 1$ and that of actual adopters is described by the condition $d = 1$ (which is equivalent to the condition $z = 1$ and $d_1 = 1$). Then the mean impact of NERICA adoption on the varietal diversity outcome of the sub-population of NERICA potential adopters (i.e. the LATE) can be determined.

There are two IV-based estimators to estimate the LATE of adoption of NERICA on varietal diversity of Benin's rice farmers. The first one is the simple non-parametric Wald estimator proposed by Imbens & Angrist (1994) and which requires only the observed outcome variable y, the treatment status variable d, and an instrument z. The second IV-based estimator is Abadie's (2003) generalization of the LATE estimator of Imbens & Angrist (1994) to cases where the instrument z is not totally independent of the potential outcomes y_1 and y_0; but will become so conditional on some vector of covariates X that determine the observed outcome y. Because the assumption of random of exposure to NERICA varieties in Benin is not held, we therefore use Abadie's LATE estimator which does not require the assumption but instead requires the conditional independence assumption: The instrument z is independent of the potential outcomes d_1, y_1 and y_0 conditional on a vector of covariates X determining the observed outcome y. With these assumptions, the following results can be shown to hold for the conditional mean outcome response function for potential adopters

$f(x,d) \equiv E(y \mid x, d; d_1{=}1)$ and any function g of (y,x,d) (see, Abadie 2003; Lee 2005). The function f(x,d) is called a local average response function (LARF) by Abadie (2003). Estimation proceeds by a parameterization of the LARF $f(\theta; x, d) = E(y \mid x, d; d_1{=}1)$.

Results

Number of known varieties per village

Throughout the study area, 24 varieties were recorded: Gambiaca, Tox, Cogbèdè, ADNY, IITA43, DJ, NERICA, IR, Mashuri, WITA4, 11365, Dabaya, Savi, sik131, WAB, FK, Beris, IITA44; BERYS, IRAT, INARIS, AG, FK and WAB.

Table 1: Average number of known varieties by village by town and type

	Township			Total
	Dassa-Zounmè	Glazoué	Savalou	
Number of villages	12	10	02	24
All varieties	**6.7 (3.84)**	**6.9 (2.90)**	**8.5 (0.52)**	**6.9 (3.32)**
Traditional	1.0	1.0	1.0	1.0
Modern	**5.7**	**5.9**	**7.5**	**5.9**
NARS varieties	4.2	4.3	5.0	4.3
WARDA varieties	1.5	1.6	2.5	1.6
NERICA	**0.5**	**0.5**	**1.0**	**0.54**
WARDA upland	0.7	0.7	1.5	0.7
WARDA lowland	0.3	0.5	0.5	0.4

Source: *Survey June-July, 2005, AfricaRice*
() Standard deviation; WARDA = ex AfricaRice ; NARS= National Agricultural Research Service

On average across the study area, seven varieties were known in each village, one traditional variety and six moderns (table 1). It was greater in Savalou with nine varieties per village. The average number of modern varieties then follows the same distribution as the total varieties since only one traditional variety was grown in the area. With respect to the standard deviation and maximum and minimum, we preclude a hasty conclusion. Thus we can deduce that the diffusion of varieties was important in Dassa-Zounmè and Glazoué.

Evolution of cultivated varieties between 2000 and 2005

The evolution of the total number of varieties cultivated each year by village follows a bell-shaped distribution in Dassa-Zounmè and Savalou (table 2).

Table 2: Evolution of average number of cultivated varieties by village and type

Townships	Type of varieties	Years						
		2000	2001	2002	2003	2004	2005	**Total**
Dassa-Zounmè	Number of villages	12	12	12	12	12	12	12
	All varieties	4.1	4.6	4.3	4.1	4.5	4.3	4.3
	Traditional	1.0	1.0	1.0	1.0	0.9	1.0	0.9
	Modern	3.1	3.6	3.3	3.1	3.6	3.3	3.3
	NARS varieties	2.5	2.7	2.6	2.3	2.7	2.5	2.6
	WARDA varieties	0.6	0.8	0.7	0.7	0.8	0.8	0.7
	NERICA	0.17	0.25	0.17	0.17	0.25	0.25	0.17
Glazoué	Number of villages	10	10	10	10	10	10	10
	All varieties	4.1	4.5	5.2	5.5	5.6	5.6	5.1
	Traditional	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Modern	3.1	3.5	4.2	4.5	4.6	4.6	4.1
	NARS varieties	2.6	2.9	3.2	3.3	3.5	3.3	3.1
	WARDA varieties	0.5	0.6	1.0	1.2	1.1	1.3	0.9
	NERICA	0.30	0.30	0.40	0.40	0.40	0.40	0.30
Savalou	Number of villages	2	2	2	2	2	2	2
	All varieties	4.0	7.5	6.5	5.5	6.0	5.5	5.8
	Traditional	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Modern	3.0	6.5	5.5	4.5	5.0	4.5	4.8
	NARS varieties	1.5	4.5	4.0	4.0	4.0	4.0	3.6
	WARDA varieties	1.5	2.0	1.5	0.5	1.0	0.5	1.16
	NERICA	0.50	0.50	1.00	0.50	0.50	0.50	0.50

Source: *Survey June-July, 2005, AfricaRice*
WARDA = ex AfricaRice ; NARS= National Agricultural Research Service

In the township of Dassa-Zounmé, this number increased from 4.1 to a maximum of 4.6 in 2001 and then declined to 4.3 in 2005. The same trend was observed at Savalou where the number of varieties increased from 4.0 in 2000 to a maximum of 7.5 in 2001 and then declined to 5.5 in 2005. In contrast, at Glazoué the number of varieties continuously increased from 4.1 in 2000 to a peak of 5.6 in 2005. Given that on average only one traditional variety is grown in the villages, the evolution of the average number of modern varieties cultivated by village followed the same distribution as that of all varieties. The great number of modern varieties was dependent on domestic varieties introduced by INRAB (NARS National Agricultural Research Service).

Varietal diversity conserved in the community

The results from computation of indexes B_1, B_2 and B_s showed that a relatively high varietal diversity is being maintained *in situ* by rice farmers at the village level. It highlighted the particularly high level of varietal diversity preserved in Glazoué with B_1 and B_2 indexes reaching 1.84 and 2.6 respectively. At Dassa-Zounmè and Savalou B_1 and B_2 values were relatively low and very similar equal to 1.25 and 2 respectively (figure 1).

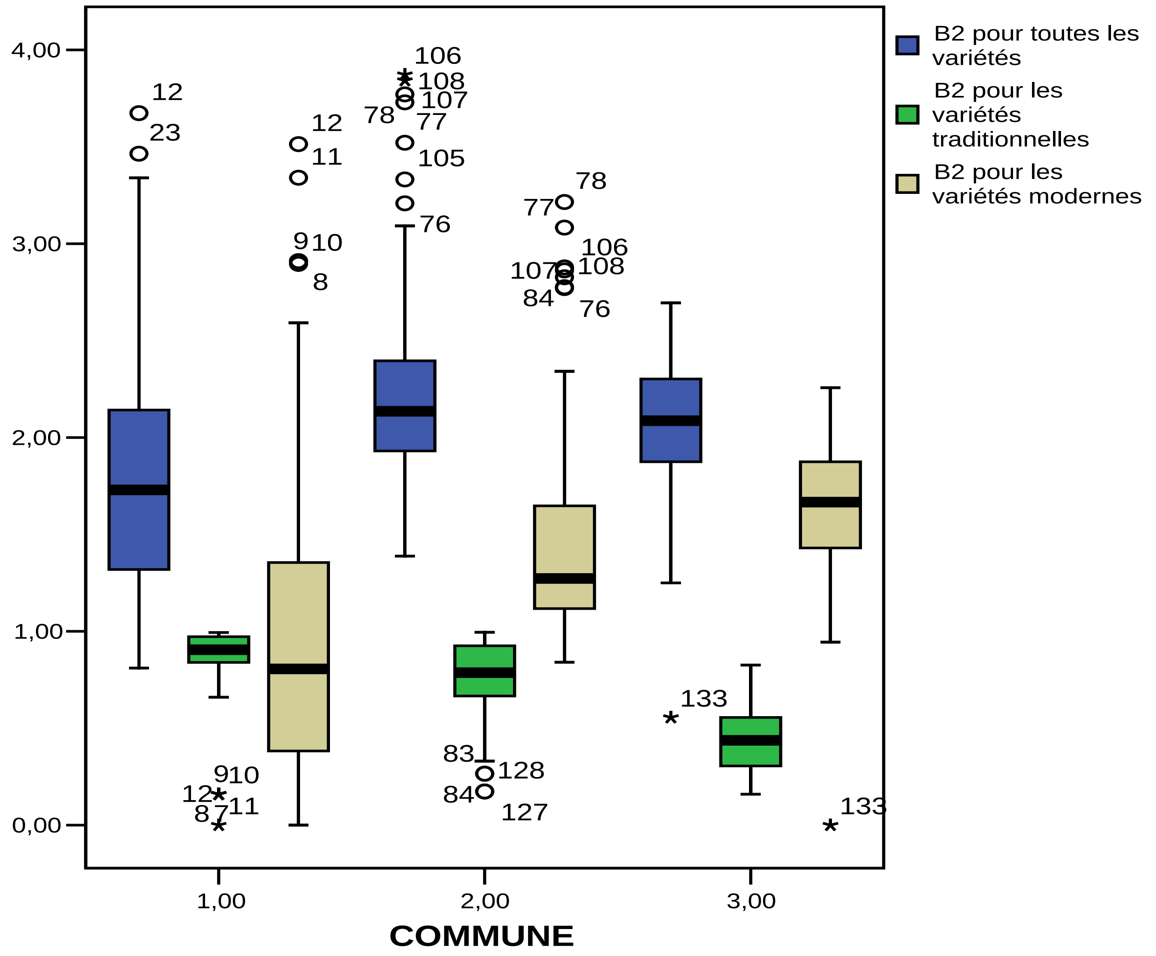

Figure 1: Distribution of index B2 by town
Source: *Survey June-July, 2005, AfricaRice*

Township 1= Dassa-Zounmè; 2= Glazoué; 3=Savalou

Comparison of the categories of rice varieties revealed that everywhere the essential diversity of varieties maintained *in situ* in the villages consists of modern varieties. That of traditional varieties represents only 14% of the total diversity estimated by each of the two indexes B_1 and B_2. This confirms once again the positive effect of the diffusion of modern varieties on the overall level of varietal diversity maintained in the villages by farmers.

B_2 index is used to analyse changes in the level and degree of *in situ* maintenance of varietal diversity. Modern varieties are preserved relatively well with an index close to 1.3. Traditional varieties have a relatively low value which is around 0.6. Modern varieties are more numerous and more cultivated than traditional varieties; they are therefore more favoured than traditional varieties and thus are facing low risk of loss. We can therefore conclude that modern varieties are preserved *in situ* better than traditional varieties. It appeared that in all villages exposed to NERICA, modern varieties are more cultivated so the risk of loss is lower. The opposite was found for the traditional variety which was more secure in non-NERICA village (table 3).

Table 3: Index B1 and B2 in NERICA and non-NERICA villages

	Non-NERICA Villages	**NERICA Villages**
Index B1		
All varieties	**1.3**	**1.6**
Traditional varieties	0.6	0.4
Modern varieties	0.7	1.1
Index B2		
All varieties	**1.8**	**2.5**
Traditional varieties	0.7	0.6
Modern varieties	1.0	1.8

Source: *Survey June-July, 2005, AfricaRice*

Impact of adoption of NERICAS on rice diversity

Like we above mentioned, exposure of NERICA in a village does not determine its conservation rank (indexes of varietal diversity). The Student test confirmed that the difference in the indexes of the two groups of village (exposed village and non-exposed village to NERICA) is not significant. The impact of exposure of NERICA on rice varietal diversity indexes B_1 and B_2 was found to be null. Therefore, varietal diversity is maintained constant at the village level since it is the same for the two type of village.

Table 4: Impact of adoption of NERICAS on rice diversity (Estimation of LATE)

	LATE by LARF	semi-parametric	OLS with interaction	OLS without interaction	Poisson with interaction	Poisson without interaction
ATE	0.8****	0,28**	0,35***	0,35***	0,33***	0,33***
ATE1		0,37**	0,41****	0,35***	0,4***	0,37***
ATE0		0,24**	0,31**	0,35***	0,28**	0,31***
PSB		0,08	0,05	7,28e-11****	0,07	0,04***
mo_N1		1,09****	1,09****	0,59****	1,09****	1,09****
mo_N0		0,59****	0,59****	1,09****	0,59****	0,59****
diffmo		0,49****	0,49****	0,49****	0,49****	0,49****

Source: *Survey June-July, 2005, AfricaRice*
*, ** and ***= significant respectively at 10%, 5% and 1%

At farmer level, estimation of LATE (Local Average Treatment Effect) that means the average impact of NERICA adoption on the number of modern rice varieties of the sub-population of NERICA potential adopters showed that NERICA adoption had a positive and significant effect. Adoption of NERICA increased on average the number of modern rice varieties of adopters by 0.8 (table 4).

Determinants of indexes of varietal diversity and number of modern varieties under cultivation

At village level, the analysis of the determinants of diversity indexes B_1 and B_2 showed that 65% of the variations of these indexes are explained by the variation of two explanatory variables: part of head of household as women and seniority on rice cultivation of the village.

The coefficients of these parameters are positive. Hence, the level of conservation of varietal diversity of the surveyed villages is not explained by exposure of NERICA. The conservation of rice varietal diversity is insured mainly by women of village and also by the old rice growers' villages (table 5).

Table 5: Regression of indexes of diversity B1 and B2

Variables	**B1**		**B2**	
	OLS with interaction	**OLS without interaction**	**OLS with interaction**	**OLS without interaction**
Exposure to NERICAs varieties	-3.61	0.057	-5.14	0.15
Proportion of women head of households	1.07*	0.20	1.85*	0.53
Number of NERICA varieties known	0.17	0.10	0.29	0.22
Education Index	-0.77	0.20	-0.76	0.71
Proportion received training on rice	-0.14	-0.12	-0.18	-0.27
Seniority on rice cultivation	0.003***	0.013**	0.0007***	0.01***
_cons	2.27**	1.02	3.45*	1.65
Sample	24	24	24	24
F(6, 17)	2.13	2.32	2.48	2.95
Prob > F	0.1007*	0.08*	0.06*	0.03**
R-squared	0.62	0.45	0.65	0.51
Adj R-squared	0.32	0.25	0.39	0.33

Source: *Survey June-July, 2005, AfricaRice*
*, ** and ***= significant respectively at 10%, 5% and 1%

To clarify the results obtained at village level, we estimate the determinants of number of modern varieties cultivated by farmers. NERICAs exposure, NERICA adoption, education level, size of rice cultivation and receiving rice cultivation training are the main determinants of number of modern varieties grown by farmers. Coefficients of these five variables are positive (table 6). Hence, NERICA exposure, NERICA adoption, education level, size of rice exploitation and training on rice cultivation increased the number of modern varieties cultivated by farmers.

Table 6: Determining factors of number of modern varieties cultivated

Variables	OLS with interaction	OLS without interaction	Poisson with interaction	Poisson without interaction
Exposure to NERICA in 2005	-0.95	0.35 ***	-0.81	0.41 ***
Sex of rice producer	-0.12	-0.003	-0.19	-0.06
Age of rice producer	-0.006	-0.006	-0.01	-0.009
Education level of rice producer	-0.002	0.05***	-0.002	0.050 ***
Household size	-0.006	0.015	-0.007	0.022
Seniority in the village	0.004	0.004	0.009	0.008
Reception of training in rice	0.21*	0.28***	0.33**	-0.34 ***
Area under rice cultivation in 2004	0.34	0.82****	0.41	0.58 ****
_cons	1.13***	0.64*	0.27	-0.31
Sample	304	304	304	304
F(10, 293)	6.49	8.09	-	-
LR chi2(10)	-	-	86.32	77.01
Prob > F	0.0000	0.0000	-	-
Prob > chi2	-	-	0.0000	0.0000
R-squared	0.3028	0.2165	-	-
Adj R-squared	0.2562	0.1897	-	-
Pseudo R2	-	-	0.1190	0.1061

Source: *Survey June-July, 2005, AfricaRice*
*, ** and ***= significant respectively at 10%, 5% and 1%

Discussion

The diffusion of varieties was important in Dassa-Zounmè and Glazoué. This can be explained by the establishment in the respective districts, site for seed multiplication and site for participatory varietal selection -PVS-. The number of rice varieties grown by farmer was on average two. This number is too small compare to farmer of Nepal who grew 18 landraces and four modern varieties (Joshi & Witcombe 2003). The evolution of varieties diversity on farm between 2000 and 2005 follows a normal distribution in Dassa and Savalou. This shows the partial adoption of modern varieties by producers. Thus, varieties introduced by the extension services or Research and Development are tested by producers for one to two years and some are abandoned once the performance of the latter does not meet their expectations. Hence, the number of varieties grown in the beginning and the end are substantially equal. This result is congruent with findings of Virk & Witcombe (2007). They illustrated that On-farm diversity is maintained by the need to trade-off among varieties but once a variety with overall superiority was found this incentive was removed. However, these results are different from those of the third area (Glazoue). In this zone, the trend of number of varieties cultivated by farmer was increasing. The latter is similar to the result of Barry *et al.* (2008) who concluded that in Guinea the number of varieties grown was increasing.

Analysing indexes B_1 and B_2 in terms of introduction of NERICAs into villages, the fact is that the two indexes for traditional varieties of NERICA-villages are lower than those of non-NERICA villages. The trend was reversed with respect to other types of variety. This means that in the non-NERICA villages traditional varieties (landraces) are the most cultivated and risk of loss is lower than in the NERICA-villages. Contrariwise, in NERICA-villages they grew more modern varieties and their risk of loss is lower. The lack of reference to assess the level and degree of conservation of genetic resources of crops, especially autogamous plants such as rice, limit the discussion of these results. Adoption of NERICA increased the number of modern rice varieties of adopters by 0.8. The value seems small regarding the number of type of NERICA introduced in these villages.

Regarding the determinants of diversity indexes B_1 and B_2, it is clear that the more is recorded in a village a high proportion of women head of household operating the higher is diversity indexes B_1 and B_2. That means that women secure better varietal heritage of a community. However, this result is opposite to one found by Rana *et al.* (2007). According to the latter, households where a female had assumed the role of head of household due to death or migrant work of her husband had less rice (*Oryza sativa* L.) varietal diversity due to lower labour availability. This opposition seems apparent because if these females did not have a constraint of labour, maybe the same results could have been encountered. In addition, the more the village is experienced in rice cultivation, the higher is the diversity. This result seems more justified insofar longer rice is introduced into the village, most of modern rice varieties were introduced, are known and adopted by several producers. These findings are totally different from those of Gauchan *et al.* (2005) who stated that the significant variables in explaining richness and evenness of rice diversity in Nepal include distance to the nearest market, subsistence ratio, modern variety sold, land types and adult labour working in agriculture

At farmer level, NERICA exposure, NERICA adoption, education level, size of rice exploitation and training on rice cultivation increased the number of modern varieties cultivated by farmers. The two last determinants were also found by Rana *et al.* (2007) as socio-economic factors which determine rice varietal diversity management on-farm in Nepal.

Conclusion

This study evaluates the impact of adoption of NERICA on rice varietal diversity. It has helped to understand the risks and benefits related to the dissemination of these new high-yield rice varieties on the maintenance of biodiversity. At village level, this work revealed that exposure of village to NERICA does not have impact on varietal diversity. The number of modern varieties grown by farmers was determined by exposure of NERICA, education level, the area under rice cultivation and training received from the extension service on rice. Adoption of NERICA had increased the number of modern rice varieties of adopters by 0.8. So we can conclude that adoption of high-yield varieties NERICAs has a positive impact on the number of modern varieties of rice grown at the farm level. It appeared that in all villages exposed to NERICA, modern varieties are more cultivated so the risk of loss is lower. The opposite was found for the traditional variety which was more secure in non-NERICA village. One can thus conclude that 100% of diffusion of NERICA could result in loss of traditional varieties. We will thus suggest not to target this scheme in Benin.

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