

The NERICA Success Story: Development, Achievements and Lessons Learned

Aliou Diagne¹, Soul-Kifouly Gnonna Midingoyi², Marco Wopereis³ and Inoussa Akintayo⁴

The Africa Rice Center (AfricaRice)

B.P. 2031 Cotonou, Benin

Tel: (229) 21 35 01 88

Fax: (229) 350 556

**Draft
April 2010**

DRAFT

¹ Impact Assessment Economist and Program leader, Policy and Impact Assessment, AfricaRice. Corresponding author; E-mail: A.Diagne@cgiar.org

² Post Master Fellow, Policy and Impact Assessment program, AfricaRice

³ Deputy Director General and Director of Research for Development, AfricaRice

⁴ Coordinator, Africa Rice Initiative, AfricaRice

The NERICA Success Story: Development, Achievements and Lessons Learned.

Aliou Diagne, Soul-Kifouly Gnonna Midingoyi, Marco Wopereis and Inoussa Akintayo

**The Africa Rice Center (AfricaRice)
B.P. 2031 Cotonou, Benin
Tel: (229) 21 35 01 88
Fax: (229) 350 556**

**Draft
April 2010**

ABSTRACT

The New Rice for Africa (NERICA) rice varieties that were developed by the Africa Rice Center (AfricaRice, ex-WARDA) and partners in Africa and have gained popularity among Africa's rice farmers in a relatively short period of time. The NERICA varieties have good agronomic performance and resistance to Africa's harsh growth conditions, and especially short growth duration, much appreciated by farmers.

The importance of the development of NERICA varieties has been recognized widely. Its significance can be understood in light of the growing importance of rice as food staple in Sub-Saharan Africa. Rice has long been the food staple in many traditional rice growing communities and in major cities in West Africa. It has now become the fastest growing food staple across the continent. Since the early 1970s rice is the number one source of calories intake in West Africa and comes third after maize and cassava for the continent as whole. Although domestic rice production has been growing at the rate of 6% per year in recent years (2001 – 2005), current production is still far short of meeting the demand which makes the continent depend on importations for up to 40% of its rice consumption costing an estimated US\$ 4 billion in foreign exchange in 2009. Relying on the world market to such extent to feed Africa's rice consumers is a risky and unsustainable strategy as it may affect food security and civil stability as shown during the food crisis in 2008.

The first generation of NERICA varieties was introduced through participatory varietal selection trials in Côte d'Ivoire and later in other member countries of AfricaRice in 1997. NERICA1 and NERICA2 were officially released in 2001 in Côte d'Ivoire. Many other countries have followed or have merely adopted the varieties because of a lack of an official release mechanism. The uptake of NERICA varieties was relatively rapid, enabling farmers to get access to new rice varieties often for the first time in their lives. NERICA varieties have shown great potential in both upland and lowland ecosystems in Africa and are already disseminated on an estimated more than 300,000 ha. Women farmers have especially profited from the NERICA varieties. However, more effort is needed to ensure that larger numbers of rice farmers can profit from these new varieties.

The NERICA Success Story: Development, Achievements and Lessons Learned

1. Introduction

The role of technological innovations in raising agricultural productivity and in fostering overall agricultural development is well-known and has been recently documented in the 2008 World Development Report (World Bank, 2008). There is now renewed interest for greater investment in agricultural innovation in Africa, a continent where the vast majority of the population derive its livelihood from agriculture and where farmers are among the poorest in the world despite a largely unexploited agricultural potential with respect to land and water. Agricultural innovation needs to internalize the biophysical, institutional and socio-economic constraints and establish efficient value chains to support sustainable growth and to reduce poverty. This is a challenging task given the numerous failed experiences of the past. Agricultural research can catalyze agricultural innovation and value chain development. One such an example are the New Rice for Africa (NERICA) rice varieties that were developed by the Africa Rice Center (AfricaRice, ex-WARDA) and partners in Africa and have gained popularity among Africa's rice farmers in a relatively short period of time. NERICA varieties were developed from crosses between the African species (*O. glaberrima* Steud.) and the Asian species (*O. sativa* L.) using conventionally biotechnology to overcome the sterility barrier between the two species. NERICA is, therefore, an inter-specific variety but not genetically modified. Out of the thousands of crosses that were done, AfricaRice distinguished two families of elite material that have been adopted in many sub-Saharan African countries and that were named NERICA varieties: 18 varieties suited for upland systems (NERICA1 to NERICA18) and 60 varieties suited for lowland systems (NERICA-L1 to NERICA-L60).

The importance of the development of NERICA varieties has been recognized widely. The Consultative Group on International Agricultural Research (CGIAR) presented the King

Baudouin Award to the Africa Rice Center (then WARDA) in 2000 for the development of NERICA varieties. Dr. Monty Jones, upland rice breeder at AfricaRice in the 1990s and until 2002 became the first African laureate to receive the World Food Prize in 2004 for his contribution to the development of the family of NERICA rice varieties suitable for upland growth conditions. Dr Moussa Sié, senior rice breeder at AfricaRice was awarded the prestigious International Koshihikari Rice Prize of Japan in recognition of his leadership in the development of the family of NERICA rice varieties suitable for lowland growth conditions.

The significance of the development of the NERICA varieties can be understood in light of the growing importance of rice as food staple in Sub-Saharan Africa. Rice has long been the food staple in many traditional rice growing communities and in major cities in West Africa. It has now become the fastest growing food staple across the continent. The *per capita* rice consumption in West Africa increased from 14 kg in the 1970s to 22 kg per person per year in the 1980s and is in 2005 almost 32 kg per person per year (Figure 1). Since the early 1970s rice is the number one source of calories intake in West Africa and comes third after maize and cassava for the continent as whole (Figure 2) . Although domestic rice production has been growing at the rate of 6% per year in recent years (2001 – 2005), current production is still far short of meeting the demand which makes the continent depend on importations for up to 40% of its rice consumption. Furthermore, 70% of the production increase comes from land expansion and only 30% is attributed to productivity enhancement (AfricaRice, 2007).

The continent as a whole imports 30% of what is traded on the world market, a potentially very risky and unsustainable situation as shown during the food crisis in 2008. Tremendous foreign exchange resources are spent on imports (close to US\$ 4 billion dollars in 2009) that could be invested in development of the domestic rice sector. Hence, raising rice productivity in Africa has become a challenge of significant importance for the food security of the

continent. In this article we look back at how NERICA varieties were developed, what was achieved in terms of uptake by farmers and what lessons can be drawn from this experience.

2. The history of Rice in Africa and the development of NERICA varieties

Rice is generally associated with Asia. But it is also an integral part of the history and culture of Africa, where it has been grown for over 3000 years. *Oryza glaberrima* was largely grown in the central delta of the Niger River and in the Higher Gambia and the Casamance region of what is now Senegal (Carney, 1998; Poteres (1962) quoted by Linares 2002). *Oryza glaberrima* was the only rice species grown in West Africa until the 16th century when the Portuguese introduced the Asian species *Oryza sativa* in the West African coastal regions (Linares 2002). *O. sativa* gradually replaced *O. glaberrima* over the years. The original African rice is now mostly grown for special occasions and in small areas of land, such as in Senegal where the Jola people employ it in sacred rites (Linares 2002). This is mostly due to some unfavorable characteristics of *O. glaberrima* related to lodging and grain shattering. The farmers who still grow *O. glaberrima* do so for mostly social or religious reasons, for its culinary and nutritional qualities or for their better adaptability to their agro-climatic environments.

Until the early 1990s, rice breeding programs in Africa almost exclusively worked on improving *O. sativa* lines for Africa's diverse rice growth environments. Some breeders even voted to accelerate the disappearance of *glaberrima* (IRAT, 1967), despite the fact that *sativa* varieties are generally much more vulnerable than *glaberrima* to the numerous biotic and abiotic stresses of the African environment (numerous rice diseases, insect attacks, soil acidity, drought, weeds, etc.).

Some visionary breeders thought about combining the favorable characteristics of *O. sativa* with the favorable characteristics of *O. glaberrima*. However, crossing both species was difficult because of a sterility barrier between the two species. A few breeders worked on the

topic in the 1970s and 1980s, including breeders from the Institut de Recherche Agronomique Tropicale (IRAT) and the Institute of Savannah (IDESSA) Bouaké in Cote d'Ivoire (Diagne 2006). Despite their effort, their work did not produce good results. In general, the crosses resulted either in sterile offspring or offspring that had some of the characteristics little appreciated in the *glaberrima* parent (lodging, shattering and low yield).

The development of the NERICA varieties began in 1991 when AfricaRice initiated an inter-specific breeding program for the upland ecosystem. This long term investment paid off and breeders were able to overcome the obstacles encountered earlier through perseverance and use of biotechnology tools such as anther culture and embryo rescue techniques. In 1994 the first inter-specific line was obtained with promising agronomic performance (EPMR, 2007; Jones et al.,1997a,b). Several hundred of inter-specific progenies were generated, thereby opening new gene pools and increasing the biodiversity of rice for the world of science and farmers.

The main objective of the breeding work that led to the NERICAs was to combine in one variety the high yielding attribute of *Oryza sativa* rice species with the resistance attribute of the indigenous *Oryza glaberrima* to the various biotic and abiotic stresses of the African environment. Another long sought attribute for a good upland variety is the ability to give acceptable yield under the low input use conditions typical of upland rice farming in Africa. One can conclude that these two objectives have been largely met if one refers to the results of agronomic trials data shown in Figure 3, which compare the performance of NERICAs progenies with that of their sativa and glaberrima parents and other sativa checks under high and low input conditions and under major stresses in upland rice ecologies in Cote d'Ivoire.

Indeed, one can see that based on this limited evidence with the NERICAs upland farmers obtain the high yield potential of the *Sativa* varieties under low or high input conditions with what is in essence an insurance against the risk of significant yield losses in the face of major

upland biotic and abiotic stresses. Furthermore, considering the fact that the *sativa* and *glaberrima* parents of these first generation NERICAs are not the best performing varieties within the respective two species, one has reasons to expect that the performance of the next generations of NERICAs will be much higher, when the NERICA basic technology is applied successfully to the best performing *Sativa* and *Glaberrima* varieties with respect to yield and the various biotic and abiotic stresses.⁵

Through participatory varietal selection, inter-specific lines have been evaluated by farmers all over Africa and the most successful lines have been named NERICA varieties. There are currently 18 varieties suited for upland growth conditions (NERICA1 to NERICA18) and 60 varieties suited for lowland growth conditions (NERICA-L1 to NERICA-L60). Agronomic characteristics of these NERICA varieties vary widely but they are generally high yielding and early maturing (a trait much appreciated by farmers), do not lodge and shatter, are appreciated by farmers for their grain quality and are relatively resistant to Africa's harsh growth environment in terms of biotic and abiotic stresses. Weed competitiveness of the NERICAs, and especially the upland NERICAs still needs improvement. More details on the development and the characteristics of different NERICA varieties can be found in Somado et al. (2008), Wopereis et al. (2008) and Kaneda (2007a, 2007b, 2007c, and 2007d).

The first generation of inter-specific progenies was introduced through participatory varietal selection trials in 1996 in Côte d'Ivoire and later in other member countries of AfricaRice in 1997. NERICA1 and NERICA2 were officially released in 2001 in Côte d'Ivoire (EPMR,

⁵ NERICA varieties have retained only about 5 to 10% of the genome of the African parent, because of backcrosses to the *O. sativa* parent. They are also based on crosses between only a handful of *O. sativa* and *O. glaberrima* accessions. AfricaRice breeders have since developed 'bridge varieties' that show full fertility when crossed with *O. glaberrima*, allowing potentially the full exploitation of all 2,300 accessions of the *O. glaberrima* species in the genebank of AfricaRice and a much greater retention of the *O. glaberrima* genome. Molecular assisted breeding is also becoming a routine tool, accelerating varietal development.

2007, Diagne 2006). Many other countries have followed or have merely adopted the varieties because of a lack of an official release mechanism.

3. NERICA: a successful innovation for African farmers

The NERICA varieties are a successful innovation for Africa's rice farmers for three reasons, two of them already highlighted in section 2:

- (i) it was the first time that inter-specific crossing of the two rice species led to progenies that were not sterile and that had favourable agronomic characteristics, significantly widening genetic variation and allowing rice farmers to profit from the *O. glaberrima* gene pool;
- (ii) The NERICA varieties have good agronomic performance and resistance to Africa's harsh growth conditions, and especially short growth duration, much appreciated by farmers; and
- (iii) The uptake of NERICA varieties was relatively rapid, enabling farmers to get access to new rice varieties often for the first time in their lives. This third reason is discussed in more detail below and in the examples of successful NERICA dissemination described in Box 2.

In 2002, the African Rice Initiative (ARI) was established to facilitate the dissemination of NERICA varieties and other improved varieties in sub-Saharan Africa. ARI is a network of rice research and extension and private sector partners and plays an important role in the availability of quality rice seed, which is often one of the weakest links in the rice value chain in Africa. NERICA varieties have now been introduced in more than 30 countries in SSA using PVS approaches, mostly thanks to ARI. As a result, 17 upland NERICA varieties have been adopted and/or certified in SSA (Table 1) and 11 lowland NERICA varieties have been adopted (Table 2) as of 2007. Where needed, ARI produced foundation seed to stimulate uptake of NERICA and other improved varieties. Seed production by ARI increased steadily from 2,733 tons in 2005 to 7,238 tons in 2007 and 13,108 tons in 2008 (Akintayo et al, 2009).

4. Adoption and Impact of NERICA varieties in Sub-Saharan-Africa

Currently, it is estimated that there is about 700,000 ha under NERICA varieties in Sub-Saharan Africa, covering an estimated 5% of upland rice growing areas of the continent (ARI, 2009). This can be considered a good result in the African context, five to ten years after release of the first varieties (Wopereis et al., 2008, Brossier, 2007, Diagne, 2006). The rapid adoption of NERICA varieties in sub-Saharan Africa and the testimony of a Malian rice farmer is illustrative of such success (Box 1). Below some evidence is presented from different studies in terms of areas under the NERICA varieties in some countries, their actual and potential rates of among farmers and their impact on rice productivity and farmer family livelihoods.

Estimated area under NERICA in SSA

Surveys conducted with national agricultural research systems (NARS) of some of AfricaRice's member countries provide estimates on the total area under NERICA varieties in different countries. Diagne et al (2006) and Adegbola et al (2006) estimated the total area under NERICA varieties as 51,000 ha in Guinea in 2004 and 5,000 ha in Benin in 2003. The National Food Reserve Agency (NFRA) of Nigeria, basing its estimates on the quantities of seed produced and distributed to farmers, reported 186,000 hectares under NERICA1 in Nigeria in 2007. The Uganda National Research Institute, citing a report of the Statistics Office of the Ministry of Agriculture in Uganda, 35,000 ha under NERICA4. National rice surveys conducted in 2009 by national agricultural research systems (NARS) and National Agricultural Statistical Services (NASS) in 21 Sub-Saharan African countries provide more recent estimates for some of the countries (AfricaRice, 2010). In particular, areas under

NERICA were estimated to be about 140,000 hectares in Guinea and 244,000 hectares in Nigeria.⁶

Except in Guinea and Benin where a survey was conducted (in 2003 and 2005 respectively) the estimated areas under NERICA reported by the NARS are based on quantities of seed produced and distributed to farmers. However, there is a need to quantify uptake of NERICA and other improved varieties in a much more reliable manner. Therefore, AfricaRice and partners are currently conducting surveys in many of the countries where NERICA is cultivated to get a better overview of the uptake of NERICA across the African continent.

Adoption of NERICA varieties

A recent study (Diagne, 2009) on adoption in SSA countries estimated the actual rates of adoption of NERICA varieties at 19%, 4%, 20% and 40%, respectively for Benin (2004), Côte d'Ivoire (2000), Guinea (2001) and Gambia (2006). Potential adoption rates in the full farmer population were estimated at 47%, 24%, 61%, 87% respectively for Benin (2004), Côte d'Ivoire (2000), Guinea (2001) and Gambia (2006). These rates illustrate a largely unrealized potential adoption rate if the full rice farming population of these countries could be exposed to NERICA varieties provided access to seed. In Nigeria, Spencer et al (2006) mentioned a considerable uptake of NERICA varieties in the Kaduna and Ekiti states. About 30% of farmers in Ekiti cultivated NERICA1 in 2005, and 42% and 19% respectively in PVS and near-PVS villages in Kaduna. Adoption of NERICA1 appears to have continued during 2004 and 2005 despite a scaling down of PVS activities in these years. In 2005, adoption of NERICA2 was observed in Kaduna with 14% and 9% of farmers growing NERICA 2 in PVS and near-PVS villages respectively. Spencer et al. (2006) noted that 35% of farmers in Ekiti

⁶ The data from these national surveys which are still being processed are expected to provide good and more accurate estimates of the total area under NERICA in Sub-Saharan Africa. However, based on preliminary figures from these surveys and from other secondary sources, we estimate the area under NERICA in sub-Saharan Africa to be around 700,000 hectares in 2009

and Kaduna near-PVS villages had not heard about NERICA1, showing the potential for increase in adoption rates.

Kijima et al (2008) found that the percentage of households that grow NERICA varieties in Uganda increased from 0.9% in 2002 to 2.9% in 2003 and reached 16.5% in 2004. They found that membership of a farmers' group, formal education of the household head, and the number of household members significantly increased the probability of adopting NERICA varieties. They also showed that rice-growing experience, membership to a farmer's group, and formal education increased the scale of area planted to NERICA varieties. The land size per person had a negative effect on the share of land planted to NERICA varieties, which suggests that land-poor households tend to allocate a larger proportion of land to cultivation of NERICA varieties. This case is also observed for female-headed households, which are likely to be poorer. Therefore poorer households in Uganda tend to allocate a larger proportion of their land to NERICA varieties, which may suggest that the adoption of NERICA has the potential to reduce poverty and improve income distribution.

Impact of NERICA varieties on productivity and livelihoods of farmers

NERICA rice varieties have been developed basically with the aim of improving the rice productivity, raising income and reducing food insecurity of poor upland rice farmers (mostly women) who rarely use fertilizer, which they say they cannot afford.

Empirical evidence from impact assessment studies conducted in West Africa which are summarized Table 4 points to a heterogeneous impact of NERICA adoption across and within countries with significantly positive impacts of NERICA adoption on rice yield in Benin and Gambia, no significant impact in Cote d'Ivoire and Guinea and generally higher impacts for women than for men in almost all countries (Diagne et al, 2009). In Benin, an additional yield gain of about 1 tone per hectare was attained by farmers adopting NERICA. However,

the impact at the national level was very limited because of the presently low diffusion of NERICA varieties in Benin (Adegbola *et al.* 2006). Results from another analysis based on data from the 2004 season show that the impact of NERICA adoption is higher for women than for men. Female potential adopters have a surplus of production of 850 kg of paddy per hectare compared to 517 kg of paddy per hectare for men and an additional gain of 171,978 CFA (≈ 337 USD) per hectare for women compared to 141,568 CFA (≈ 277 USD) for men (Agboh-Noameshie *et al.* 2007). In Gambia, results indicate that an additional rice yield gain of 0.14 ton per hectare was achieved by mostly women rice farmers adopting NERICA varieties (Dibba, 2008)⁷. In Côte d'Ivoire, results show that the impact on average rice yield of adopting NERICA varieties is heterogeneous with a sizable and statistically significant impact found for female farmers (+0.7 tone per hectare) and a non-statistically significant impact found for male farmers (Diagne 2006, Diagne *et al.* 2009).

In Uganda, NERICA was found to have positive effects on productivity and allow farmers to improve their yield (Kijima *et al.* 2006; Kijima *et al.* 2008, Kijima *et al.* 2009 and Lodin J B. 2006). According to Kijima *et al.* (2006), the average yield of NERICA in Uganda was found to be 2.2 tons per hectare, which is twice as large as the average rice yield in sub-Saharan Africa. They found that there is a large difference in yield between experienced and non-experienced households, namely, 2.46 and 1.72 tones per hectare, respectively, indicating that experience does matter in achieving high yields. Other yield determinants included rainfall (drought decreased yield significantly) and this implies that timing of planting NERICA varieties is a crucial determinant of its yield. The cropping pattern in the previous season was found to be an important factor affecting rice yield.

⁷ Ninety three percent of sample farmers in Gambia are women (The sample number of men is only 39 compared to 532 for women). So it is not surprising that the average for the whole sample is practically (and statistically) the same as for the average for women. Moreover the average gain for men is not significant. The 0.14 tones (i.e. 140 kilogram) per hectare average gain from adoption NERICA although seemingly small is statistically significant and represent about 15% of the average rice yield obtained by farmers (just under 1 tone per hectare).

The impact of NERICA varieties adoption on household income and poverty, are also documented in few studies which find generally NERICA to increase household income and to contribute to better income distribution within African rice growers' households (Table 4). The analysis of impact on income and poverty showed that in Uganda, NERICA has the potential to increase per capita income by 20 USD (12% of actual per capita income) and to decrease the poverty incidence, measured by the head count ratio, by 5 percentage points (from 54.3% to 49.1%) (Kijima et al 2008). This authors also found that, not only the head count ratios but also poverty gap index and squared poverty gap index decline by the introduction of NERICA, suggesting that its income enhancement can be realized among the poorest of the poor in this country of Eastern Africa.

In West-Africa, Glove (2009), Dibba et al (2010) and Dibba (2010) finds NERICA adoption to have positive impact on household rice and total incomes in Gambia. In particular, Dibba (2010) found that adoption of NERICA increases the rice farmer's daily income by about 10 Dalasi (≈ 0.34 USD) on average. For Benin, Sogbossi (2008) identified NERICA adoption as a key determinant in poverty reduction and found that NERICA adoption contributed at 13% decrease in the probability of being poor⁸. In addition, the gender-based analysis demonstrated that the impact of NERICA adoption is higher on women farmer (reduction of probability of being poor is 19%) than men (reduction of probability of being poor is 6%). Findings from another study conducted in Nigeria indicated that adoption of NERICA increased total farm household income and per capita expenditures by respectively ₦63,771.94 (≈ 554.5 USD) and ₦4,739.96 (≈ 41.2 USD), thereby increasing their probability of escaping poverty (Dontsop et al, 2010).

These results on impact of NERICA adoption in Africa reviewed above seem to confirm that NERICA can bring hope for millions of small-scaled poor farmers in the continent by

⁸ The poor is defined using of the income poverty line in Benin estimated at CFA 51,413 per year in rural areas and CFA 91,709 per year in urban areas (Sogbossi, 2008)

reducing poverty and income inequality within population. But the realization of such hope is conditioned by its wider dissemination which can only take place if the seed bottlenecks and other production constraints mentioned in the lessons learned in the next section are addressed.

DRAFT

5. Lessons learned

PVS and seed production

The use of the PVS approach allowed farmers to evaluate the new varieties in comparison with their own material and enhanced capacity building and ownership of the NERICA varieties among farmers and national research and extension communities. PVS also reduced the time involved in the varietal release process in many countries (Box 3).

Different partnerships and different approaches were essential for NERICA adoption and seed production. In many countries the active involvement of government authorities helped stimulate uptake with Presidential Initiatives on Rice in Guinea, Uganda, Mali and Nigeria focused on NERICA varieties (Box 2). In Benin, a private entrepreneur was instrumental in the diffusion of NERICA varieties, paying for demonstration plots across the country, and promoting seed production.

The NERICA dissemination project funded by the African Development Bank and the African Rice Initiative greatly accelerated the uptake of NERICA varieties across SSA (Figure 4). Still, seed production remains a major bottleneck, especially in West and Central Africa, where many farmers have no access to improved rice varieties. In many countries national seed regulatory bodies are not existing or non-functional. Such bodies are essential to estimate and meet rice seed demand for different ecosystems and consumer preferences. Functional and decentralized seed control systems are much needed and often do not exist. Incentives should be provided to small-scale enterprises to develop a viable seed business.

The data on potential adoption rates of NERICA varieties illustrate that there is still tremendous potential to reach more farmers. The constraints to do so are numerous and vary from country to country. One major factor is the desperate lack of capacity at all levels in the rice value chain and especially the neglect of Africa's rice research capacity. A survey conducted among AfricaRice's member states in 2008 showed that approximately 250 to 275 researchers (about 15 women) are involved to some extent in rice research. Most of them work on many other crops and only spend a fraction of their time on rice.. Egypt alone takes the lion share of this research pool with 50 highly qualified researchers working full time on rice, including 12 rice breeders. In comparison, a country the size of Nigeria has only two rice breeders.

Other issues include lack of access to seed, fertilizer, credit and adequate rice production, processing, distribution and marketing infrastructure. These factors need to be identified and relevant actions taken to develop the rice sector. An integrated approach from seed to plate is needed.

Expansion in the lowlands

Africa has a tremendous potential to expand the area under rice cropping, especially in the rainfed lowland ecosystem. It has been estimated that 200 million hectares of rainfed lowland area could be developed for rice across the continent. If just 2 million hectares of these lowlands was allocated to growing rice producing an average yield of only 3 tons per hectare, this would produce a major dent in the current 10 million tones of rice imports. The lowlands offer great potential for the sustainable expansion and intensification and diversification of rice-based systems. Given this tremendous potential, the lowland NERICA

varieties and their successors are expected to make an even bigger impact than the upland NERICA varieties.

6. Conclusions

The rapid increase of rice consumption across sub-Saharan Africa means that the continent is currently importing one-third of what is available on the world market costing an estimated US\$ 4 billion in 2009. Relying on the world market to feed Africa's rice consumers is a risky and unsustainable strategy as it may affect food security and civil stability as shown during the food crisis in 2008. Encouraging the development of Africa's rice sector is crucial and it may serve as an important engine for economic growth (IFPRI, 2007).

Development of Africa's rice sector will require an integrated 'seed to plate' value chain approach. One important element in this chain is obviously the rice variety used by the farmer. Much more work is still needed in defining what varieties farmers need for the various ecosystems in which rice is grown under current and future climate scenarios and that respond to consumer demand. This requires a much greater input in varietal development at national level than is currently the case because of a desperate lack of rice breeding capacity across the continent.

NERICA varieties have shown great potential in both upland and lowland ecosystems in Africa and are already disseminated on an estimated more than 300,000 ha. Women farmers have especially profited from the NERICA varieties. More effort is needed to ensure that larger numbers of rice farmers can profit from these new varieties - farmers who have often not seen a new rice variety in their entire life, especially in the rainfed ecologies.

AfricaRice is already working on new varieties that will replace the first generation of NERICA varieties in the future, hand-in-hand with the few rice breeders that are left on the

African continent and in close collaboration with the International Rice Research Institute and other advanced research institutes. These new breeding efforts, together with a better definition of farmers' needs and consumer demands are expected to lead to the development of varieties that will eventually outperform the current generation of NERICA varieties.

AfricaRice is an active member of the Coalition of African Rice Development (CARD), an initiative of JICA and AGRA, regrouping major rice research and extension institutions and donors (including the World Bank) that aims to double rice production between 2008 and 2018 in sub-Saharan Africa. Such partnerships and commitment at national and regional level to hire, train and retain new staff in rice research and invest in rice production, storage, processing and distribution capacity will be instrumental to boost Africa's rice sector.

DRAFT

7. References

- Adégbola, P.Y., Arouna, A., Diagne, A. and Souléïmane, A.A. (2006). Evaluation de l'impact économique des nouvelles variétés de riz NERICA au Bénin : évidence avec les modèles basés sur l'approche contre factuel. Paper presented at the first Africa Rice Congress, Dar es Salaam, Tanzania, July 31–August 4, 2006.
- Adékambi, A. S., Diagne, A. Kinkingninhoun-Medagbe, F. and Biauou, G. (2009). The Impact of Agricultural Technology Adoption on Poverty: A Case Study of NERICA Varieties in Benin. Paper prepared for the International Association of Agricultural Economists' 2009 Conference, Beijing, China, August 16-22, 2009
- AfricaRice (2010). Rice Data Systems for Sub-Saharan Africa: Contribution to the Japan-AfricaRice Emergency Rice Project. Updated Synthesis Report submitted to the Government of Japan. Africa Rice Center, Cotonou, Benin, September 30, 2010.
- Afriquenligne (2009) Le riz NERICA pour assurer la sécurité alimentaire. In Actualités africaine en ligne. Available on the internet at the following address : <http://www.afriquenligne.fr/actualites/economie/le-riz-nerica-pour-assurer-la-securite-alimentaire-200804252475.html>
- Agboh-Noameshie, A. R., Kinkingninhoun-Medagbe, F.M. and Diagne, A. (2007). Gendered impact of NERICA adoption on farmers' production and income in central Benin. Paper presented at the International conference of African Association of Agricultural Economists (AAAE), 20-22 August 2007, Accra, Ghana.
- Bentley, J., Almekinders, C., Yawovi, D. and Dalohoun, D (2008) Center Commissioned External Review of the African Rice Initiative. AfricaRice
- Camara, B., Conde, A., Diallo, M.S., Barry, M.B., Sekou, B. and Berhe, T. (2002). NERICA, the Guinea experience. Report of the Departments of National Research, Extension and Rural Development and Sasakawa Global 2000/Guinea Agricultural Project
- Carney, J. A. (1998) The Role of African Rice and Slaves in the History of Rice Cultivation in the Americas Judith A. Carney. Human Ecology, Vol. 26, No. 4, 1998. Available at <http://www.jstor.org/page/info/about/policies/terms.jsp>
- Dalton, Timothy. J. (2004). "A household hedonic model of rice traits: economic values from farmers in West Africa." *Agricultural Economics* 31: 149 - 159.

- Diagne A. (2006) Le Nerica, mythe et réalités ? in Grain de sel, la revue de l'inter-réseau Mars - Aout 2006, Agriculture d'Afrique de l'Ouest, un paysage qui se dessine.. N° 4 and 5.
- Diagne A. (2009) "Technological Change in Smallholder Agriculture: Bridging the Adoption Gap by Understanding its Source." AERC conference on Agriculture for Development, Whitesands Hotel, Mombasa, Kenya May 28-29, 2009
- Diagne, A., and Demont, M. (2007). Taking a new look at empirical models of adoption: Average treatment effect estimation of adoption rates and their determinants. *Agricultural Economics* 37:201–10.
- Diagne, A., Midingoyi, G.S and Kinkinginhoun, F. (2009) The Impact of NERICA Adoption on Rice Yield in West Africa: Evidence from four countries. Paper presented at the International Association of Agricultural Economists' 2009 Conference, Beijing, China, August 16-22, 2009
- Dibba, L, A. Diagne, F. Simtowe, M.J. Sogbossi and M. Mendy. 2008a. Diffusion and adoption of NERICA in Gambia. Mimeo, WARDA
- Dibba, L, A. Diagne, F. Simtowe, M.J. Sogbossi and M. Mendy. 2008b The impact of NERICA adoption on yield in Gambia. Mimeo, WARDA
- Dibba, L. (2010) Estimation of NERICA adoption rates and impact on productivity and poverty of the small-scale rice farmers in The Gambia. Thesis submitted to the Faculty of Agriculture, Department of Agricultural Economics, Agri-business and Extension in partial fulfillment of the requirements for the degree of Master of Philosophy in Agricultural Economics.
- Dibba, L. Diagne, A. and Fialor, S. (2010) Impact of NERICA adoption on productivity and poverty of the small-scale rice farmers in the Gambia. Kwame Nkrumah University of Science and Technology Kumasi (Ghana) and Africa Rice Center (AfricaRice)
- Dontsop, P. Diagne, A (2010) Impact of Improved Rice Technology on Income and Poverty among Rice Farmers in Nigeria: The Case of NERICA varieties. University of Ibadan (Nigeria) and Africa Rice Center (AfricaRice).
- FAO (2009) the special challenges for subsaharian Africa. High level experts forum. Rome, 12 – 13 october 2009. Available on :http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Africa.pdf

- Glove, S. (2009) Agricultural technology dissemination in West Africa: A Quantitative Analysis of NERICA Adoption and its Impact in Guinea and The Gambia. Dissertation in Economics, submitted in partial fulfilment of the requirements for the degree of MSc in Development Economics of the School of Oriental and African Studies (University of London).
- Akintayo, I. Ajayi, O. Agboh-Noameshie R. A. and Cissé B. (2009) 7th African Rice Initiative Steering Committee/Experts Meeting May 4-6, 2009, Cotonou, Benin, Report, IRAT, 1967. Les variétés de riz au cercle de Banfora. IRAT/Haute-volta. L'Agronomie Tropical, V. 24, p. 691-707.
- Johnson, D.E (1997) Weeds of rice in West Africa. ADRAO/WARDA
- Jones, M.P., Dingkuhn, M., Aluko, G.K. & Semon, M. (1997a). Interspecific *Oryza sativa* × *O. glaberrima* Steud. progenies in upland rice improvement. *Euphytica*, 92: 237-246.
- Jones, M.P., Dingkuhn, M., Johnson, D.E. & Fagade, S.O. (eds). (1997b). Interspecific hybridization: progress and prospect, p. 21-29. Bouaké, Côte d'Ivoire, WARDA.
- Kaneda, C. (2007a) Breeding and disseminating efforts of NERICA : Breeding of Upland rice. Japan Association for International Collaboration of Agriculture and Forest. Review article. *Journal of Japanese Tropical Agriculture* 51 (1) 1- 4 : 2007 1
- Kaneda, C. (2007b) Breeding and disseminating efforts of NERICA : Evaluation of important characteristics. Japan Association for International Collaboration of Agriculture and Forest. Review article. *Journal of Japanese Tropical Agriculture* 51 (2) 41- 45 : 2007
- Kaneda, C. (2007c) Breeding and disseminating efforts of NERICA : Important characteristics of Lowland rice. Japan Association for International Collaboration of Agriculture and Forest. Review article. *Journal of Japanese Tropical Agriculture* 51 (2) 41- 45 : 2007
- Kaneda, C. (2007d). Breeding and disseminating efforts of NERICA: Efforts for dissemination of Nerica in Africa. Japan Association for International Collaboration of Agriculture and Forest. Review article. *Journal of Japanese Tropical Agriculture* 51 (4) 145- 151, 2007.
- Kijima Y, Otsuka K and Sserunkuuma D (2008) Assessing the impact of NERICA on income and poverty in central and western Uganda. *Agricultural Economics* 38 (2008) 327–337

- Kijima, Y. Sserunkuuma, D. and Otsuka, K. (2006) How revolutionary is the “NERICA revolution”? evidence from uganda. *The Developing Economies*, XLIV-2 (June 2006): 252–67
- Linares, O.F (2002) African rice (*Oryza glaberrima*): History and future potential. Smithsonian Tropical Research Institute
- Lodin J B. (2006) The NERICA conundrum: From Rice to Riches, experiences of New Rice for Africa, Report from a Minor Field Study in Hoima district in Uganda. Bachelor’s level study, Lund University, Sweden
- Ndjiondjop, M-N., Semagn, K., Cissoko, M. Jones, M .P. and McCouch, S. (2008) Molecular Characterization of NERICA lines. Contribution to the book on New Rice for Africa compendium. AfricaRice
- Solidarité et progrès (2008) Mauvais temps pour les malthusiens ! La production de riz explose en Afrique. Brief available on the internet at the following address: <http://www.solidariteetprogres.org/article5783.html>
- Sogbossi, M-J. (2008) Riziculture et réduction de la pauvreté au Bénin : Impact de l’adoption des nouvelles variétés rizicoles sur la pauvreté et l’inégalité du revenu dans le Département des Collines (Bénin). Memoire submitted in partial fulfilment of the requirement of master degree at University of Abomey-Calavi (Benin).
- Somado, E. Guei, R. and Keya, S.O (2008) NERICA: New Rice for Africa – a compendium: Africa Rice Center.
- Spencer, D., A. Dorward , G. Abalu, D. Philip and D. Ogungbile. (2006) “Evaluation of Adoption of NERICA and other Improved Upland Rice Varieties Following Varietal Promotion Activities in Nigeria.” A Study For The Gatsby And Rockefeller Foundations. Final Report, January 2006.

Rice per capita consumption

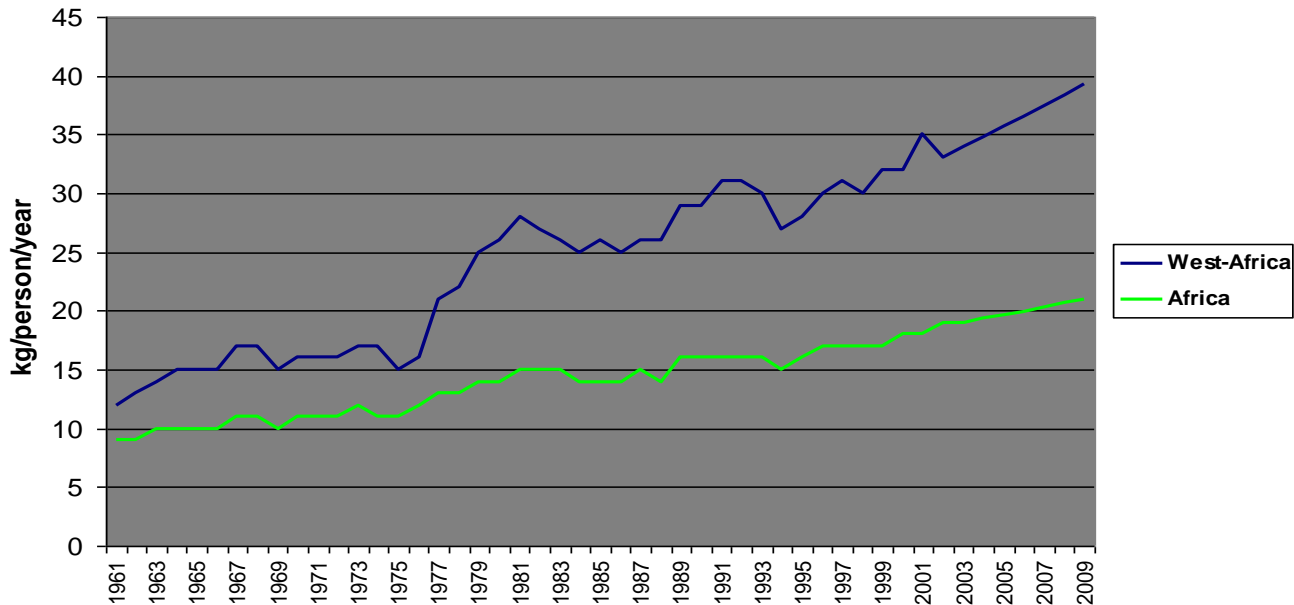


Figure 1: Evolution of rice consumption in Africa and West-Africa
Data source: FAO, 2009

Evolution of Calorific Intake in SSA

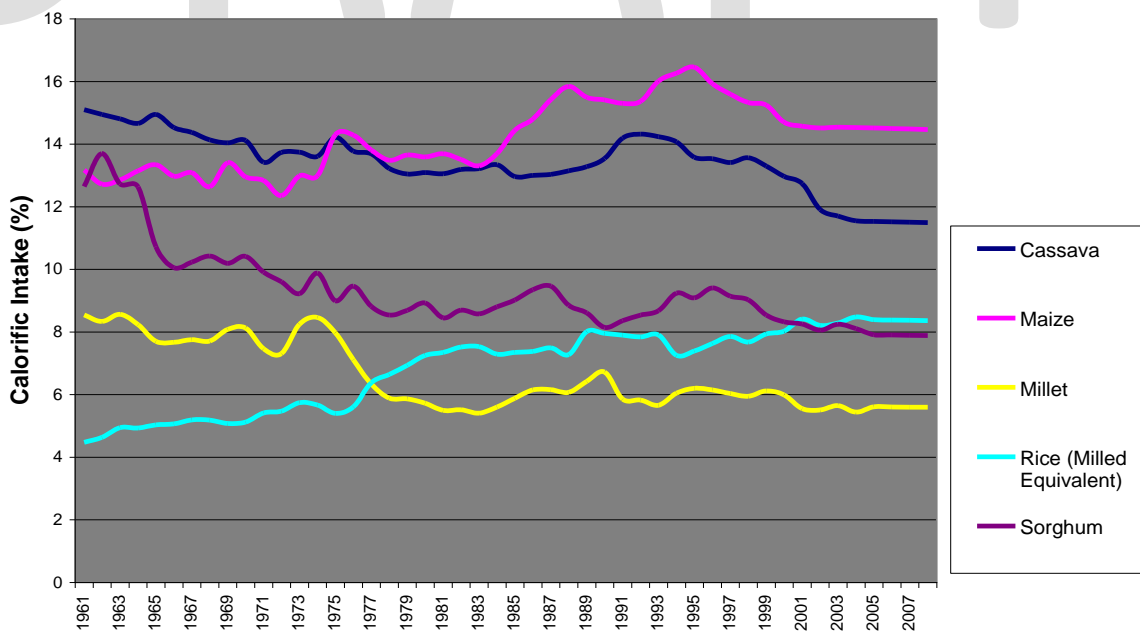


Figure 2: Evolution of calorific intake in SSA
Data source: FAO, 2009

Figure 3 : Box plots of performance of NERICA progenies under low and high inputs conditions and major stresses in upland rice ecosystems*

Figure 3A: Yield under low and high input conditions

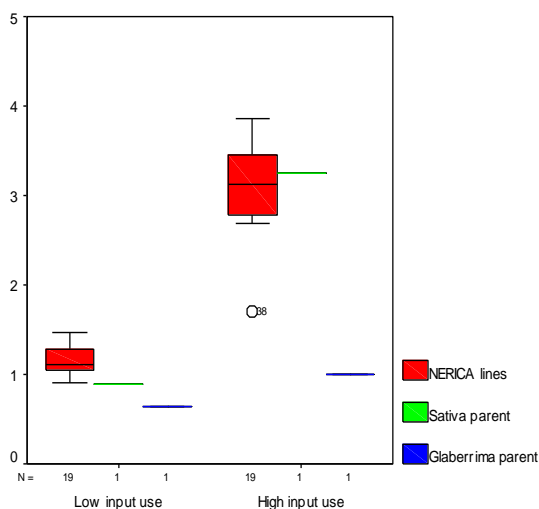


Figure 3B: Yield under drought and non-drought conditions

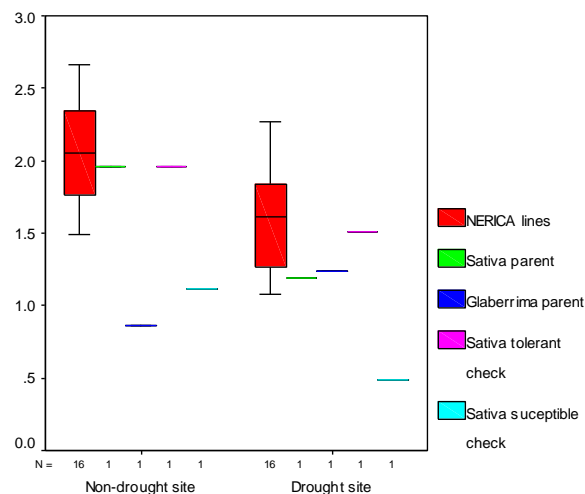


Figure 3C: Yield under acid and nonacid soils

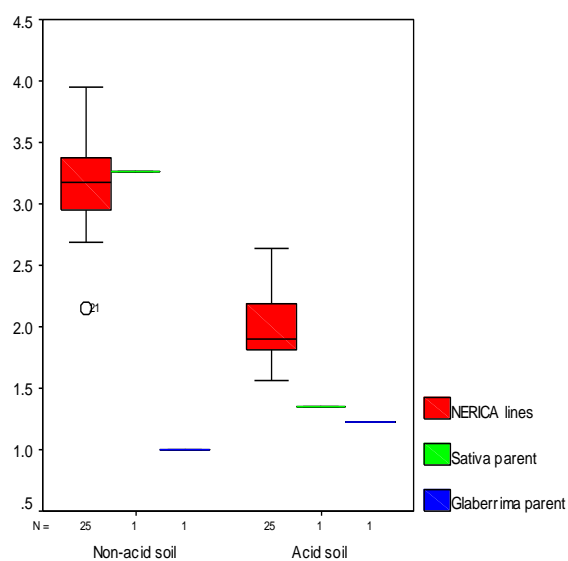
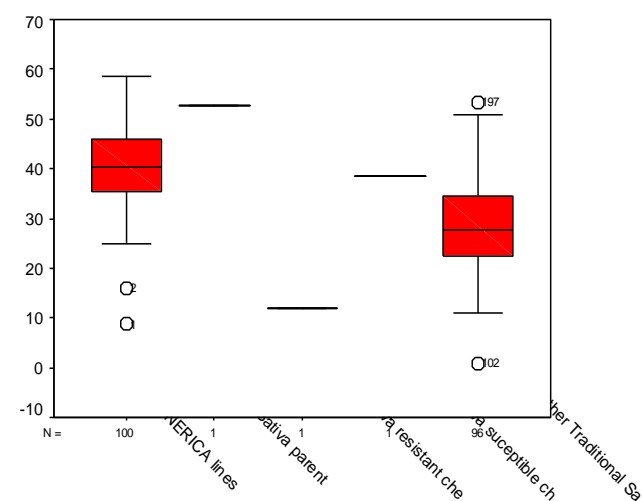


Figure 3D: Susceptibility to African Gall midge attack



*The agronomic trials data are from experimental trials conducted in 1999 by the AfricaRice Breeding program at its headquarters in M'bé in Côte d'Ivoire and at two of its on-farm research sites (Man and Korhogo) also in Côte d'Ivoire. AfricaRice (then WARDA) has five on-farm research sites in Côte d'Ivoire, which are known as "key sites". The key sites were selected in the early 1990s when AfricaRice moved its headquarters to Côte d'Ivoire from Liberia. The location of the key sites was chosen so as to cover all the different rice ecologies and the main rice producing regions in the forest and savanna agro-ecological zones of Côte d'Ivoire. The agronomic trials used a randomized complete block design with 3 replicates at each site. They involved Nerica progenies, their two sativa and glaberrima parents (WAB56 104 and CG14), and a select set of sativa checks which varied across the trials. The set of Nerica progenies are also different across the trials

Gambia	A	A	A	A	A	A	A													7	
Ghana	H	A																			2
Guinea	H	H	H	H	H	H	H														7
Kenya	A			A						A	A										4
Madagascar			A	A																	2
Mali				H					A	A					A					A	5
Nigeria	H	H	A																		3
Ouganda	H		A	H						H											4
Sierra Leone	A	A	A	A	A	A															6
Soudan				A				A													2
Liberia	A			A				A	A												4
Togo	A		A	A																	3
Total	12	8	9	14	4	4	5	2	1	3	1	1	1	1	1	0	1	2	2	70	

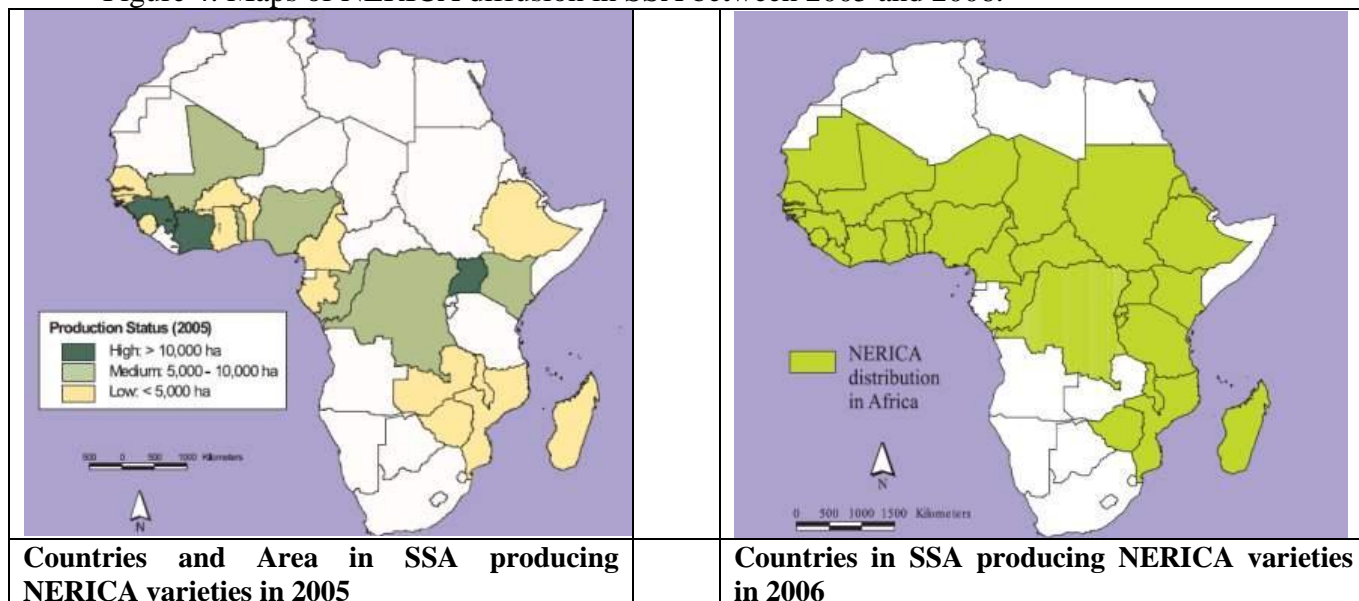
A=adopted, H=released

Table 3: Lowland NERICA varieties adopted/certified SSA

Countries	NERICA-L								WAS 161-B-9-2	WAS 122-IDSA -15-WAS 6-1	WAS127-B-5-2	Total
	19	20	34	39	41	42	49	60				
Burkina-Faso	H	H			H			H				4
Cameroon	A											1
Gambia									H	H	H	3
Mali	H					H						2
Niger				H			H					2
Sierra Leona	A	A										2
Togo	A		A									2
Total	5	2	1	1	1	1	1	1	1	1	1	16

A=adopted, H=released

Figure 4: Maps of NERICA diffusion in SSA between 2005 and 2006.



Box 1: Testimony of a farmer from Mali

The testimony of a farmer from Mali

Mr. Bakary Togola is a rice farmer and presently the president of the Permanent Assembly of Chambers of Agriculture of Mali (Assemblée Permanente des Chambres d'Agriculture du Mali (APCAM)). He had been cropping rice since 1984 and NERICA 4 since 2003. His reason for cropping NERICA was that he has access to land and decided to explore the new rice when he heard about its performance elsewhere. In 2008, he cultivated 185 ha of NERICA 4 with a mean yield of 4.7 t ha⁻¹ and a total yield of 869.5 t. This compared with 60 ha (total yield of 270 t) in 2006 and 80 ha (total yield of 368 t) in 2007.

He hoped to expand production to 200 ha in 2009. He received some subsidy on tractors, seed, thresher and a 50% subsidy on fertilizer from the Government of Mali 2008 Rice Initiative. He produces seed for his own use and for sale. He had no difficulty in disposing his produce and production of NERICA was highly profitable for him. In 2008, he received many visitors at his rice farm, including Mali's Prime Minister and Minister of Agriculture (Figure 28), and a delegation from ARI. His constraints were poor rural roads, inadequate supply of fertilizer, and the lack of a good quality harvester. He felt that government subsidies should be continued for some time through a revolving fund. The 15 km road was initially improved by him. He was prepared to pay for other inputs provided they were of good quality. His impressions were that NERICA 4 is early maturing and high yielding but that its taste needs to be improved upon.

Source: Akintayo et al (2009)

Box 2: Examples of successes in NERICA dissemination in sub-Saharan Africa

Guinea

The first inter-specific lines were introduced in Guinea in 1997 by the *Institut de Recherche Agronomique de Guinée* (IRAG) and the *Service National de la Promotion Rurale et de la Vulgarisation* (SNPRV) through an intensive program of introduction of new upland rice varieties of AfricaRice. NERICA varieties subsequently experienced a very rapid spread in the regions of Upper Guinea and Forest Guinea after only two years of experimental testing and participatory selection (PVS) (Camara et al, 2002; Diagne 2006.). A recent study conducted by researchers from AfricaRice, IRAG and SNPRV in the four regions of Guinea estimated the area under NERICA varieties as 51,000 hectares in 2003, slightly less than 10% of the 525,000 hectares grown to rice in 2003 according to FAO statistics. This is a remarkable achievement in a relatively short time. Moreover in 2007 the area under NERICA varieties in Guinea was estimated at 82,930 hectares corresponding to 12% of the total rice area, with a total production of 145,000 tons (ARI, 2008).

Several factors explain this success of NERICA varieties in Guinea. Firstly, NERICA varieties appeared when Guinea experienced a period of prolonged drought that had pushed the Guinean government to seek assistance from AfricaRice to put at the disposal of the Guinean farmers short-season varieties that could better cope with drought (Diagne 2006). NERICA varieties corresponded well to what was needed. Secondly, Guinean farmers were very receptive to experimenting new varieties in their fields. Thirdly, an effective partnership between national and international institutions greatly contributed to the rapid adoption of the new rice varieties. The World Bank funded the program through its Special Program for Agricultural Research in Africa (SPAAR). The national research (IRAG) and extension institutions (SNPRV) worked together to select the most appropriate testing sites and methods of introduction, joining hands with an international NGO, Sasakawa Global 2000 (SG2000). This facilitated access to inputs for the farmers involved in the trials. AfricaRice staff provided training to IRAG and SNPRV scientists and technicians in the conduct of the PVS trials and seed production throughout the duration of the program (Brossier 2008, Kaneda 2007d, Diagne 2006).

Gambia

The NERICA varieties were introduced into The Gambia through PVS trials in 1998, initially in three villages and later to more widely in the country through farmers' own channels and efforts by the National Agricultural Research Institute (NARI) and Department of Agricultural Services (DAS). The uptake of NERICA varieties continued through the ARI and the NERICA dissemination project funded by the AfDB in 2004. Even the head of State was growing NERICA varieties on his own land and encouraged farmers to grow these varieties. According to FAO data, from 2001 to 2007, rice growing area was relatively constant, i.e. about 17,000 ha. A doubling to 34,000 hectares occurred in 2008, partly due to the enthusiasm generated by NERICA varieties and the support of government and the precious efforts of researchers and technicians. At present NERICA varieties are cultivated in all six agricultural regions of the country. The introduction of the NERICA varieties has brought hope for increased rice productivity and poverty reduction.

Burkina Faso

Progress has also been observed in Burkina Faso where domestic rice production increased by an astonishing 241% in 2008 compared to 2007 (Solidarité et Progres, 2009), which was attributed partly to NERICA varietal adoption by the FAO Rice Monitor. This remarkable success was achieved as a reaction to the world food crisis in 2008 by the Burkinabé government. This emergency support consisted in facilitating farmers' access to mineral fertilizer and to quality seed of high-yielding rice varieties, including NERICA varieties.

Uganda

Rice farming is relatively marginal in East Africa and especially in Uganda. Before 2002, rice farming was practiced by only a few farmers on a very small area and only for marketing purposes. Research support had been abandoned since the 1970s and rice yields gradually declined to reach a level of about 0.4 t ha⁻¹ in 2002. The introduction of NERICA enabled farmers to attain yields of up to 3 tons per hectare on fertile land in Uganda. The introduction of NERICA also led to a drastic increase of the rice area that was estimated in 2004 at about 10,000 ha. Today, NERICA varieties are cultivated in many parts of Uganda. Akintayo *et al* (2009) report that rice acreage in Uganda has increased six-fold since the new varieties were released, from 6,000 ha in 2002 to 40,000 ha in 2008, while the number of rice growers went up from 4,000 in 2004 to 35,000 in 2007. Uganda reduced its rice importation from 60,000 metric tons in 2005 to 35,000 metric tons in 2007 (i.e. a 50% reduction in rice imports, and saving about US\$ 30M).

Several factors explain the rapid update in Uganda. The great interest shown by the National Institute of Agricultural Research for the new varieties at the time of revitalizing its rice program and the dynamism of SG2000 played a very important role in the introduction and diffusion of NERICA varieties. The interest and dynamism of the private sector was essential in producing and marketing seed of NERICA varieties as was the active involvement of the highest political authorities of the country (the Vice president in particular).

Box 3: The Participatory Varietal Selection (PVS) methodology (Gridley and Sie, 2008).

Participatory varietal selection (PVS) is part of a varietal selection process aiming at improving rice production through direct involvement of farmers who play an active role in varietal selection, development and spread (Gridley and Sie, 2008). PVS is an adjunct to conventional breeding and markedly reduces the time taken for new varieties to reach farmers. Indeed, in conventional breeding schemes selection and testing procedures involve a series of multi-location trials over 08 to 12 years of a diminishing number of varieties. Through PVS, a large number of new potentially interesting varieties reach the farmer – for evaluation - in five years and farmers have a major input into the selection of varieties to be released. By involving farmers in the varietal selection process, PVS aims at responding to a diversity of demands for varieties, thereby taking account of site-specificity for agronomic adaptation and selection criteria.

AfricaRice's approach to PVS research (PVS-R) is a three-year program. In the first year, breeders identify centralized fields near villages and plant a 'rice garden' trial of up to 60 upland varieties. The varieties range from traditional and popular *O. sativas* to NERICAs, African *O. glaberrimas* and local checks. Men and women farmers are invited to visit informally the plot as often as possible but the farmers are brought as groups for formal evaluation of the varieties at three key stages: maximum tillering, maturity and postharvest. For the first two, farmers compare agronomic traits. Each farmer's varietal selection and the criteria for selection are recorded and later analyzed.

In the second year, each farmer receives as many as six of the varieties he or she has selected in the first year to grow on his or her farm. Thus genetic diversity enters the communities. PVS observers, who may compromise breeders and/or technicians from NGOs and Extension Services, visit participating farmers' fields to record performance and farmer appreciation of the selected varieties. At the end of the year, farmers evaluate threshability and palatability to provide an overall view of the strengths and weaknesses of the selected varieties.

For the third year, farmers are asked to pay for seeds of the varieties they select providing evidence of the value they place on them. Thus, in three years, PVS allows the farmers to select varieties with specific adaptation and preferred plant type and grain quality characters. These, in turn, can be integrated into the breeding programs to tailor varieties for farmers.

Table 4: Impact of NERICA adoption on yield, income and poverty from various studies

	Benin ^{1,2,3}			Cote-d'Ivoire ⁴			Gambia ^{5,6}			Uganda ^{7,8}	N
	All	Men	Women	All	Men	Women	All	Men	Women	All	A
Yield (tons/ha)	0.71***	0.26***	0.97***	-0.44	-0.44	-0.45	0.146***	0.18	0.142***		
Income (USD)	25***	22***	38***				10.2**	4.6	10.6**	20	5
Per capita household expenditure (USD)											4
Poverty (Probability of being poor (%))	-13	-6	-19							-5	

***=Significant at 1% level; **= Significant at 5% level

¹ Agboh-Noameshie *et al.* (2009), quantity of paddy per hectare from data collected in 2004 cropping season

² Agboh-Noameshie *et al.* (2009), per capita income from data collected in 2004 cropping season

³ Sogbossi (2008), data were from 2004 cropping season

⁴ Diagne *et al.* (2009), quantity of paddy per hectare from data collected in 2000 cropping season

⁵ Dibba (2008), quantity of paddy per hectare from data collected in 2006 cropping season

⁶ Dibba (2008), total household daily income from data collected in 2006 cropping season

⁷ Kijima *et al.* (2008), per capita income

⁸ Kijima *et al.* (2008)

⁹ Dontsop *et al.* (2010), total farm household income from data collected in 2006 cropping season

¹⁰ Dontsop *et al.* (2010), per capita household expenditures from data collected in 2006 cropping season