FASID Discussion Paper Series on International Development Strategies
No. 2007-10-001

Assessing the Impact of a NERICA on Income and Poverty in Central and Western Uganda

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August 2007

Abstract

Persistent food shortage and the deteriorating poverty incidence in Sub-Sahara Africa (SSA) are major development issues. New Rice for Africa (NERICA) was developed to boost the rice yield and income of rural households in SSA. Although its high yielding traits have become fairly well known, there is no empirical analysis of its impact on income and poverty. By taking the case of Uganda where a NERICA promoting program was initiated as one of the major poverty eradication measures, this study attempts to compare actual income with the hypothetical income without NERICA. We found that on average a shift from maize to NERICA with proper crop rotation increases income by USD 250 per hectare. Moreover, introduction of NERICA decreases poverty to a significant extent without deteriorating income distribution.

Key words: Poverty Reduction, Food Security, NERICA, Uganda, Rice

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We are grateful for financial support from the Foundation for Advanced Studies on International Development. We thank Tatsushi Tsuboi, Motonori Tomitaka, Robert Anyang, and staff in SG2000 Uganda office for their knowledge bout rice in Uganda and other African countries. We also thank the excellent enumerators from their hard work and to sampled households for their time and patience. We thank Takeshi Sakurai, Takashi Kurosaki, Aliou Diagne, Ousman Badiane, and seminar participants in University of Tokyo, Japanese Economic Association 2006 Fall Meeting, and the Annual Bank Conference on Development Economics (ABCDE, by the World Bank) Tokyo 2006.

1. Introduction

While poverty has been a critical issue of development economics for many years, its importance was highlighted by the declaration of the Millennium Development Goals (MDGs) in the United Nations (UN) resolutions and agreements in 2000. Some studies such as Sahn and Stifel (2003) predict that the MDGs are almost impossible to achieve, especially in Sub-Saharan Africa (SSA). To ensure that the MDGs are met, the world must accelerate capacity building, the improvement of economic policies, and the delivery of appropriate investments (Sachs, 2005). Since most of the poor live in rural areas and, hence, the livelihoods of rural households depend on agriculture, developing and disseminating improved agricultural technologies must be a central strategy, one which requires urgent attention (NEPAD, 2004; Deininger and Okidi, 2001).

In areas where land is scarce, including high-potential areas in SSA, agricultural production should be enhanced by developing and disseminating fertilizer-responsive and high-yielding technologies, which are also land-saving (Hayami and Ruttan, 1985). Some studies show, however, that with the currently available technologies and inefficient marketing systems characterized by high fertilizer prices and low crop prices in SSA, it is unprofitable for farmers to apply chemical fertilizer (Pender et al., 2004a; Otsuka and Kalirajan, 2005, 2006). Unless improvements are made in the market systems as well as in the development of more profitable technologies, neither input application nor agricultural output will be increased, resulting in the vicious cycle of unfavorable relative prices and low productivity.

Recently, the Ugandan government has introduced New Rice for Africa (NERICA), a high-yielding upland rice variety suited to the African environment,[1] as one of its poverty eradication strategies. NERICA can serve both as a cash crop and a subsistent food crop in Uganda.[2] Even though most farmers in Uganda currently grow NERICA without fertilizer, its average yield is more than twice as high as the average upland rice yield in SSA at 2.3 ton per hectare (Kijima et al., 2006). As with the Green Revolution in Asia, NERICA is expected to boost rice production and income for rural Ugandan households.

A critical question at present concerns the extent to which NERICA has contributed to poverty reduction and affected income distribution in rural Uganda. In

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[1] NERICA is an interspecific cross between Oriza sativa (Asian rice) and O. glaberrima (African rice) (Jones, et al. 1997). In Uganda, only one NERICA variety was introduced, and it is known as NARIC3 or Suparica 2. This is not backcrossed with local Ugandan rice. NERICA is considered to be cultivable in most parts of Uganda according to a suitability map based on GIS information (annual rainfall, elevation, and soil pH). The reason why rice was not widely adopted earlier in Uganda is partly because the yield of traditional upland rice is low. Traditionally, rice is not a major staple food in Uganda. However, the popularity of rice has increased even in rural areas. In our sample NERICA producing households, the average proportion of output sold to the market is 0.37 and the remainder was consumed at home.

[2] Similar to other African countries, NERICA has received external support. There have been different kinds of interventions in Uganda. The major one is the Vice-President Program in which NERICA seeds are distributed through NGOs such as APEP and SG2000. In some areas, farmers can obtain seeds at no charge while seeds are distributed on credit in other areas (farmers have to return the seeds or money to the micro-finance institution after harvest). In some areas, seeds are distributed to local farmers' groups by agricultural extension workers, and then group members allocate the seeds to individual farmers by themselves. In other areas, seeds can be obtained from NGO offices by those who are interested in cultivating NERICA. Another way is contract farming with a private seed company and an agricultural research organization from which farmers obtain NERICA seeds and to which farmers sell outputs.

order to answer these questions, it is critically important to examine the effect of NERICA adoption on labor demand, as the poor tend to depend on such income. It is also important to identify the determinants of NERICA adoption, as new technology may particularly favor educated, wealthy farmers. This study thus examines the effect of NERICA on poverty reduction and income distribution by using household survey data collected in 2005 in 10 NERICA growing areas in rural areas in Central and Western Uganda.

It is important to emphasize here that in most of the sampled areas, NERICA is the first upland rice variety ever introduced. In most areas, many households have increased the total cultivated area by converting fallowed land into NERICA fields to avoid reducing the size of land planted to traditional subsistence crops such as beans, maize, and cooking banana (Matoke).[3] In a few sample areas, however, NERICA has replaced traditional crops. In Hoima district, for example, the plots planted to tobacco in the first cropping season were usually planted to maize, millet, and upland rice varieties other than NERICA in the second cropping season.[4] Currently, however, farmers often plant NERICA after tobacco.

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[3] The reason why farmers left some land uncultivated before NERICA was introduced is because opening land is a very strenuous task. Unless the returns are expected to be high, households do not have incentives to extend the cultivated land. The major upland rice growing areas are located in northern Uganda. Since the Northern part of Uganda has been socially and politically unstable, we could not conduct out survey in these areas. We also tried to compare the areas with non-NERICA upland rice and the areas with NERICA. However, in areas where non-NERICA upland rice was cultivated, most of the households had already switched to NERICA, and thus we could not find such controlled areas.

[4] In most parts of Uganda, there are 2 cropping seasons a year.

The rest of the paper is organized as follows. Section 2 provides an overview of NERICA adoption in Uganda and presents the household and community level data used in this study. In Section 3, we explore the determinants of NERICA adoption. Section 4 presents the estimation strategy for measuring the effect of NERICA on income and the regression results. In Section 5, we conduct simulation analyses to assess the impact of NERICA on poverty and income distribution, while Section 6 provides the policy implications and conclusions.

2. Data

As of February 2005, the number of farm households growing NERICA was increasing in areas with a NERICA seed dissemination program. The number of such areas in the nation as a whole, however, was limited. In areas without such programs, there were very few rice growing households. Therefore, we use two data sets to conduct the analyses in this paper. One is a relatively large and representative household survey covering broad areas of rural Uganda except the Northern districts, and the other is a comparatively smaller survey, which contains more detailed questions regarding NERICA. We call the former the "RePEAT survey" and the latter the "NERICA survey". The RePEAT survey data are mainly used to assess how the NERICA sample is different from the representative sample. Unless we indicate the

"RePEAT survey" as the data source, the analyses in the later sections are based on the NERICA survey data.

2.1 RePEAT Survey

Under the Research on Poverty, Environment, and Agricultural Technologies (RePEAT) project, we collected farm household data in 2003 and 2005. For the RePEAT project, which was largely based on an earlier International Food Policy Research Institute (IFPRI) survey,[5] we selected sample households from 94 out of the original 107 Local Council 1s (the lowest administrative unit in Uganda) covered by the IFPRI survey. From each LC1, we randomly selected 10 households, and thus a total of 940 households were interviewed. The questionnaire covers broad issues such as household demographics, farm and non-farm income, livestock and household assets, and consumption expenditure.[6]

2.2 NERICA Survey

In order to obtain a relatively large sample of farmers who adopted NERICA, we intentionally focused on the NERICA growing areas, given the low adoption rate at

[5] The IFPRI survey selected sample LC1s based on agricultural potential, market access, and population density. More details about the IFPRI survey can be found in Pender et al. (2004b).

[6] Detailed information about the RePEAT survey is provided in Yamano et al. (2004).

the national level.[7] At the same time, we attempted to achieve broader geographical coverage and to choose areas with different NERICA-growing experience.[8] We drew a random sample of 25 households who grew NERICA (NERICA households, hereafter) and 15 households who did not grow NERICA in the second cropping season of 2004 ("non-NERICA households", hereafter) in each of 10 selected areas.[9] The total number of sample households is, therefore, 400.

The NERICA survey questionnaire contains detailed questions about the adoption history of NERICA, the labor and capital inputs used for NERICA production, and the past cropping patterns of current NERICA plots. The structure and questions in the other sections of the NERICA survey questionnaire basically follow those of the RePEAT survey, allowing us to make comparisons between these two surveys.

To control for over-sampling of the NERICA households, we calculated the sampling weights from the information collected during the NERICA survey. These weights are used to compute the descriptive statistics and to conduct the regression analyses, where the sampling weight for the NERICA households in area i is calculated

[7] According to the RePEAT data collected in 2005, the adoption rate of rice is 6.3%, out of which 0.67% grew NERICA (Kijima and Sserunkuuma, forthcoming). The reason why the majority of households have not yet adopted NERICA is simply because the scale of the dissemination program is not large enough to provide NERICA seeds to all the households, even in areas where NERICA was introduced. Another explanation is that we conducted our survey just after the dissemination program started.

[8] The selected areas are the districts of Masindi, Kibaale, Kamwenge, Hoima, Mbarara, Wakiso, Mpigi, Mubende, Kiboga, and Luwero. In half of the areas, NERICA was introduced in 2004. Each area covers about 3 LC1s.

[9] Since many questions are related to NERICA production, we use a different questionnaire for the non-NERICA households in which questions about household demographics, knowledge about NERICA, land holdings, livestock and household assets are asked.

by the ratio of the total number of NERICA growing households in area *i* over the number of sampled NERICA households in that area, and a similar scheme is applied for non-NERICA households. In our sample areas, the adoption rate of NERICA is 16.5%, which although low, is still much higher than the average adoption rate in the nation as a whole.[10]

2.3 Characteristics of Sample Areas and NERICA Households

Table 1 shows the rainfall, the market access measured by the distance to the nearest town and the traveling time to a rice miller by means commonly used by the sample households, and the average cultivated land size per household in the sample areas, including the average area planted to NERICA. Most of the sample areas have more than 1200 mm of rainfall annually, which is the minimum requirement for upland rice cultivation under rainfed conditions.[11] Market access varies considerably across the sample areas. The areas in Wakiso and Mpigi districts have good access not only to nearby towns but also to the capital city, Kampala. Except for these areas, the sample areas are located far from rural towns and have some of the available farmlands fallowed or uncultivated.

[10] The adoption rate in the sample area is calculated by dividing the number of NERICA adopters by the total number of households in the sample area. We obtained the names of all the NERICA adopted households in our sample areas to draw a stratified random sampling.

[11] According to our own interview with a Japanese rice specialist who has been providing technical support on NERICA production in Africa, at least 100 mm of monthly rainfall is necessary for NERICA cultivation.

The average area planted to NERICA ranges from 0.2 ha to 0.5 ha. The area planted to NERICA appears to be positively correlated with the years since NERICA was introduced to the area, as shown in the last column. In areas where NERICA was introduced only in 2004, the area planted to NERICA is limited to 0.2 - 0.3 ha, whereas it is about 0.4 ha in areas where it was introduced earlier. This is probably because rice growing experience reduces the risk of crop failure, prompting farmers to increase the area planted to NERICA. Another possible reason is related to the scarcity of NERICA seeds on the market at the time of our survey because of underdeveloped seed sectors. The early adopters of NERICA were able to save seed from the previous harvest, allowing them to plant larger areas than farmers who newly purchased NERICA seeds.

Table 2 shows the per capita income and the share of income sources,[12] as well as the area planted to NERICA and the total land area per household member, by per capita income quartile.[13] The last column indicates whether the means of variables for lower- and higher-income households are statistically different. Note that as will be shown in the later sections, the income distributions of the NERICA survey and the

[12] In rural Uganda, households generate income from crop production, livestock production, non-farm activities, and labor employment. Income is calculated as the value of products minus paid-out costs. For crop income, paid-out costs include the costs of seeds, fertilizer, hired labor, and oxen rental. In the case of livestock income, revenue consists of sales of animals and livestock products, such as milk and eggs. Paid-out costs for livestock production include purchased feeds, expenditure on artificial insemination services, bull services, and animal health care services. Non-farm activities include non-farm micro enterprises such as trading various goods and seasonal labor activities. Wage income includes salaries from jobs that provide regular monthly salary as well as wage earnings from casual agricultural jobs.

[13] The total cultivated land area includes owned land minus rented-out and lent-out areas, rented-in land, and borrowed–in land.

RePEAT survey households in the same districts can be considered equal from the Kolmogorov-Smirnov test. Thus, the income quartiles in the NERICA survey are comparable to those in the smallholder population in Central and Western Uganda.

There are several important findings in this table. First, the total land area per person increases from the lowest to the highest income quartile (see the last row), indicating the importance of land as a source of income, which is typical in traditional agriculture (Estudillo and Otsuka, 1999). Thus, land-poor households in the rural areas of Uganda tend to be poor.[14] Second, whereas the area planted to NERICA is larger in the higher income quartiles, the proportion of NERICA planted area in total land is higher in the lower income quartiles. This may suggest that comparatively poorer households are not disadvantaged in adopting NERICA, which is similar to the Green Revolution experience in Asia (David and Otsuka, 1994). Third, the major income source for the sample households is crop cultivation, which accounts for 70% of the total income on average. For households in the lower income quartiles, the crop income shares are higher than those for households in the higher income quartiles. Specifically, the rice income share is highest in the second lowest quartile (31% of income), and the rice income share of the bottom quartile (27%) is much higher than that of households in higher income brackets. These findings suggest that introducing NERICA might have

[14] Even if we use land per adult equivalent measures instead of land size per person, we find a similar relationship between land scarcity and income ranks. This relationship is also observed in the RePEAT survey where the average land size per adult equivalent among poor households is 0.9 hectares while that among non-poor households is 1.8 hectares.

a pro-poor effect on income distribution. These results from the descriptive analyses will be tested econometrically in the later sections.

2.4 Characteristics of NERICA

In this subsection, we examine the economic characteristics of NERICA through factor share analysis to examine the factor use bias of crop choice and to determine which factors gain more relative to others. This method is commonly used when new technologies or new crops are introduced (David and Otsuka, 1994).[15]

In this analysis, we compute the gross value of the harvested crops, the actual paid-out costs of the purchased current inputs, hired labor, animals, and machinery, and the imputed cost of the unpaid family labor hours to produce NERICA and an alternative crop, which were cultivated on two contiguous plots at each household.[16] To eliminate the possibility of overestimating the income from NERICA production if NERICA is planted to plots with better soil quality than those planted to the alternative crops, we chose plots located close by to each other. The most common alternative crops were

[15] As mentioned, in some areas, NERICA seeds are given to farmers at no charge. This may act as an incentive for farmers to adopt NERICA by decreasing the production cost. In the analysis here, specifically when we calculate profit, we use the imputed seed cost for the households who received NERICA seeds without charge so as to control for this effect.

[16] We selected an alternative crop plot in the same parcel where NERICA plot is located. If there are many plots in the NERICA parcel, we selected the maize plot. If there is no maize plot, then we picked the legume plot. If there is neither a maize nor a legume plot, we selected a roots/tuber crop plot. The average sizes of the NERICA plot and the alternative plot are 0.42 ha and 0.24 ha, respectively (Appendix Table 3). Intercropping is not common in the NERICA plot (8%) while it is more likely for the classification of crop types in alternative-crop plots (28%). If plots are intercropped, then we take the major crop planted to a larger area.

maize and beans. To estimate the profit, we impute the family labor cost using the average hourly earnings of hired labor in various agricultural tasks. We also calculate the rental value of family-owned capital such as draft animals using the prevailing rental rates in the locality.

Table 3 shows the average factor payments per hectare and the factor share in the second cropping season of 2004 for NERICA, beans, and maize. The gross value of output per hectare on the NERICA plot is close to three times as high as that on plots planted to maize and beans. Thus, NERICA can be regarded as a high-value crop in Uganda. Similarly, the factor payments to all categories of inputs are much higher on NERICA plots than on plots planted to the alternative crops except capital, which suggests that adopting NERICA can result in higher returns to almost all the factor inputs, including family labor. There are classic characteristics of pro-poor green revolution crops as argued by Lipton (1989). However, the factor share of labor is much lower for NERICA (65%) than for the other crops (80 - 83%). As a result, the residual, which is supposed to capture the returns to land and management ability, are higher for NERICA than for other crops, implying that NERICA is more profitable than the alternative crops.[17]

To explore the reason why the absolute factor returns to family labor are much

[17] We think the surplus from the NERICA production is accounted for by the returns to management ability and the risks taken by the NERICA producers.

higher for NERICA than for the other crops, Table 4 presents the family labor hours per hectare by farm activity. We can observe that for NERICA production, households spend about 350 hours on scaring birds during a cropping season, while for the other crops, family labor is hardly required for this activity. Family labor is also more intensively used for land preparation, planting, and harvesting in rice production. There seems to be no question that labor demand increases with the adoption of NERICA.[18]

2.5 NERICA-Driven Change in Farming System

Table 5 shows the fertilizer application and the cropping pattern by district. As can be seen, manure and compost are rarely applied in almost all the areas.[19] Also the use of chemical fertilizer in NERICA production is very limited. This is mainly because fertilizer is expensive in SSA, unlike in Asian countries (Otsuka and Kalirajan, 2005, 2006). Even within the East African region, the price of chemical fertilizer in Kampala is more than double that in Nairobi and Dar es Salaam (Nkonya et al., 2005). During the survey, crop rotation was found to be the most common practice used by farmers to maintain soil fertility. We later examine the effects of the cropping pattern

[18] The labor use in NERICA rice production may be higher partly because many households cultivated NERICA for the first time and are not used to activities such as planting and harvesting rice which are quite different from those in maize and bean production.

[19] This is likely because of the lack of animals such as improved cows, which are the main sources of manure and compost in East Africa (Otsuka and Yamano, 2005), as well as the high-labor requirement of using manure (Sserunkuuma, 2005).

on the yield and income from NERICA production as well as the fertilizer use to show the importance of soil fertility management.

Table 5 shows the distribution of the previous cropping pattern on the plots planted to NERICA in the second cropping season of 2004. Thirty-one percent of the NERICA plots were under fallow or bush in the first cropping season.[20] The rest were planted to legumes (beans and ground nuts), tobacco, non-rice cereal crops (maize and millet), and root crops (sweet potato and cassava). It is clear that there are notable regional differences. For example, in Mbarara, Masindi, and Luwero districts, about 40% of the households planted NERICA on the plots that were previously under fallow or bush. However, farmers in Hoima and Kiboga districts commonly grew NERICA in the second cropping season on the plots planted to tobacco which is associated with the application of large amounts of chemical fertilizer in the first cropping season.

These differences in crop rotation may result in different rice yields. Table 6 shows the rice yield by the crop planted in the preceding cropping season. The rice yield is highest on the plots planted to tobacco in the first cropping season,[21] followed by legume crops, and the previously fallowed or virgin land. It is important to note that in districts where NERICA was introduced earlier such as Kamwenge and Kibaale,

[20] Fallowed land indicates areas which were left unused at least for one cropping season. In our sample, however, 78% of the NERICA plots whose previous use was fallow were kept uncultivated at least for 3 years. Fallowing land for one cropping season is rare (6%).

[21] This is because the fertilizer applied on tobacco in the previous season leaves behind sufficient nutrients in the soil to boost the rice yield.

households are more likely to plant rice on the plots previously planted to legumes in the first cropping season (Table 5). No farmer was found to grow rice continuously on the same plot. These observations indicate that farmers may be able to determine the desirable cropping patterns that sustain or enhance rice yield from experience. In a later section, we examine statistically whether certain cropping patterns in fact affected farmers' income significantly.[22]

3. NERICA Adoption

Since the effect of NERICA on household income depends on the size of land under NERICA, we first analyze the determinants of the absolute area, as well as the share of land planted to NERICA in this section.

3.1 Analytical Model

Even if a new technology has the great potential to increase farmers' income substantially, it may not be adopted due to a variety of reasons such as credit constraints, aversion to risk, and limited family labor availability (Feder et al., 1985; Dalton, 2004). As with the existing literature (Munshi, 2004; Conley and Udry, 2001; Foster and Rosenzweig, 1995; Besley and Case, 1994), this study focuses on the role of access to information in the diffusion process of a new technology. This is because NERICA has only recently been released, and many farmers do not have much information about it

[22] Cropping patterns can be explained also by geographical differences and access to credit.

yet (Kijima and Sserunkuuma, forthcoming). To adopt NERICA, farmers need to obtain the relevant information first. Thus, we hypothesize that accessibility to information is a crucial determinant of adopting NERICA, especially at the initial stage of the diffusion process.

We use two variables to proxy accessibility to information. One is a dummy variable of whether a household member belongs to any farmers' organizations or groups.[23] Since member households tend to gather new information regularly and exchange their experience, it is expected that membership to such groups enhances access to information on NERICA. The other variable is the years of formal education of the household head. This is because educated farmers tend to have greater ability to decode new information such as that obtained from printed material distributed by extension agents and NGOs (Schultz 1975).

Since most Ugandan farmers have never planted rice, rice cultivation in general may be considered riskier than other food crops, and thus deter NERICA adoption. However, for farmers who have experienced growing rice, the risk of crop failure may be lower, thereby increasing the probability of adopting NERICA. Therefore, we hypothesize that rice growing experience has a positive effect on NERICA adoption. Following the methodology in previous technology adoption studies, we examine the

[23] Farmers' organizations tend to be formed with various objectives such as water users groups, service associations, consumer goods associations, dairy associations, women's groups, and elders groups. A few farmers' groups in our sample areas were formed to introduce NERICA. We eliminate these NERICA-related farmers' groups to construct the membership variable.

determinants of the probability of adopting NERICA by using the Probit model.[24]

It is also important to determine whether the availability of land, capital, and labor limits the scaling up of NERICA cultivation. We analyze to what extent NERICA is adopted by the Tobit model since the dependent variable is truncated at zero for non-adopters. Besides accessibility of information, we include village dummies as explanatory variables in the adoption regressions since external interventions and rice production experience vary across villages.[25]

3.2 Estimation Results

The estimation results for the NERICA adoption function are provided in Table 7. Columns (1) – (3) are estimated by using the full sample, while only the NERICA adopters are used in the rest of the columns. In column (1), we estimate the probability of adopting NERICA by the Probit model and the figures indicate marginal effects. The determinants of the share of NERICA planted area and the absolute area planted to NERICA are examined in column (2) and (3) by the Tobit model. In the analyses among the NERICA adopters, the ordinary least squares (OLS) method is used since all the adopters grow NERICA by definition.

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[24] To make a projection of the NERICA adoption rate in the future in the whole country, the method employed by Diagne (2006) is useful.

[25] In addition to these variables, receiving extension services on rice growing and free inputs can be important explanatory variables in NERICA adoption. These variables, however, are not included as explanatory variables since they tend to be endogenous.

Column (1) shows that the proxy variables for accessibility to information, i.e., membership to a farmer's group and the formal education of the household head, significantly increase the probability of adopting NERICA, which supports our hypothesis. As expected, households with non-NERICA rice growing experience are more likely to adopt NERICA. While the number of household members has a positive and significant effect, livestock assets, household assets, and the total land area per household member do not have a significant effect. The insignificance of the asset variables may be explained by the fact that farmers in Uganda still practice traditional low-input agriculture, even for NERICA, as indicated in Table 5.

The results for the share of NERICA planted area and the area planted to NERICA (columns 2 - 5) are qualitatively similar to those for the probability of adopting NERICA discussed above; i.e., rice-growing experience, membership to a farmer's group, and formal education increase the scale of area planted to NERICA. The estimation result of the determinants of area planted to NERICA indicates that households with more family labor adopt NERICA on a larger scale (columns 3 and 5). Thus, the availability of family labor constrains the size of land planted to NERICA.

In addition, columns (2) and (4) indicate that the land size per person has a negative effect on the share of land planted to NERICA, which suggests that land-poor households tend to allocate a larger proportion of land to NERICA cultivation. This is also the case for female headed households, which are likely poorer. We therefore conclude that poorer households tend to allocate a larger proportion of their land to NERICA, which may suggest that the adoption of NERICA has the potential to reduce poverty and improve income distribution.

4. Impacts on Crop Income

To assess the impacts of NERICA on income, we first tested whether the error terms in NERICA adoption and the yield functions are correlated. This is because it is possible that NERICA adopters are more capable than non-adopters in farming, which would bias the estimation results of the NERICA yield function. If these error terms are correlated, we need to correct such a bias in the NERICA yield function by the Heckman model. As shown in the Appendix Table 1, however, we found that these error terms are not correlated. Thus, we estimate the plot-level income from NERICA and the alternative crops by OLS.

4.1 Analytical Framework

The total household income from crop production is determined not only by the technology and factor endowments but also by the management practices, which may be reflected in the cropping patterns. We expect that the choice of a certain cropping pattern tends to be correlated with the plot specific characteristics such as soil fertility and the farmers' unobserved management ability. Our strategy to identify the pure effects of NERICA adoption on household income is (1) to obtain information from two plots (NERICA and the alternative crop) which are located in the same parcel and are located nearby each other, and (2) to estimate the crop income function by the household fixed effects model, which eliminates the effects of the remaining unobserved plot and household characteristics. The empirical model is specified as follows:

(1) $y_{sji} = \gamma Z_{sji} + \delta H_{ji} + \beta X_i + u_i + \varepsilon_{sji}$,

where y_{sji} is the crop income from plot *s* (subscript *N* refers to the NERICA plot and *O* to the other crop plot) at parcel *j* of household *i*, Z_{sij} is a set of characteristics of plot *s* at parcel *j* of household *i*, H_{ji} is a set of characteristics of parcel *j* of household *i*, X_i is a set of household *i*'s characteristics, *u* is household's fixed effects, and ε is an error term. If we estimate this crop income function by OLS, it is likely that the estimates are biased because the household's unobserved characteristics such as farming ability are not controlled for. By estimating equation (1) by the household fixed effects model, we will eliminate such a bias.[26] The plot characteristics include the size of the plot, the

[26] This is because $y_{sji} - \bar{y}_i = \gamma(Z_{sji} - \bar{Z}_i) + \delta(H_{ji} - \bar{H}_i) + \beta(X_i - \bar{X}_i) + (u_i - \bar{u}_i) + (\varepsilon_{sji} - \bar{\varepsilon}_i)$

$= \gamma(Z_{sji} - \bar{Z}_i) + (\varepsilon_{sji} - \bar{\varepsilon}_i)$, where $\bar{y}_i = 0.5(y_{Nji} + y_{Oji})$, $\bar{Z}_i = 0.5(Z_{Nji} + Z_{Oji})$, $\bar{H}_i = 0.5(H_{ji} + H_{ji}) = H_{ji}$,

$\bar{X}_i = 0.5(X_i + X_i) = X_i$, $\bar{u}_i = 0.5(u_i + u_i) = u_i$, $\bar{\varepsilon}_i = 0.5(\varepsilon_{Nji} + \varepsilon_{Oji})$.

crop planted in season *t*, the plot use in the previous season (*t-1*), and whether the plot is planted in pure stand or intercropped.[27]

To estimate the effect of rice-growing experience on the income from NERICA production, we also employ the interaction terms of the NERICA plot with the years of growing rice (varieties other than NERICA) and the years of growing NERICA as additional explanatory variables.[28] We add NERICA and non-NERICA rice growing experience variables separately to accommodate the possibility of their having different effects on income.

4.2 Estimation Result

Table 8 exhibits the estimation results of the plot-level crop income functions. In column (2), the interaction terms of rice-growing experience with the NERICA-plot dummy are added to a set of explanatory variables in column (1). Columns (1) and (2) show that the income from the NERICA plot are significantly higher on plots previously fallowed or planted to legume crops, tobacco, and cereal, than on plots where non-rice cereals were grown for at least the past two seasons (i.e., cereal-cereal, which is the omitted cropping pattern). These results suggest that the NERICA yield is highly

[27] There is information on steepness and the distance to the homestead from the parcel. Because of our sampling strategy, there is no variation on these parcel-level characteristics of each household.

[28] Non-NERICA rice includes other upland varieties and lowland varieties. Some sample households immigrated from the Eastern and Northern districts where non-NERICA rice has been cultivated. In Hoima and Kibaale districts, a few non-NERICA upland varieties were grown before NERICA was introduced.

responsive to soil fertility; i.e., plots previously fallowed or uncultivated as well as those planted to leguminous crops or tobacco are more suitable for NERICA production.[29]

Households with NERICA growing experience derive much higher income from the NERICA plot as shown by the significant coefficients of the interaction terms of the NERICA plot with NERICA growing experience in column (2). In this specification, the coefficients of some of the preferred cropping patterns (tobacco-NERICA, fallow-NERICA, and legume-NERICA) become smaller than those in columns (1) and (3), which strongly suggests that there is a positive correlation between rice growing experience and the better management practice of soil fertility through crop rotation.[30] Thus, the extent to which NERICA adoption has impacts on income depends on the cropping pattern chosen.

5. Impact on Poverty and Income Distribution

5.1 Analytical Framework

To examine the effect of NERICA on poverty reduction, we conduct simulation

[29] One may argue that higher yields associated with the tobacco-NERICA rotation cannot be accessible to all farmers since tobacco-growing households have a larger labor pool to draw from than non-tobacco-growing households. At least in our sample, this is not the case. There are no significant differences in cultivated land size per adult equivalent, households, adult equivalent, the number of male adult members, and the number of female adult members between tobacco-growing and non-tobacco-growing households. However, the tobacco-NERICA cropping pattern may not be adopted in some areas since tobacco is likely to be adopted where a tobacco company (British American Tobacco) offers credit and contract farming in Uganda.

[30] We tried a specification with the interaction terms of the cropping pattern and rice growing experience. The coefficients of some of these interaction terms are significant (fallow-NERICA and tobacco-NERICA cropping patterns), which suggests that rice growing experience has a positive impact on crop incomes only by adopting appropriate cropping patterns.

analyses by estimating the hypothetical income under three different scenarios.[31] In the first scenario, we estimate the income if NERICA had not been adopted and its plot planted to an alternative crop.[32] We call this hypothetical income “without NERICA” or “hypothetical income I”. For this simulation analysis, we assume that households would grow the alternative crop on the NERICA plot if NERICA had not been introduced. For example, if tobacco was planted in the first cropping season and a legume crop was planted as the alternative crop on the adjacent plot in the second cropping season, we assume that the cropping pattern on the NERICA plot would have been tobacco-legume, rather than the currently observed tobacco-NERICA.

Using the estimated coefficients from the crop income model, the net gain or loss of income from growing NERICA compared with the alternative crop is estimated for each household. Since the area planted to NERICA differs across households, the actual increment of income due to NERICA production is also adjusted by the size of the NERICA plot.

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[31] There are other ways to evaluate the effect of NERICA on household income, such as the difference-in-difference estimator by collecting baseline data, propensity score matching, and randomized experiments as Ravallion (2005) states in detail. Since NERICA has been adopted in various ways and the adoption process has not been completed yet, we could not conduct the baseline survey and randomized experiments. Regarding the propensity score matching, the Heckman et al. (1998) demonstrate that failure to compare participants and controls at the common propensity score is a major source of bias in evaluations. Besides, the NERICA survey sample was drawn by stratified random sampling which does not suit the application of the propensity score matching technique. Thus, we did not choose to use it for this study. We believe that this analysis provides valuable information even with its strong caveats and limitations.

[32] In our analyses, the prices are assumed to be constant. Given that rice is imported in Uganda, the domestic rice price is essentially determined by the international price which has been increasing recently. Because of this, we think that setting the rice price constant for the simulation is not an unrealistic assumption, even when rice production increases as NERICA becomes widely adopted in Uganda.

The second scenario is the case in which households without NERICA growing experience before 2004 hypothetically gained such experience. By using the coefficient of the interaction term of the NERICA plot with the years of NERICA growing experience, we computed the hypothetical income arising from the NERICA growing experience as the sum of the actual income and the incremental income gain from one-year's NERICA growing experience for those who did not have NERICA growing experience before the 2nd cropping season of 2004.

In addition to this direct effect of NERICA growing experience on crop income, the third scenario incorporates the indirect effect of NERICA growing experience through the effect of an increase in the area planted to NERICA. We used the coefficient of the area planted to NERICA function and estimated hypothetical income III under the assumption that the actual size of the NERICA plots would increase for households with no NERICA growing experience. After estimating these hypothetical incomes for each household, we calculated the poverty and inequality measures to assess the effect of NERICA production.

Some may argue that examining poverty and income distribution among NERICA adopters is not appropriate since this simulation does not take into account the possibility that adopters may obtain higher yields than non-adopters (Dalton 2004) and, hence, the former tend to be wealthier than the latter (Whitehead 2006, Little et al. 2006, Peters 2006). To show that the sample of NERICA adopters has an income distribution similar to the sample of the representative household survey, we tested whether the distributions of the per capita income in the households of the NERICA survey and in the RePEAT survey are equal by the Kolmogorov-Smirnov test (K-S test, hereafter).[33] Figure 1 shows the kernel density functions of the per capita income from the RePEAT survey and that from the NERICA survey. The K-S test cannot reject the null hypothesis that the two distributions are equal at a p-value of 0.189.[34] Thus, our simulation analyses using the NERICA survey data can be justified.

5.2 Simulation Results

Table 9 shows the simulation results on the poverty and inequality measures within the sample areas.[35] Hypothetical income I (without NERICA adoption) is smaller than the actual per capita income by USD 16 on average, while the per capita income with one-year NERICA experience (hypothetical income II and III) is higher than the actual income by USD 7 – 14 depending on whether the indirect effect of NERICA growing experience via area expansion is incorporated.

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[33] To make a proper comparison with the NERICA survey data, we only use households in districts that the NERICA sample covers.

[34] A more equivalent comparison should be the income from the RePEAT sample and the hypothetical income I (without NERICA) since NERICA was not disseminated in most of the sample districts other than the NERICA growing areas. We conducted the same analyses for these distributions. The K-S test cannot reject the null hypothesis at a p-value of 0.211. The kernel density functions can be obtained from the authors upon request.

[35] We use the coefficients in column (2) of Table 8 to evaluate the effect of cropping patterns and rice growing experience separately on crop income.

Now let us examine the effect of NERICA adoption on poverty and inequality. According to scenario I, poverty among sample farmers decreased from 52.6% to 48.6% due to the introduction of NERICA.[36] In scenarios II and III, all the estimated poverty measures indicate a further reduction in poverty. For example, the head count ratios decline to 46.7% and 42.2%, respectively, if all the NERICA adopters acquired one-year's NERICA growing experience.

As inequality measures, we use the Gini coefficient and the Theil index. Both measures show that the actual income distribution with NERICA is more equitable than the hypothetical income distribution without NERICA (hypothetical income I). The hypothetical income distributions in the second and third scenarios also suggest that the introduction of NERICA tends to improve income distribution. This is because poorer households plant NERICA on a larger proportion of their cultivated land and use more labor on NERICA production.

6. Concluding Remarks

This study examined the effect of new farm technology on the income of poor farmers in Sub-Saharan Africa using the case study of NERICA in Central and Western Uganda. NERICA has the potential to increase per capita income by USD 16 (10% of

[36] The poverty line calculated in Yamano et al. (2004) is inflated up to the 2005 price level by using the CPI given in UBOS (2005).

actual per capita income) and to decrease the poverty incidence, measured by the head count ratio, by 4 percentage points. These results support Schultz's hypothesis that introducing a new profitable technology in traditional agriculture is an effective strategy to reduce poverty (Schultz, 1964, 1979). Such a positive effect of NERICA, however, can only be realized when its adoption is combined with the use of appropriate cropping patterns to maintain soil fertility. Another important finding is that further increases in income are possible after households gain rice-growing experience. These results suggest that both the development of new high-yielding, labor-using technologies, and the effective extension and dissemination of technological knowledge about the new technologies are critical to enhance the income of poor farmers.

Since the amount of rainfall is high in most areas of the country, there is the potential for the countrywide diffusion of NERICA in Uganda. In addition, the price of rice is relatively high because of the land-locked nature of Uganda and the rapidly increasing demand for rice due to increasing urbanization and population growth. Unlike traditional cash crops such as tobacco and coffee, which are grown exclusively for cash income, rice is also home-consumed, implying that NERICA can contribute to the improvement of household food security.

The current NERICA adoption rate, however, is estimated to be less than 1 percent at the national level, which seems to suggest the existence of serious constraints on the adoption of NERICA such as the shortage of NERICA seeds and ineffective extension services. Thus, while this study highlights the significant poverty-reducing effect of NERICA in areas where it has been adopted, this has yet to be realized in most parts of the country. Only if more effective NERICA dissemination programs are implemented, can NERICA contribute significantly to poverty reduction in Uganda.

Since our analyses are based on cross-sectional data, the analysis of the long-term effects of NERICA on income and poverty is beyond the scope of the present study. Yet, our analysis clearly indicates the importance of soil fertility management in sustaining the "NERICA Revolution," which is potentially comparable to the Green Revolution in Asia in terms of yield growth (Kijima et al., 2006). The most cost-effective and sustainable land management practices for NERICA production, however, remain unknown. To achieve sustainable NERICA-driven poverty reduction, its effect on soil fertility must be studied, and the results must be disseminated to establish the most efficient soil fertility management practices.

References

Alene, A.D., Manyong, V.M., 2006. Farmer-to-farmer technology diffusion and yield variation among adopters: the case of improved cowpea in northern Nigeria. Agricultural Economics 35, 203-211.

Besley, T., Case, A., 1994. Diffusion as a learning process: evidence from HYV cotton. Working paper, Department f Economics, Princeton University.

Conley, T., Udry, C., 2001. Social learning through networks: the adoption of new agricultural technologies in Ghana. Amer. J. Agr. Econ. 83, 668-673.

Dalton, T.J., 2004. A household hedonic model of rice traits: economic values from farmers in West Africa. Agricultural Economics 31, 149-195.

David, C., Otsuka, K., 1994. Modern rice technology and income distribution in Asia. Lynne Rienner, Boulder.

Deininger, K., Odiki, J., 2001. Rural households: incomes, productivity, and non-farm enterprises, in Reinikka, R.,Collier, P. (Eds.), Uganda’s recovery: the role of farms, firms, and government. The World Bank, Washington, DC.

Diagne, A., 2006. The diffusion and adoption of NERICA rice varieties in Cote d’Ivoire. Developing Economies 44, 208-231.

Estudillo, J., Otsuka, K., 1999. Green revolution, human capital, and off-farm employment: changing sources of income among farm households in central Luzon, 1966-94. Economic Development and Cultural Change 47 (3), 497-523.

Feder, G., Just, R.E., Zilberman, D., 1985. Adoption of Agricultural Innovations in Developing Countries: A Survey. Economic Development and Cultural Change 33, 255-298.

Foster, A.D., Rosenzweig, M.R., 1995. Learning by doing and learning from others: human capital and technical change in agriculture. Journal of Political Economy 103, 1176-1209.

Hayami, Y., Ruttan, V., 1985. Agricultural development: an international perspective.

Johns Hopkins University Press, Baltimore, MD.

Heckman, J., Ichimura, H., Smith, J., Todd, P., 1998. Characterizing selection bias using experimental data. Econometrica 66, 1017-1099.

Jones, M., Dingkuhn, M., Johnson, D.E., Fagade, S.O., 1997. Interspecific hybridization: progress and prospect. In Proceedings of the worldshop: Africa/ Asia join research, Interspecific hybridization between African and Asian rice species, ed. Oryza glaberrima and oryza sativa. Bouake: WARDA.

Kijima, Y., Sserunkuuma, D., Otsuka, K., 2006. How revolutionary is the "NERICA revolution"? evidence from Uganda. Developing Economies 44 (2), 232-51.

Kijima, Y., Sserunkuuma, D., forthcomming. The adoption of NERICA rice varieties at the initial stage of the diffusion process in Uganda. East African Journal of Rural Development.

Lipton, M., 1989. New seeds and poor people. Baltimore: Johns Hopkins University Press.

Munshi, K., 2004. Social learning in a heterogeneous population: technology diffusion in the Indian Green Revolution. Journal of Development Economics 73, 185-213.

NEPAD, 2004. Implementing the comprehensive Africa agricultural development programme and restoring food security in Africa.
Available at <http://www.sarpn.org.za/nepad_1.php?id=48>

Nkonya, E., Pender, J., Kaizzi, C., Edward, K., Mugarura, S., 2005. Policy options for increasing crop productivity and reducing soil nutrient depletion and poverty in Uganda. Environment and Production Technology Division Discussion Paper No. 134, International Food Policy Research Institute, Washington, D.C.

Otsuka, K., Kalirajan, K., 2005. An exploration of a green revolution in sub-Sahara Africa. Journal of Agricultural and Development Economics 2 (1), 1–6.

Otsuka, K., Kalirajan, K., 2006. Rice green revolution in Asia and its transferability in Africa. Developing Economics 44 (2), 107-22.

Otsuka, K., Yamano, T., 2005. The possibility of a green revolution in sub-Saparan Africa: evidence from Kenya. Journal of Agricultural and Development Economics 2, 7-19.

Pender, J., Ssewanyana, S., Edward, K., Nkonya, E., 2004a. Linkages between poverty and land management in rural Uganda: evidence from the Uganda national household survey, 1999/2000. Environment and Production Technology Division Discussion Paper No. 122, International Food Policy Research Institute, Washington, D.C.

Pender, J., Jagger, P., Nkonya, E., Sserunkuuma, D., 2004b. Development pathways and land management in Uganda. World Development 32 (5), 767-792.

Peters, P., 2006. Rural income and poverty in time of radical change in Malawi, Journal of Development Studies 42, 226-247.

Ravallion, M., 2005. Evaluating anti-poverty programs. World bank working paper 3625, Washington, D.C.

Sachs, J., 2005. The end of poverty: economic possibilities for our time. Penguin Press, New York.

Sahn, D., Stifel, D., 2003. Progress toward the millennium development goals in Africa. World Development 31 (1), 23-52.

Schultz, T.W., 1964. Transforming traditional agriculture. Yale University Press, New Haven.

Schultz, T.W., 1975. "The value of the ability to deal with disequilibria." Journal of Economics Literature 13, 827-846.

Schultz, T.W., 1979. The economics of being poor. Journal of Political Economy 88, 639-51.

Sserunkuuma, D., 2005. The adoption of impact of improved maize and land management technologies in Uganda. Journal of Agricultural Development Economics 2, 67-84.

UBOS, 2005. Consumer price index august 2005. Press Release. Uganda Bureau of Statistics.

Whitehead, A., 2006. Persistent poverty in north east Ghana. Journal of Development Studies 42, 278-300.

Yamano, T., Sserunkuuma, D., Otsuka, K., Omiat, G., Ainembabazi, J.H., Shimamura, Y., 2004. The 2003 REPEAT survey in Uganda: results. FASID Development Database 2004-09-01, Foundation for Advanced Studies on International Development, Tokyo, Japan.

Table 1. Rainfall, Access to Nearby Town, and Land Use in Sample Areas

District	Total rainfall in 2003 (mm)[a]	Traveling time to rice miller (minutes)[bd]	Distance to nearby town (km)[c]	Average area cultivated (ha)[c]	Average area fallowed (ha)[c]	Area planted to NERICA (ha)[c]	Year NERICA introduced[c]
Masindi	1294	66	21	3.42	1.65	0.32	n.a.[e]
Kibaale	1602	47	17	1.88	4.04	0.54	2001
Kamwenge	643	58	16	1.57	1.16	0.41	2001
Hoima	1530	24	9	1.36	2.12	0.34	2002
Luwero	1373	33	17	1.95	0.99	0.41	2003
Mbarara	765	50	13	1.20	1.25	0.19	2004
Wakiso	1460	26	7	1.08	0.97	0.32	2004
Mpigi	1454	47	2	1.70	1.71	0.32	2004
Mubende	1248	115	25	2.11	1.60	0.22	2004
Kiboga	818	77	8	2.63	3.29	0.29	2004

[a] Data is obtained from Department of Meteorology, Uganda.
[b] Calculated from NERICA household survey data.
[c] NERICA community survey data.
[d] Traveling time by a means commonly used by sample households (in most of the areas, the common means is bicycle).
[e] The year in which NERICA was introduced for the first time is not known.

Table 2. Per Capita Income, Income Sources, NERICA Adoption, and Land Endowment by Income Quartile [a]

	Per capita income quartile				
	1	2	3	4	
Per capita income (US$)	38	100	167	356	**
Share (%) of crop income	79	79	65	62	**
Share (%) of livestock income	13	7	12	8	
Share (%) of other income	9	15	23	30	**
Share (%) of rice income	27	31	20	20	**
Area planted to NERICA (ha)	0.38	0.41	0.55	0.51	*
Percent of area planted to NERICA in total land area	16.4	21.1	12.3	16.6	*
Total land area (ha)	3.1	3.6	5.3	5.1	**
Number of household members	8.9	7.0	8.2	7.0	
Years of schooling of household head	6.2	6.8	7.1	8.6	**
Total land area per household member (ha)	0.36	0.52	0.66	0.77	**

[a] All the means and proportions are calculated with sampling weights.
** and * indicate that the means of higher-income and lower-income households are statistically different at significance levels 1% and 5%, respectively.

Table 3. Factor Payments (USD/ha) and Factor Share (%) by Crop in Second Cropping Season in 2004

	NERICA	Beans	Maize
Gross value	662.2	267.1	264.4
Current inputs	52.8	18.5	11.6
	(8.0)	(6.9)	(4.4)
Imputed (own) [b]	34.6	0.0	0.2
Paid	18.2	18.5	11.4
Capital	1.0	0.0	7.0
	(0.2)	(0.0)	(2.6)
Owned [b]	0.8	0.0	3.6
Hired	0.2	0.0	3.4
Labor	433.4	221.6	211.6
	(65.4)	(83.0)	(80.0)
Family [b]	318.4	187.8	148.9
Hired	115.0	33.8	62.7
Residual (Profit)	175.0	27.0	34.2
	(26.4)	(10.1)	(12.9)
Leasehold rent	3.0	0.0	0.6
Surplus	172.0	27.0	33.6

[a] Ugandan shilling is converted to US dollars by using exchange rate of Shs 1700 being US$1.00. Figures in parentheses are factor shares (%). All the means and proportions are calculated with sampling weights.

[b] Imputed labor cost is calculated by using average hourly wage earnings under piece-rate contracts in various agricultural tasks, whereas cost of owned capital and current inputs (mainly own seeds and free fertilizer provided by projects) are imputed by using prevailing market rental rates and prices, respectively.

Table 4. Family Labor Spent (Hours/ha) by Crop in the 2nd Cropping Season in 2004 [a]

	NERICA	Beans	Maize
Total family labor	2360	998	720
	(1589)	(769)	(590)
Land preparation	502	374	205
	(660)	(471)	(316)
Planting	311	167	99
	(287)	(176)	(122)
Weeding	464	274	209
	(577)	(221)	(239)
Scaring birds	353	0	30
	(391)	(--)	(123)
Harvesting	730	182	178
	(591)	(198)	(180)

[a] The numbers in parentheses are standard deviations.
All the means are calculated with sampling weights.

Table 5. Fertilizer Application and Cropping Pattern by District [a]

District	% of NERICA plots with positive application of		% of alternative crop plots w/ chemical fertilizer	% of NERICA plots whose previous use was:				
	Manure/ compost	Chemical fertilizer		Non-rice cereal	Legume	Tobacco	Fallow/ virgin	Roots/ tubers
Masindi	9	8	8	42	0	0	42	17
Kibaale	0	8	4	28	28	12	28	4
Kamwenge	0	7	0	23	43	0	30	3
Hoima	0	12	0	4	4	62	27	4
Luwero	0	0	0	36	3	0	55	6
Mbarara [b]	0	20	0	30	10	10	40	10
Wakiso [b]	0	0	0	54	7	0	32	7
Mpigi [b]	4	18	0	43	11	0	18	29
Mubende [b]	0	21	7	45	21	4	11	14
Kiboga [b]	0	29	4	50	0	29	21	0
Average	0	8	2	29	17	17	31	6

[a] All the proportions are calculated with sampling weights.
[b] In these districts, NERICA was first introduced in 2004.

Table 6. NERICA Yields, Revenue, Paid-out Cost, and Income by Crops Grown in the Previous Season [a]

	Yields (ton/ha)	Revenue (USD/ha)	Paid-out Cost (USD/ha)	Income (USD/ha)
Previous crop:				
Tobacco	3.26	979	118	860
	(1.43)	(622)	(103)	(574)
Legume crop	2.86	711	169	542
	(1.52)	(502)	(132)	(454)
Fallow/Virgin land	2.53	697	211	486
	(1.31)	(419)	(156)	(422)
Cereal crop	2.33	625	141	484
	(1.64)	(457)	(144)	(413)

[a] The numbers in parentheses are standard deviations.
All the means are calculated with sampling weights.

Table 7. Determinants of NERICA Adoption [a]

	All households			HHs adopted NERICA only	
	Pr(adopt =1)	Share of NERICA planted area	Area planted to NERICA (ha)	Share of NERICA planted area	Area planted to NERICA (ha)
	[Probit]	[Tobit]	[Tobit]	[OLS]	[OLS]
	(1)	(2)	(3)	(4)	(5)
=1 if household with a member of farmer's group (non-rice related)	0.171	0.138	0.328	0.079	0.189
	(13.13)**	(5.84)**	(5.89)**	(2.69)**	(2.68)**
Years of experience of growing rice (except NERICA)	0.029	0.012	0.052	-0.005	0.016
	(11.71)**	(3.63)**	(6.94)**	(1.64)	(2.31)*
Years of formal education of household head	0.010	0.009	0.013	0.003	-0.012
	(7.47)**	(3.45)**	(2.09)*	(1.28)	(1.93)
=1 if head is female	-0.050	-0.022	-0.101	0.063	-0.019
	(3.97)**	(0.74)	(1.42)	(1.79)	(0.23)
Age of household head (100 years)	0.019	-0.057	-0.160	-0.166	-0.335
	(0.54)	(0.81)	(0.95)	(1.99)*	(1.67)
Number of household members	0.014	0.002	0.040	-0.011	0.026
	(8.05)**	(0.61)	(5.70)**	(3.71)**	(3.59)**
Proportion of male adults aged 15-59	0.053	0.094	0.117	0.081	0.139
	(1.49)	(1.26)	(0.70)	(1.13)	(0.81)
Proportion of female adults aged 15-59	-0.030	-0.118	-0.092	-0.072	-0.113
	(0.95)	(1.72)	(0.61)	(0.91)	(0.59)
Land size per person	0.008	-0.062	0.066	-0.124	0.155
	(0.93)	(2.71)**	(1.73)	(6.07)**	(3.17)**
Value of livestock (1000 USD)	0.007	0.000	0.051	-0.013	0.136
	(0.80)	(0.02)	(1.51)	(0.65)	(2.78)**
Value of household asset (1000 USD)	-0.011	-0.018	0.004	-0.014	0.023
	(0.92)	(0.60)	(0.11)	(0.55)	(0.38)
Traveling hours to rice miller by common traveling means	0.011	0.002	0.014	0.008	0.001
	(1.38)	(0.14)	(0.39)	(0.54)	(0.02)
Constant		-0.177	-0.780	0.264	0.008
		(2.75)**	(5.07)**	(3.51)**	(0.04)
District dummies	Yes	Yes	Yes	Yes	Yes
Observations	400	400	400	250	250
Log likelihood	-695.1	-27.1	-226.3		
R-squared (Pseudo R-squred)	(0.44)	(0.72)	(0.34)	0.31	0.35

[a] ** and * indicate significance at 1% and 5% level, respectively. Columns (1): Number in parentheses is z-statistics. Numbers are marginal effects, not estimated coefficients. Columns (2) - (5): Number in parentheses is t-statistics.

Table 8. Estimation Results of Plot-level Income Function (USD per hectare), Household Fixed Effects Model [a]

	(1)		(2)	
	coefficient	(t-stat)	coefficient	(t-stat)
Cropping patterns [b] (previous crop -- current crop)				
Cereal - NERICA	411.117**	(3.11)	368.647**	(2.68)
Legume - NERICA	499.073**	(3.12)	455.201**	(2.71)
Roots/ tubers - NERICA	496.884*	(2.03)	457.570+	(1.86)
Tobacco - NERICA	650.702**	(3.74)	560.520**	(3.02)
Virgin - NERICA	513.906*	(2.57)	514.677*	(2.57)
Fallow - NERICA	365.663*	(2.31)	341.089*	(2.14)
Cereal - Legume	13.160	(0.05)	22.229	(0.09)
Legume - Legume	211.644	(0.79)	184.259	(0.68)
Roots/ tubers - Legume	-89.852	(0.41)	-103.548	(0.47)
Tobacco - Legume	3.648	(0.01)	-12.810	(0.05)
Virgin - Legume	571.124	(1.56)	568.385	(1.54)
Fallow - Legume	-57.634	(0.28)	-73.222	(0.35)
Cereal – Roots/ tubers	371.020	(1.00)	374.792	(1.01)
Legume – Roots/ tubers	284.648	(1.11)	307.424	(1.19)
Roots – Roots/ tubers	320.093	(1.45)	267.909	(1.19)
Virgin – Roots/ tubers	425.686	(0.69)	436.278	(0.71)
Fallow – Roots/ tubers	377.135+	(1.87)	394.723+	(1.94)
Legume - Cereal (non rice)	-7.351	(0.03)	53.951	(0.23)
Roots/ tubers – Cereal (non rice)	-17.043	(0.07)	13.145	(0.06)
Tobacco – Cereal (non rice)	273.925	(0.93)	232.104	(0.77)
Virgin – Cereal (non rice)	14.649	(0.07)	27.676	(0.13)
Fallow – Cereal (non rice)	117.447	(0.67)	130.730	(0.75)
Size of the plot (ha)	-94.260	(0.86)	-151.882	(1.38)
Chemical fertilizer application (kg/ha)	51.438	(0.31)	112.274	(0.69)
Intercropping (=1 if plot is intercropped)	28.267	(0.27)	71.958	(0.69)
NERICA plot × years of NERICA growing experience			148.356*	(2.53)
NERICA plot × years of non-NERICA rice experience			26.534	(1.81)
Constant	-94.778	(0.22)	-165.872	(0.39)
Number of Observations	488		488	
R-squared	0.60		0.62	

[a] Numbers in parentheses are *t*-statistics.
**, *, and + indicate 1%, 5%, and 10% levels of significance, respectively.
All the means and proportions are calculated with sampling weights.
[b] The default of cropping pattern is non-rice cereal – non-rice cereal.

Table 9. Actual and Hypothetical Income Distribution and Poverty Incidence with and without NERICA Production [a]

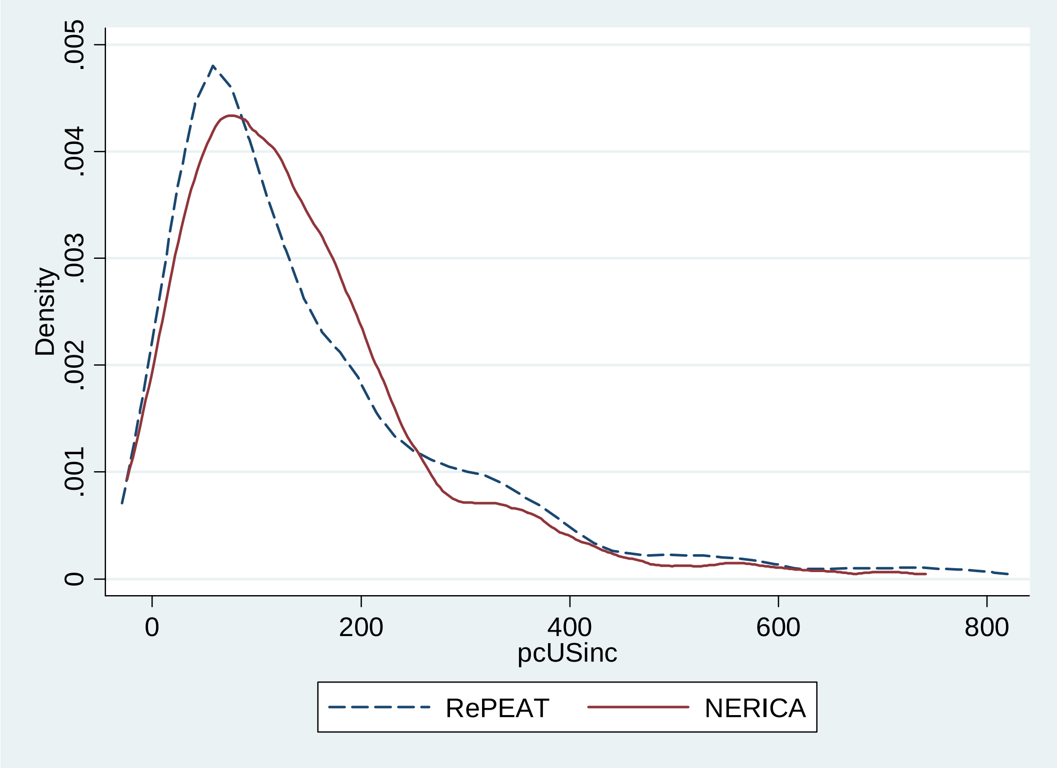
	Hypothetical [b] Income I	Actual Income	Hypothetical [b] Income II	Hypothetical [b] Income III
Per capita income (USD)	146	162	169	176
(s.d)	(131)	(139)	(143)	(149)
Poverty Line = USD 128 [c]				
Head Count Ratio (HCR)	52.6	48.6	46.7	42.2
Poverty Gap Index	26.9	24.0	20.1	17.9
Squared Poverty Gap	18.4	15.4	12.2	10.7
Inequality Measures				
Gini coefficient	0.438	0.409	0.405	0.397
Theil index	0.324	0.288	0.285	0.276

[a] All the means and proportions are calculated with sampling weights.

[b] The hypothetical income is estimated by assuming that an alternative crop had been grown on the NERICA plot. The hypothetical income I is the income if NERICA was not introduced. The hypothetical income II is the income if households without the NERICA growing experience before 2004 had NERICA growing experience. The hypothetical income III is the income if households without the NERICA growing experience earned NERICA-growing experience (direct effect) and expanded the area planted to NERICA by 0.1 hectare due to one-year NERICA-growing experience (indirect effect).

[c] The poverty line calculated in Yamano et al. (2004) is adjusted to 2005 price level by using the CPI given in UBOS (2005).

Figure 1 Comparison of Distributions of Per Capita Income [a]



[a] "RePEAT" indicates the sample data from the RePEAT Uganda survey in 2005 collected in the same districts as in the NERICA survey. Actual income in the NERICA adopter households is indicated as "NERICA"

Appendix. Test for Selection Bias

Since it is generally observed that early adopters tend to be more productive than the followers (Alene and Manyong, 2006), assessing the effect of NERICA only among NERICA adopters may cause serious estimation bias. Whether such a systematic relationship between NERICA adoption and yields exists can be tested by the Heckman model as follows:

(A1) $y = \beta X + u_1, \quad u_1 \sim N(0, \sigma)$

(A2) y is observed if $Z + u_2 < 0, \quad u_2 \sim N(0, 1)$

(A3) $corr(u_1, u_2) = \rho$,

where y and X are the dependent variable and regressors for the NERICA yield function, respectively, and Z is a set of variables thought to determine NERICA adoption. Specifically, we test the null hypothesis that the correlation between u_1 and u_2 is zero by estimating the Heckman model. The selection model is the same as the adoption model shown in column (1) of Table 7. The identifying variable is membership in a farmer's group. Column (2) of Appendix Table shows the result of the NERICA yield function with the selection bias. The Wald test cannot reject the null hypothesis that the NERICA yield and adoption functions are independent with statistics of 1.0 (P-value is 0.32).[37] Thus, we consider that self-selection bias is not a problem at least in our sample data.

[37] We used the "heckman" command in the statistical software (STATA) which provides the Wald test result for the independent equations.

Appendix Table 1. NERICA Adoption and Yield (Heckman Selection Model) [a]

	Pr(adopt =1) [Probit] (1)	NERICA yields [OLS] (2)
=1 if household with a member of farmer's group (non-rice related)	0.171	
	(13.13)**	
Years of experience of growing rice (except NERICA)	0.029	0.027
	(11.71)**	(0.77)
Years of formal education of household head	0.010	0.020
	(7.47)**	(0.56)
=1 if head is female	-0.050	-0.475
	(3.97)**	(-1.45)
Age of household head (100 years)	0.019	-1.453
	(0.54)	(-1.85)+
Number of household members	0.014	-0.025
	(8.05)**	(-0.71)
Proportion of male adults aged 15-59	0.053	0.064
	(1.49)	(0.08)
Proportion of female adults aged 15-59	-0.030	0.020
	(0.95)	(0.03)
Land size per person	0.008	-0.027
	(0.93)	(-0.15)
Value of livestock (1000 USD)	0.007	-0.185
	(0.80)	(-0.76)
Value of household asset (1000 USD)	-0.011	0.025
	(0.92)	(0.08)
Traveling hours to rice miller by common traveling means	0.011	0.069
	(1.38)	(0.47)
Constant		3.268
		(3.00)**
District dummies	Yes	Yes
Observations	400	
Wald test of independent equations =0.24 (p-value=0.63)		

[a] **, *, and + indicate significance at 1%, 5%, and 10% level, respectively. Column (1) is the selection function. Number in parentheses is z-statistics. Numbers are marginal effects, not estimated coefficients. This column is same as column (1) of Table 7. In column (2), number in parentheses is t-statistics.

Appendix Table 2. Household-level Descriptive Statistics

	NERICA adopter households		NERICA non-adopter households	
	mean	s.d.	mean	s.d.
Share of NERICA planted area	0.166	(0.162)	0	-
Area planted to NERICA (ha)	0.460	(0.401)	0	-
=1 if household with a member of farmer's group	0.875	(0.332)	0.393	(0.490)
Years of experience of growing rice (except NERICA)	2.01	(3.70)	0.181	(1.073)
Years of formal education of household head	7.19	(4.01)	4.46	(3.58)
=1 if head is female	0.085	(0.279)	0.353	(0.479)
Age of household head	43.6	(13.3)	45.8	(15.8)
Number of household members	7.78	(3.57)	5.64	(3.03)
Proportion of male adults aged 15-59	0.244	(0.163)	0.230	(0.230)
Proportion of female adults aged 15-59	0.220	(0.147)	0.257	(0.236)
Land size per person (ha)	0.576	(0.512)	0.530	(0.554)
Value of livestock (USD)	297.2	(486.6)	219.9	(648.2)
Value of household asset (USD)	155.8	(383.9)	138.4	(896.5)
Traveling time to rice miller (hours)	0.759	(0.755)	0.924	(0.630)
Number of Observations	250		150	

Appendix Table 3. Plot-level Descriptive Statistics [a]

	NERICA plot	Alternative crop plot
Previous crop/ use dummies		
Cereal	0.285	0.217
	(0.452)	(0.413)
Legume	0.174	0.144
	(0.380)	(0.352)
Roots/ tubers	0.062	0.191
	(0.241)	(0.394)
Tobacco	0.173	0.066
	(0.379)	(0.249)
Virgin	0.091	0.096
	(0.288)	(0.295)
Fallow	0.215	0.286
	(0.411)	(0.453)
Size of the plot (ha)	0.419	0.245
	(0.362)	(0.263)
Chemical fertilizer application (kg/ha)	0.313	0.026
	(1.980)	(0.278)
Intercropping (=1 if plot is intercropped)	0.079	0.285
	(0.270)	(0.452)
Number of Observations	244	244

[a] In 6 households, there is insufficient information. Thus, the number of observation decreases to 244*2 = 488.