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An Empirical Analysis of Expanding Rice Production in Sub-Saharan Africa

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Evidence from the Sustainable Irrigated Agricultural Development (SIAD) Project in Eastern Uganda

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On the Possibility of a Lowland Rice Green Revolution in Sub-Saharan Africa: Evidence from the Sustainable Irrigated Agricultural Development (SIAD) Project in Eastern Uganda

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Abstract

In many countries in Sub-Saharan Africa, rapid urbanization has led to a surge in demand for rice in urban areas. However, most of the supply depends on imported rice since rice is not a staple food in the rural areas and domestic production is still limited. In order for domestically grown rice to compete with imported rice, improvements in the productivity of rice cultivation are essential in Eastern Uganda. Although rice production has been expanding since the end of the 1990s, its productivity is quite low because basic rice cultivation practices have not been widely adopted. To raise this low level of productivity, JICA has provided training on basic production practices along with small irrigation schemes that are constructed by the farmers themselves. This study attempts to understand the impacts of the demonstration of or training in improved lowland rice management practices on their diffusion and on rice yields using the case of the JICA program in Eastern Uganda. The most important finding of this study is that lowland rice yields can be extremely high in Uganda if basic production practices, such as bunding, leveling, and straight-row planting, are adopted along with the introduction of modern rice varieties and the use of simple irrigation systems, even if chemical fertilizer is not applied. The major challenge is how to find the most appropriate means of disseminating such a package of improved production practices to the farmers. According to our analysis, the intensity of participation in the training is the key to the adoption of these basic production practices. It was also found that training participation decreases the further the distance the participants live from the demonstration plot.

Keywords: lowland rice, cultivation practices, diffusion of technology, yield enhancement, Uganda

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1. Introduction

In contrast to the dramatic success in increasing agricultural productivity in Asia since the late 1960s, agricultural productivity has been largely stagnant in sub-Saharan Africa (SSA) (Otsuka and Yamano 2005). Due to the rapid population growth and urbanization in the region, the consumption of rice has been increasing far more rapidly than domestic rice production in SSA, thereby increasing the net importation of rice (Balasubramanian et al. 2007; Africa Rice Center 2008). In addition, the sharp rise in cereal prices since 2008 has resulted in serious food insecurity among the poor in this region (Ivanic and Martin 2008; Benson, Mugarura, and Wanda 2008). Given that rice is a major cereal crop that has great potential for an increase in productivity in SSA, strategic efforts to enhance rice production are required urgently not only for food security, but also for income generation (Diao, Headey, and Johnson 2008; Otsuka and Kijima 2010).

It is well known that the rice Green Revolution in Asia was led by the development of high-yielding modern rice varieties, irrigation investment, and the ample use of chemical fertilizers (Hayami and Godo 2005). In SSA, however, irrigation investment by donors and the governments has been low due partly to the high cost of constructing irrigation facilities and partly to the mismanagement of past large-scale government-led irrigation projects (Fujiie et al. 2005; Balasubramanian et al. 2007; Inocencio et al. 2007; Kajisa et al. 2007). The further expansion of upland rice production is limited by abiotic factors (variable rainfall with droughts and dry spells, low temperatures in high altitude areas, poor and degraded soils, surface sealing, erosion on slopes) and biotic factors (weeds, blast and brown spot disease, nematodes, rodents, bird damage) (Balasubramanian et al 2007). In addition, soil degradation is occurring due to the reduced fallow periods (Sakurai 2006). The recent expansion of the area under rice cultivation in SSA has been concentrated in the rainfed lowlands where adequate water control has seldom been implemented (Dalton and Guei 2003). In addition, the actual yields in the lowland ecosystem are much lower than the potential yields (WARDA 1999;

Balasubramanian et al. 2007). In other words, rice production in the rainfed lowlands is considered to have high potential for increasing rice production in SSA.[1]

Poor water control is the main factor that limits rice production in the rainfed lowlands of SSA. Many abiotic and biotic stresses also diminish rice yields in this ecosystem. Abiotic stresses include variable rainfall with drought and flooding occurring in the same season, iron, aluminum and manganese toxicity in the humid forest zones and in the poorly drained soils of the coastal lowlands, and inland salinity and alkalinity in dry areas. Weeds, insect pests (stem borers, African rice gallmidge, rice bugs), diseases (blast, brown spot, rice yellow mottle virus), rats and birds are the major biotic stresses for rainfed lowland rice in SSA (Balasubramanian et al. 2007).

In addition, one of the reasons why the yields of lowland rice are currently far lower than their potential in SSA is that many rice growers cultivate lowland rice without applying appropriate cultivation practices (Balasubramanian et al. 2007). In many countries, chemical fertilizers are so expensive that farmers apply very little fertilizer to their rice crops, leading to continuous soil mining (Sanchez 2002). In some cases, the seeds are broadcasted, which decreases the germination rate and makes it difficult to maintain the proper spacing for planting and to remove weeds when no space is provided to carry out this procedure. Even when transplanting is adopted, the seedling tends to be too old, and straight-row planting is not practiced, which would facilitate weeding and maintain the proper spacing of the plants. Bunding and leveling are not applied or properly practiced so that the available water is not stored evenly in the paddy fields.[2] In order to achieve high productivity in lowland rice

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[1] Water is the main limiting factor for rice production or for that matter, any other crop. Valley bottoms in SSA are the most important locations, but they are not fully exploited even though they can be used to produce rice sustainably with good land preparation, leveling and crop management practices, as described in this paper. However, other constraints such as human diseases associated with marshlands in SSA, the lack of access for the rice production centers in valley bottoms to markets in ,large cities, and the fragile level of cooperation among farmers in relation to water sharing and the maintenance of irrigation structures may limit the full exploitation of these valuable resources. If the infrastructure is developed and human diseases are controlled, rice production in valley bottoms can contribute significantly to food security and a Green Revolution in SSA.

[2] Soil leveling is associated with the even distribution of water in the field, which helps to control weeds,

farming, the Japan International Cooperation Agency (JICA) has initiated a sustainable irrigated agricultural development (SIAD) project in Eastern Uganda that provides training in lowland rice cultivation practices based on experience in Asia.

This study attempts to understand the impact of demonstrations or training based on the new rice technology on its diffusion and on rice yields using the case of the JICA program. Before starting the actual program, the current rice-growing conditions, constraints and problems of the farmers in the study area were assessed and analyzed in order to select suitable solutions and technologies that would address the problems identified. Specifically, the effects of the training on the production performance were divided into four parts: (1) participation in the training, (2) understanding of the recommended cultivation practices, (3) adoption of practices and feedback from the farmers regarding adoption of the technology, and (4) yield enhancement. By conducting this study, the intention was to highlight the potential for a lowland rice Green Revolution. Our empirical analyses show that (1) participation in the training is mainly determined by the distance of the location of the participant from that of the demonstration plot, (2) the training increases the participant's understanding of the recommended cultivation practices but one day of training is not sufficient for farmers to fully understand the appropriate production knowledge, (3) the level of participation in the training increases with the potential for applying bunding and straight-row planting, but not for leveling and planting at the proper age of the seedlings, and (4) lowland rice yields can be extremely high in Uganda if basic production practices are adopted along with the adoption of modern varieties and the use of simple irrigation systems.

The rest of this paper is structured as follows. Section 2 describes the present state of lowland rice production in Eastern Uganda and the contents of the JICA project. Section 3 describes the sample data used in this paper and examines the descriptive statistics. In section 4, the estimation models on participation in the training, the adoption of new cultivation practices,

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and is another critical factor limiting rice yields in the rainfed lowlands.

the level of understanding of the training materials, and the yield function are introduced and the estimation results are presented. The last section concludes the paper with a presentation of its policy implications.

2. Lowland rice production in Eastern Uganda and the SIAD project

2-1 Lowland rice production in Eastern Uganda

In Uganda, about 10 percent of the country is covered by wetlands or swamps in valley-bottoms (FAO 2006), which are particularly suitable for lowland rice production. In fact, rice is one of the few profitable cash crops grown in the lowlands in this region. In Eastern Uganda, lowland rice cultivation technology and modern rice varieties were introduced in the 1970s by the Chinese in the Kibimba Rice Scheme and Doho Rice Scheme (FAO 2006).[3] Since then, unutilized swamps (normally covered with papyrus) have been rapidly converted to lowland rice fields.

The modern variety of rice developed by the International Rice Research Institute (IRRI) was crossed with local varieties. "K5" (a rice variety from one of the first rice production attempts under the irrigation scheme, namely Kibimba) and "supa" (meaning rice) are improved local varieties that have been widely adopted in the lowland areas of Eastern Uganda. It is said that the origin of K5 was one of the early modern varieties developed by IRRI, but the origin of supa is less clear. In the upland areas, sweet potato, maize, and cassava are grown for home consumption. Eastern Uganda is located in the bimodal rainfall zone, and farmers in the irrigation schemes are engaged in the double-cropping of rice in both seasons (Nakano 2010). In many rainfed lowlands, unless the rainfall is too low, the double-cropping of rice is common.

[3] In the 1970s, the Chinese initiated the development of rice schemes with the Kibimba rice scheme (600 ha) as a rice technology development scheme and the Doho rice scheme (1000 ha) for seed multiplication and the popularization of production. These areas are still major rice production areas in Eastern Uganda.

2-2 SIAD project

The objective of this JICA project is to increase rice production and productivity by introducing the sustainable rice cultivation practices that have been widely adopted in Asia in combination with small-scale simple irrigation facilities. The project covers 22 districts in Eastern Uganda and was implemented from July 2008 and will be completed in June 2011. The training starts in phases: the first cropping season of 2009 (called Group A in 10 districts), the second cropping season of 2009 (Group B in 6 districts), and the first cropping season of 2010 (Group C in 6 districts).

One project site is selected for each district. The selection of these sites is purposive since lowland rice cannot be grown in upland areas. Indeed, all the project sites are wetlands with seasonal or year-round springs and streams. In addition to this geographical condition, the formation of an association of rice farmers was a prerequisite for implementing the project in the selected areas. Thus, it is reasonable to assume that farmers in the project sites tend to be more motivated and to have relatively more favorable access to water than the average Ugandan farmer and the sites selected by JICA are more or less similar in terms of the environment for rice cultivation.

Training was provided for the district agricultural officer (DAO), extension workers, and lead farmers with a view to disseminating the basic knowledge regarding rice cultivation practices and small irrigation management practices by word of mouth communication. JICA experts and extension workers provided field training to the farmers at demonstration plots in each project site, with the plots ranging from 0.2 ha to 0.4 ha. The training consisted of four parts: (1) the establishment of a demonstration plot and the construction of irrigation channels in the surrounding area [3 days]; (2) the preparation of nursery beds, the seeding of the nursery beds, and leveling the main field [half a day]; (3) transplanting and weeding [half a day]; and (4) harvesting and threshing [half a day].

JICA was responsible for setting up the demonstration plot and building the irrigation channels that connect the demonstration plot with a source of water. The farmers were required to construct their own irrigation channels with guidance and help from JICA by digging the ditches using hand hoes. This small irrigation scheme does not require the establishment of a systematic water sharing mechanism among the farmers. When water needs to be provided to the plots, the farmers do this according to their need. Normally, the channels are not cleaned communally. The farmers only clean the channels adjacent to their own plots. In many schemes, the farmers do not know how to control water or understand the role of drainage.[4] There are no devices for metering the intake of water into individual fields. Even though the title of the project includes the term "irrigation," it does not involve the construction of modern irrigation facilities, which are expensive to construct and maintain. This is because JICA experts believe that even if modern irrigation systems are constructed, the productivity of rice cultivation cannot be enhanced significantly without the institution of proper cultivation practices. Thus, only simple irrigation facilities are being promoted in this JICA project.

3. Data

3-1 Sampling

Among Group A, five districts have been carrying out similar projects since 2005.[5] To assess the mid-term impact of the training project, two sites from Group A (namely Bugiri and Mayuge, where the water source consists of seasonal streams) were sampled. Although pre-project information on these two sites could not be obtained, information was collected for the new sites (namely Pallisa and Bukedea, where the water source consists of year-round springs) where the training started just prior to data collection. The data on yields and cultivation practices in the previous season were collected. Thus, the adoption of cultivation

[4] Evidence that farmers do not understand the role of drainage includes the fact that many of them also use water from drainage sources.

[5] The name of the project is "The Study on Poverty Eradication through Sustainable Irrigation in Eastern Uganda" (the "Development Project" in short) under which pilot projects were implemented in 2005 and 2006 for the purpose of promoting sustainable irrigation development and the components of the project were about the same as for SIAD.

practices and rice yields were not affected by the JICA training in these new sites. By using this difference in the starting time of the training, measurement of the average effect of the training on treatment, including the spillover effect from the training participants to non-participants, was measured whereby the new sites were the control group and the other two sites were the treatment group.

At each site, 75 households were selected based on the distance from the demonstration plot to the rice plot of each household in order to capture the diffusion process beginning from the demonstration plot.[6]

3-2 Descriptive statistics

Table 1 shows the status of participation in the JICA training by project site. In Bugiri, just after JICA started the training, the number of training participants was large and by the end of 2007, 70% of the sample households had taken part in the training at least once. In contrast, the training participation rate was lower in Mayuge and it was only 35% by 2007. This low participation rate was not due to the lack of information about JICA's demonstration project on the part of non-participants. In the case of the Mayuge site, 41% of the non-participants answered that they were not interested in the training. The intensity of the training received among the participants was also quite different. In Bugiri, 28% of the sample farmers attended the training for more than 5 days. The difference in training intensity is likely to result in a difference in the effect of the training on the comprehension of what was taught in the training sessions.

The trend in yields over time is shown in Table 2. In normal years (i.e., 2007 and 2008), the average rice yield was about 2.7 tons per hectare in the four sites. The yield in the new sites (Bukedea and Pallisa) was significantly lower by 2 tons per hectare than that in

[6] The sample lowland areas are oval shaped with one long diameter and one short diameter. Across the short diameter there are 6-10 plots. One plot was selected randomly at approximately 25-meter intervals from the demonstration plot in two directions along the long diameter. Half of the plots were rented land and 70% of these were rented before 2008.

Bugiri and Mayuge where JICA provided training from 2005. Since there is no data on pre-program yields in Bugiri and Mayuge, it is not possible to show the difference in yields before and after the training in these areas. It is, however, likely that the situation in the new sites was similar to that in Bugiri and Mayuge before JICA started the training.

In Bugiri, the average rice yield reached 4.7 tons per hectare, while in the new sites, the yield was lower at 1.3 tons to 1.6 tons per hectare. The yield in Mayuge fell somewhere in between. The superior performance of Bugiri may be due to the fact that Bugiri has an irrigation facility covering 10 hectares that was constructed by JICA in addition to the areas outside of the scheme where the farmers created channels between the water source and their fields, which was similar to other project sites. Subsequently, there may be a difference in the yields between the farmers inside the JICA irrigation scheme and those outside in the Bugiri site. The yields are, however, not significantly different between the farmers inside and those outside the scheme (in 2009, 4.05 and 3.99 tons per hectare inside and outside the scheme, respectively). This finding suggests that simple irrigation facilities constructed by farmers can significantly improve the efficiency of rice farming.

Table 3 shows the adoption of improved cultivation practices in the cropping seasons of the September 2008 to August 2009 period. In Bugiri, all the recommended cultivation practices were adopted by most of the sample households including both the training participants and non-participants. In Mayuge and Pallisa, the proper timing of transplanting and straight-row planting was not implemented on a large scale. In Bukedea, the adoption rate of all the practices was as low as 10% to 28%. Although proper chemical fertilizer application was not taught in the SIAD training,[7] the amount of chemical fertilizer used in the sample areas is indicated in the table. It is clear that chemical fertilizer is rarely applied in the sample sites.

Table 4 shows the rice yield separately according to the number of new improved

[7] In the Development Project in 2005 the use of chemical fertilizer was taught in the training.

cultivation practices actually adopted between September 2008 and August 2009. It is clear that the average yield rises the more of the practices that are adopted by the farmers. In Bugiri, the yield was 4.5 tons per hectare when four of the practices were adopted, while the yield when only one practice was adopted was 2.3 tons per hectare. This significant difference in yield suggests that there is some complementarity between the improved cultivation practices. There is no clear relationship between the number of practices applied and the yield in the new sites. This suggests that these farmers applied them incorrectly since they had not yet received the training.

Table 5 indicates the availability of water in the rice plots. In Burigi and Mayuge, water is supplied through irrigation channels to most of the rice plots. In the new sites (Bukedea and Pallisa), 21% of the plots have wells in the plots. In Bukedea, water flows into the plot directly from neighboring plots without the use of irrigation channels (cascade irrigation from field to field) in 68% of the plots. The yield tends to be higher when water flows into the plot from irrigation channels and there is also a well in the plot than in plots without these sources. Another measure of water availability is the subjective assessment of the farmers. Farmers were asked about the moisture status of the soil at the flowering stage when the availability of water critically affects the yield. The table shows that about 20% of the plots were dry at the flowering stage and 53% of the households actually controlled the water intake at the flowering stage. The yield in the plots with water at the flowering stage is much higher than in those without water. However, the difference is not significant, probably because the drought negatively affected the plots with water at the flowering stage as well.

4. The models and their results

In this section, four empirical models are analyzed. Firstly, the determinants of participation in the training are examined. This is because, as indicated in the previous section, the participation rates in the training vary according to the program sites. Even when the training enhances the productivity of rice harvests, the effect of the training will be limited without the participation of the farmers. Secondly, an examination was conducted as to whether the farmers understood the contents that were taught in the training. This is important since participation in the training does not guarantee that the information has been adequately acquired by the participants. If this is correct, then an increase in the amount of participation in the training will not necessarily contribute to an increase in rice productivity. Thirdly, the determinants of the adoption of the practices taught in the training are analyzed. Even when farmers participate in the training and understand the materials of the training, the farmers that participated may not adopt the technologies that were taught in the training. In this case, it is crucial to identify the factors that prevent these farmers from adopting the technology in order to accelerate its adoption. Fourthly, the yield function is estimated in order to quantify the impact of participation in the training, the participant's understanding of the technology, and the level of adoption of the technology.

4-1 Participation in the training

To increase the effectiveness of the training, it is important to understand the factors that determine participation in these training sessions. For the Bugiri and Mayuge sites, it is difficult to examine this properly since there is no pre-program data. For the new sites (Bukedea and Pallisa), it is possible to assess more accurately the determinants of participation in the training.

Since those farmers whose plots are close to the demonstration plot and who belong to a farmers group are expected to have better access to information concerning the training through established geographical and social networks among the farmers, their participation rates in the training are expected to be higher. Thus, the decision as to whether a particular household participates in the training is assumed to be a function of the distance from the demonstration plot to their own plot and the social network that the household has access to.

The dependent variable is the number of days of training that the households participated in between September 2008 and August 2009 since the program was initiated in August 2009 at the new sites. The explanatory variables were measured in September 2008. This model is estimated according to Ordinary Least Squares (OLS) analysis.

Table 6 shows the results of the estimation. At the new sites, the number of days of training that the participants attended is mainly determined by the distance from the demonstration plot, not by the number of farmers in the group that the household belongs to. This is to be expected since the program had just started establishing the new sites and JICA was preparing to expand the number of training participants by offering training sessions to neighboring households during the remaining period of the program. When the effects of the training become apparent to the training participants and information concerning the positive effects of the training is shared with the non-participants, the distance to the demonstration plot may become an insignificant determinant of participation in the training.

4-2 Does training enhance understanding of the improved production practices?

Examination of the factors that enhance understanding of the cultivation practices is important since the training materials first need to be understood correctly, otherwise the training cannot be effective. It is reasonable to postulate that the level of understanding of the materials is higher when the period of participation is longer and the farmers are better educated. To analyze this rigorously, a regression model was run.

To measure the level of knowledge concerning cultivation practices by the farmers, the sampled farmers were asked to take a simple quiz about rice cultivation. This quiz was given on the last page of the questionnaire so that it would not affect the responses to the rest of the questionnaire. The quiz covers what was taught in the JICA training sessions such as the importance of field leveling and using seedlings of an appropriately young age for transplanting. In this model, the dependent variable takes unity when the households answer the quiz questions correctly and is zero otherwise. The data indicates that the proportion of sample households that correctly answered the quiz concerning leveling and the seedling age for transplanting was 40% and 62%, respectively. There is a positive correlation between the proportion of positive responses and the number of days of training.

In order to measure the intensity of the training, which is an important explanatory variable, the number of days of training accumulated by the time the quiz with the farmers was conducted was used as the variable. This means that this variable takes non-negative values at the new sites since some farmers had already participated in the JICA training just before the collection of the data. Since it is the more able farmers who tend to seek training opportunities and such farmers would have also performed better on the quiz than non-participants, even if they had not participated in the training, the training participation variable can be endogenous. To correct the bias arising from this simultaneity, the instrumental variable Probit estimation model was applied, where the distance from the demonstration plot to the household's rice plot was used as an instrumental variable for the training participation variable.

Table 7 shows the results of this estimation, whereby the estimated coefficients demonstrate the marginal effects. In the first column, the dependent variable is a dummy variable representing whether a farmer answered the question on leveling correctly or not. In the second column, the dependent variable takes unity if the farmers answered the question on the appropriate seedling age for transplanting correctly and zero otherwise. In both columns, participation in the training increases the probability of giving the correct answer for the questions on cultivation practices taught in the training. The estimated marginal effect of the training suggests that one additional day of training increases the probability of correctly answering the question by 12% to 15%. Thus, it is desirable to provide repeated training sessions for the farmers in order to enable them acquire the appropriate production knowledge.

4-3 Effect of training participation on the adoption of the cultivation practices

Whether the recommended cultivation practices were adopted or not should be affected by the characteristics of the household such as access to information, rice cultivation experience, and asset holdings, as well as the plot characteristics such as water availability and land tenancy. As shown in the previous sub-section, participation in the JICA training enhances the knowledge that was gained regarding the improved production practices, which is expected to increase the adoption rate. Even without the training, some farmers may learn effective ways of growing rice according to their experience, which leads to an increased adoption rate among experienced farmers. Since these practices require more labor inputs and households may need to hire labor, asset holdings may affect their adoption. These practices also have particularly significant impacts on rice production when water is available, thus their adoption is also determined by the availability of water. If the plot is rented, these farmers may attempt to maximize the net returns to at least recover the land rental fee, which requires intensification such as the adoption of better cultivation practices.

In the regression analyses, a dependent variable takes unity if a new cultivation practice (bunding, leveling, timing of transplanting, or straight-row planting) was adopted between September 2008 and August 2009. Explanatory variables at the household level take the values at the beginning of September 2008 and those at the plot level are measured in each respective cropping season. As explained above, the training variable is considered to be an endogenous variable. Thus, the IV Probit model is applied.

Table 8 shows the estimation results for the adoption of the four critically important cultivation practices taught in the JICA training. The probability of applying bunding and straight-row planting increases with any increase in the number of days that households participated in the JICA training. The adoption rate of straight-row planting increases with greater lowland rice cultivation experience. Better access to water, measured by a well dummy, also increases the likelihood of using proper young seedlings and applying straight row planting, indicating the complementarity between water availability and the improved production practices related to the planting. When a plot is rented, the use of proper young seedlings is less likely to be implemented.

4-4 Effect of the training on rice yields

Whether participation in the training increases rice yields is examined in this sub-section. The determinants of the yield in the cropping seasons of 2008-2009 are examined using cross-sectional data. The yield in the cropping season between September 2008 and August 2009 is assumed to be determined by the household characteristics such as participation in the training before September 2008, knowledge and application of the recommended practices, rice cultivation experience, asset holdings, and household composition in September 2008 as well as the plot characteristics such as water availability and the security of tenure of the plot in the respective cropping seasons. Given that training participation, knowledge, and application of the recommended practices are highly correlated, these variables are used separately. Although the training variable seems endogenous, the test for endogeneity shows that it is not endogenous. Thus, the yield function is estimated using OLS.

Table 9 shows the estimation results of the yield function in the cropping seasons of 2008-2009. As shown in column 1, participation in the training increases the rice yields: Each additional day of training increases the yield by 0.2 tons per hectare. The correct knowledge about seedling age has a positive effect on yield, suggesting 0.6 tons per hectare, if the farmers answered the quiz correctly. In terms of its actual application, only straight-row planting has a significant impact on yield.

Unexpectedly, lowland rice cultivation experience does not increase the yield. Recent migrant households tend to have a lower yield in all specifications. Households owning a larger per capita land area tend to obtain higher yields. The other household characteristics do not have a significant impact on rice yields. Among the plot characteristics, the size of the plot is the only variable that is significant. A smaller plot is associated with higher yields, probably due to better field leveling and water control and good crop management.

Conclusions

The most important finding of this study is that lowland rice yields can be extremely high in Uganda if basic production practices, such as bunding, leveling, the use of young seedlings, and straight-row planting, are adopted along with the adoption of modern varieties and the use of simple irrigation systems, even if chemical fertilizer is not applied. Thus, there is no question that a lowland rice Green Revolution is possible in Eastern Uganda and in similar areas (valley bottoms) of sub-Saharan Africa.[8] Note that aside from the lack of the application of chemical fertilizer, the other production practices are those commonly adopted in Asia, which suggests the high transferability of Asian rice farming practices to SSA. The major challenge is how to disseminate such a package of improved production practices to a large number of farmers with limited education and experience in modern rice cultivation.

According to our analysis, the intensity of training participation is the key to the adoption of the basic production practices. It was also found that participation in the training decreases as the distance from the demonstration plot increases. At the same time, however, non-participants in the training learn from those who participated. Further research is obviously needed to identify the most effective ways of disseminating new lowland production practices towards the achievement of major productivity gains in rice farming in Uganda and possibly in other areas of SSA.

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[8] Soils in the valley bottoms are rich in nutrients due to runoff and leaching from the adjacent slopes and uplands. As such, yields will be high in the initial stages, but with continuous cultivation yields may decline due to mining of the soil nutrients and the development of multiple nutrient deficiencies. Maintenance of the soil nutrient status and soil fertility is critical to sustaining high yields over the long term. In addition, new insect pests and diseases may emerge and precautions must be taken from the beginning to prevent such attacks by developing resistant varieties and clean cultivation practices.

References

Africa Rice Center (AfricaRice). 2008. *Africa rice trends 2007*. Cotonou, Benin: Africa Rice Center (AfricaRice).

Balasubramanian, V., M. Sie, R. J. Hijmans, and K. Otsuka. 2007. Increasing rice production in sub-Saharan Africa: Challenges and opportunities. *Advan. Agron.* 94: 55-133.

Benson, T., S. Mugarura, and K. Wanda. 2008. Impacts in Uganda of rising global food prices: The role of diversified staples and limited price transmission. *Agricultural Economic* 39 (s1): 513-24.

Conley, T., and C. Udry. 2001. Social learning through networks: The adoption of new agricultural technologies in Ghana. *American Journal of Agricultural Economics* 83 (3): 668-73.

Dalton, T., and R. Guei. 2003. Productivity gains from rice genetic enhancements in West Africa: Countries and ecologies. *World Development* 30 (2): 359–74.

Diao, X., D. Headey, and M. Johnson. 2008. Toward a green revolution in Africa: What would it achieve, and what would it require? *Agricultural Economics* 39 (s1): 539-50.

FAO. 2006. AQUASTAT Uganda. http://www.fao.org/nr/water/aquastat/countries/uganda/index.stm (accessed on July 1, 2010)

Fujiie, M., Y. Hayami, and M. Kikuchi. 2005. The Conditions of collective action for local commons management. *Agricultural Economics*, 33 (2): 179-89.

Hayami, Y., and Y. Godo. 2005. *Development economics: From the poverty to the wealth of nations*. Oxford, UK: Oxford University Press.

Inocencio, A., M. Kikuchi, M. Tonosaki, A. Maruyama, D. Merrey, H. Sally, and I. de Jong. 2007. Costs and performance of irrigation projects: A comparison of sub-Saharan Africa and other developing regions. IWMI Research Report 109.

Ivanic, M., and W. Martin. 2008. Implications of higher global food prices for poverty in low-income countries. *Agricultural Economics* 39 (s1): 405-16.

Kajisa, K., L. Palanisami, and T. Sakurai. 2007. Effects on poverty and equity of the decline in collective tank irrigation management in Tamil Nadu, India. *Agricultural Economics* 36 (3): 347-62.

Nakano, Y. 2010. The irrigation management in the Doho Rice Scheme in Uganda: An inquiry into the potential of a green revolution in sub-Saharan Africa. PhD diss., National Graduate Institute for Policy Studies.

Otsuka, K., and Y. Kijima. Forthcoming. Technology policies for a green revolution and agricultural transformation in Africa. *Journal of African Economies*.

Otsuka, K., and T. Yamano. 2005. The possibility of a green revolution in sub- Saharan Africa: Evidence from Kenya. *Journal of Agricultural and Development Economics* 2 (1): 8-19.

Sanchez, P. A. 2002. Soil fertility and hunger in Africa. *Science* 295: 2019-20.

Sakurai, T. 2006. Intensification of rainfed lowland rice production in West Africa: Present status and potential green revolution. *Developing Economies* 44 (2): 232-51.

West Africa Rice Development Association (WARDA). 1999. *Mid-term plan, 2000-2002*. Bouake: WARDA.

Table 1. Participation in the JICA training

	Bugiri	Mayuge	Pallisa	Bukedea
Number of sample households	75	75	75	75
Year the JICA training started	2005	2005	2009	2009
No. of HH participating in the JICA training for the first time in 2005	30	9	0	0
No. of HH participating in the JICA training for the first time in 2007	20	11	0	0
No. of HH participating in the JICA training for the first time in 2008	3	5	0	0
No. of HH participating in the JICA training for the first time in 2009	0	4	15	25
Percentage of households with				
Number of training days=0	29.3	61.3	66.7	80.0
0 < Number of training days <=5	42.7	26.7	24.0	14.7
5 < Number of training days <=10	22.7	12.0	9.3	5.3
10 < Number of training days <=20	5.3	0.0	0.0	0.0
Number of Non-participants in the JICA training	22	46	60	50
% of non-participants who did not know about the demonstration plot	27.9	8.8	19.8	14.0
Reason why they did not participate in the JICA Training (% of Non-Participants)				
Did not know about it	68.9	45.5	83.1	78.7
Not interested	15.6	40.9	11.9	21.3
Busy	13.3	9.1	3.4	0.0
Did not have the money to pay to join the association	2.2	4.6	1.7	0.0

Table 2. Rice yields in 2007 - 2009

	All	Bugiri/ Mayuge	Bukedea/ Pallisa		Bugiri	Mayuge	Bukedea	Pallisa
2005	3.08	3.60	1.77	*	3.98	2.72	1.40	2.10
	(2.52)	(2.72)	(1.11)		(2.96)	(1.81)	(0.94)	(1.16)
2007	2.65	3.50	1.52	*	4.64	2.17	1.31	1.61
	(2.85)	(2.98)	(1.03)		(3.35)	(1.71)	(0.98)	(1.06)
2008	2.65	3.40	1.43	*	4.75	2.32	1.35	1.56
	(2.83)	(2.79)	(1.46)		(2.80)	(2.90)	(1.51)	(1.40)
2009	2.50	3.02	1.35	*	4.03	1.82	1.29	1.46
	(2.61)	(2.78)	(1.69)		(3.21)	(1.43)	(1.89)	(1.26)

The numbers show the means for the rice yield and the standard deviations are in parentheses.
* This asterisk indicates that the difference in the yields between the treatment districts and the control districts is statistically significant at the 5% level.

Table 3. Adoption of cultivation practices in September 2008 – August 2009

	All	Bugiri	Mayuge	Bukedea	Pallisa
		Adoption %			
Bunding	83.8	100.0	95.2	24.1	81.5
Leveling	69.7	83.3	84.1	27.6	48.1
Transplanting	75.1	100.0	71.4	10.3	92.6
Proper timing of transplanting	43.8	69.7	39.7	10.3	25.9
Straight-row planting	33.0	81.8	4.8	10.3	3.7
Fertilizer use	1.1	2.8	0.0	0.0	0.0
Fertilizer application (kg/ha)	13.2	13.2	---	---	---
(s.d.)	(1.4)	(1.4)	---	---	---
		Adoption % among the training participants *			
Number of observations**	90	49	25	12	4
Bunding	92.2	100.0	92.0	58.3	100.0
Leveling	73.3	85.7	76.0	25.0	50.0
Transplanting	81.1	100.0	68.0	25.0	100.0
Proper timing of transplanting	54.4	75.5	32.0	25.0	25.0
Straight-row planting	57.8	93.9	12.0	25.0	0.0
Fertilizer use	2.1	3.8	0.0	0.0	0.0
Fertilizer application (kg/ha)	13.2	13.2	---	---	---
(s.d.)	(1.4)	(1.4)	---	---	---
		Adoption % among the training non-participants			
Number of observations	95	17	38	17	23
Bunding	75.8	100.0	97.4	0.0	78.3
Leveling	66.3	76.5	89.5	29.4	47.8
Transplanting	69.5	100.0	73.7	0.0	91.3
Proper timing of transplanting	33.7	52.9	44.7	0.0	26.1
Straight-row planting	9.5	47.1	0.0	0.0	4.4
Fertilizer use	0.0	0.0	0.0	0.0	0.0
Fertilizer application (kg/ha)	---	---	---	---	---
(s.d.)	---	---	---	---	---

* The "Participants" in Bukedea and Pallisa participated in the training after the survey period. The difference in the adoption rate between the participants and non-participants in these two districts cannot be interpreted as the impact of the training.

** The number of observations is lower than that shown in Table 1 (those who participated in the training) because some households had not obtained any harvest by the end of August 2009 and such households were dropped in the plot-level analyses below.

Table 4. Rice yields according to the cultivation practices adopted in September 2008 – August 2009

	All	Bugiri	Mayuge	Bukedea	Pallisa
4 practices	4.13	4.47	2.89	1.22	0.37
	(3.14)	(3.20)	(1.83)	(0.74)	---- a
3 practices	3.20	4.15	1.89	---	1.54
	(2.78)	(3.17)	(1.31)	---	(1.14)
2 practices	2.25	3.07	2.00	3.95	2.26
	(1.75)	(3.44)	(1.44)	(1.40)	(1.09)
1 practice	1.81	2.30	1.91	1.89	1.38
	(1.43)	(0.80)	(1.13)	(1.87)	(1.23)
Non-adopters	1.33	---	0.79	1.42	0.66
	(1.99)	---	---a	(2.10)	(0.56) b
Fertilizer use	7.55	7.55	---	---	---
	(2.28) c	(2.28) c	---	---	---

The numbers show the means for the rice yield in tons per hectare and the standard deviations are in parentheses.
a Only 1 observation. b Only 3 observations. c Only 4 observations.
4 practices = bunding, leveling, proper timing of transplanting, straight-row planting.
3 practices = among the 4 practices, 3 of the practices were implemented.

Table 5. Water availability in September 2008 – August 2009

	All	Bugiri	Mayuge	Bukedea	Pallisa
% of plots where					
Water comes through irrigation channels	71.0	95.4	79.1	10.6	53.6
Well in the plot	5.9	0.0	0.0	21.3	21.4
Water flows through neighboring plots	23.1	4.6	20.9	68.1	25.0
Yields					
Water comes through irrigation channels	3.16	4.17	2.10	0.84	1.75
	(2.76)	(3.21)	(1.44)	(0.75)	(1.00)
Well in the plot	1.79	---	---	1.51	2.26
	(1.54)	---	---	(1.52)	(1.59)
Neither	1.88	4.42	1.57	1.81	1.19
	(1.97)	(2.20)	(1.02)	(2.24)	(1.14)
Subjective water availability					
Flowering stage: with water	49.8	54.6	46.5	46.8	46.4
Flowering stage: wet	29.7	26.9	29.1	36.2	32.1
Flowering stage: dry	20.4	18.5	24.4	17.0	21.4
Controlling water at the flowering stage	53.2	60.2	57.0	23.4	64.3
Yield					
Plot with water at the flowering stage	2.93	4.13	1.71	2.33	2.32
	(2.37)	(2.73)	(0.87)	(2.33)	(1.15)
Dry plot at the flowering stage	2.26	3.53	1.84	1.23	0.85
	(2.49)	(3.35)	(1.31)	(1.95)	(0.95)

The numbers show the means and the standard deviations are in parentheses.

Table 6. Determinants of the number of days of training that were participated in (OLS)

	Bukedea (1)	Pallisa (2)
Distance from demonstration plot (km)	-1.136	-0.168
	(3.65)**	(3.57)**
Number of farmers groups the participant belonged to	-0.267	0.023
	(1.26)	(0.55)
Year the household started cultivating lowland rice	-0.008	-0.003
	(0.63)	(1.15)
Moved to this area after 2000 dummy	0.305	0.030
	(1.26)	(0.67)
Female-headed household dummy	0.080	0.057
	(0.21)	(0.46)
Land owned (ha)/number of adult family members (aged 15-64)	0.292	0.081
	(1.28)	(1.67)+
Initial assets (household, agricultural, livestock) (USD)	0.000	0.000
	(0.86)	(0.22)
Household head's age	0.036	-0.000
	(2.54)*	(0.27)
Household head's years of education	-0.018	0.015
	(0.50)	(2.24)*
R-squared	0.69	0.68
Observations	52	75

The numbers shown are coefficients and the t-statistics are in parentheses.
Household-level data. + significant at 10%; * significant at 5%; ** significant at 1%

Table 7. Effect of the training on understanding of the technology

(Household level, IV Probit, Marginal Effects)

	Leveling (1)	Seedling age (2)
Number of days of training [a]	0.119	0.147
	(1.89)+	(2.17)*
Member of a non-rice association	0.034	0.461
	(0.21)	(1.23)
Year the household started cultivating lowland rice	0.015	-0.062
	(1.23)	(0.34)
Moved to this area after 2000 dummy	-0.119	-0.211
	(0.63)	(0.13)
Female-headed household dummy	-0.344	1.850
	(0.86)	(2.19)*
Land owned (ha)/number of adult family members (aged 15-64)	0.228	0.198
	(1.40)	(0.42)
Initial assets (household, agricultural, livestock) (USD)	-0.000	0.000
	(0.19)	(1.01)
Household head's age	0.004	0.006
	(0.55)	(0.82)
Household head's years of schooling	0.003	0.051
	(0.15)	(2.03)*
Bugiri	-0.429	-0.727
	(1.68)+	(2.57)*
Pallisa	-0.141	-1.247
	(0.51)	(2.18)*
Bukedea	-0.040	-0.888
	(0.15)	(0.41)
Number of observations	276	276

The numbers shown are the marginal effects at the means and the z-statistics are in parentheses.

[a] Training participation = endogenous, instrumented by distance to the demonstration plot.

+ significant at 10%; * significant at 5%; ** significant at 1%

Table 8. Effect of training participation on the adoption of the new technology (cultivation practices)

(Plot-level, IV Probit Model, Marginal Effects)

	Bunding (1)	Leveling (2)	Proper seedling age (3)	Straight-row planting (4)
Number of days of training participated in (before Sep. 2008)	0.176	0.069	0.132	0.362
	(2.08)*	(0.63)	(1.42)	(14.15)**
Year the household started cultivating lowland rice	0.001	-0.033	-0.009	-0.005
	(0.03)	(1.10)	(1.10)	(1.75)+
Moved to this area after 2000 dummy	-0.208	0.049	-0.275	-0.344
	(0.58)	(0.53)	(0.34)	(1.45)
Female-headed household dummy	-0.215	0.109	-0.656	
	(0.31)	(0.13)	(1.00)	
Land owned (ha)/number of adult family	0.221	0.108	0.108	0.161
members (aged 15-64)	(0.82)	(0.26)	(0.09)	(0.33)
Initial assets (household, agricultural, livestock)	0.000	0.000	0.000	0.000
(USD)	(0.24)	(0.50)	(1.26)	(0.98)
Household head's age	-0.005	-0.024	-0.024	-0.032
	(0.42)	(2.06)*	(0.36)	(1.61)
Household head's years of schooling	-0.036	0.067	-0.017	-0.023
	(0.94)	(0.52)	(1.12)	(0.97)
Water from channels	0.388	0.486	0.323	0.942
	(1.02)	(0.81)	(0.81)	(0.91)
Well in the plot	0.549	0.480	0.878	0.616
	(1.09)	(0.45)	(1.71)+	(1.88)+
Plot is rented	0.403	0.870	-0.200	-0.104
	(1.02)	(0.68)	(1.98)*	(0.54)
Size of the plot (ha)	0.809	0.252	-0.798	-0.624
	(1.06)	(0.44)	(1.47)	(1.12)
Plot is under a customary tenure system	-0.064	0.507	-1.337	0.215
	(0.13)	(0.58)	(0.58)	(0.38)
Bugiri		-0.342	0.200	
		(0.92)	(0.53)	
Pallisa	-0.305	-1.352	0.784	-0.427
	(0.43)	(1.36)	(1.36)	(0.55)
Bukedea	-1.852	-1.805	-1.491	-2.379
	(2.31)*	(2.81)**	(1.23)	(1.88)+
Constant	-0.698	69.581	18.530	-1.316
	(1.81)+	(1.14)	(1.14)	(26.00)**
Wald chi-squared	47.3	60.0	60.5	208.4
Observations	253	253	253	253

The numbers shown are the marginal effects at the means and the z-statistics are in parentheses.
+ significant at 10%; * significant at 5%; ** significant at 1%

Table 9. Yield function (ton/ha), September 2008 - August 2009 (OLS)

	(1)	(2)	(3)
Number of days of the JICA training (before Sep. 2008)	0.188		
	(4.47)**		
Answered quiz on leveling correctly =1		0.096	
		(0.29)	
Answered quiz on the seedling age correctly =1		0.594	
		(1.85)+	
Bunds =1			0.347
			(0.62)
Leveling =1			0.284
			(0.76)
Proper seedling age =1			-0.205
			(0.63)
Straight row planting =1			0.734
			(1.71)+
Household head's age	-0.009	-0.013	-0.012
	(0.68)	(0.99)	(0.88)
Household head's years of schooling	-0.041	-0.031	-0.027
	(1.01)	(0.75)	(0.64)
Female-headed household	-0.792	-0.818	-0.707
	(1.03)	(1.03)	(0.88)
Year the household started cultivating lowland rice	0.257	0.249	0.236
	(0.97)	(0.91)	(0.86)
Moved to this area after 2000 dummy	-0.036	-0.046	-0.042
	(1.76)+	(2.18)*	(1.96)+
Land owned (ha)/number of adult family members (aged 15-64)	0.615	0.574	0.680
	(1.79)+	(1.61)	(1.88)+
Initial assets (household, agricultural, livestock) (USD)	0.000	0.000	0.000
	(1.12)	(1.09)	(1.23)
Water from channels	-0.309	-0.296	-0.366
	(0.75)	(0.69)	(0.84)
Well in the plot	0.073	0.139	0.037
	(0.11)	(0.21)	(0.06)
Plot is rented	-0.459	-0.256	-0.384
	(1.56)	(0.84)	(1.26)
Size of the plot (ha)	-4.120	-4.200	-4.112
	(5.39)**	(5.30)**	(5.13)**
Plot is under a customary tenure system	0.102	0.134	0.091
	(0.16)	(0.20)	(0.14)
Bugiri =1	1.376	1.913	1.454
	(3.89)**	(5.51)**	(3.16)**
Bukedea =1	-0.472	-0.501	-0.432
	(0.64)	(0.65)	(0.51)
Pallisa =1	-0.571	-0.684	-0.739
	(0.71)	(0.81)	(0.87)
Constant	76.314	96.522	87.350
	(1.84)+	(2.26)*	(2.03)*
Observations	268	268	268
R-squared	0.36	0.32	0.32

The numbers shown are estimated coefficients at the means and the t-statistics are in parentheses.
+ significant at 10%; * significant at 5%; ** significant at 1%. [a] This variable is tested to see whether it is an endogenous variable or not. It is found that it is not endogenous (by using the Stata command "estat endogenous"; the test statistics cannot reject that they are exogenous variables). OLS is therefore used.

Abstract (in Japanese)

要約

　サブサハラアフリカ諸国の多くで、急速な都市化に伴い、米の需要が急速に伸びている。農村部では、米は主食ではなく生産量も少ないため、都市部の米の供給の多くはアフリカ外からの輸入に依存している。輸入米と競争するためには、生産性の向上が不可欠である。東部ウガンダでは、1990 年代末から稲作が広がり始めているが、栽培技術が未発達であるために、低い生産性に留まっている。そこで JICA は、農民が自ら建設可能な小規模灌漑の導入と、稲作栽培技術の改善を目的とする技術展示・研修を実施した。本研究では、東部ウガンダにおける JICA のプログラムをケースに取り、技術展示・研修が生産性上昇に及ぼす効果を明らかにする。主要な結果として以下のことが示された。(1) 基本的な栽培技術（畦造成、均平化、条植え）と改良品種の採用により、ウガンダにおいては、肥料を使用せずに水稲の収量が 5 トン程度まで高くなる。(2) 研修への参加が、基本的な栽培技術の採用確率を高くする。(3) 研修圃場からの距離が遠い家計ほど、研修への参加確率は低くなる。