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

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Expansion of Lowland Rice Production and Constraints on a Rice Green Revolution: Evidence from Uganda

Yoko Kijima*

Abstract

In Uganda, rice production has increased rapidly in the past 10 years while the yield has been stagnant. To examine this mixed story in detail, we use data on 600 rural households with access to wetlands. The estimation results on the expansion of rice cultivation show that the high population density in upland farm areas has pushed farmers to rice cultivation in wetlands. Although applying proper cultivation practices such as constructing bunds, leveling, and transplanting is considered to be critical in yield enhancement, as well as using chemical fertilizer and improved varieties, such cultivation practices are rarely adopted in Uganda. The rice production function estimation results show that these practices do not increase the yield significantly once village fixed effects are controlled for. This suggests that these practices are not being adopted since the rice yield is not enhanced effectively by the cultivation practices. This is probably explained by the fact that the water supply in wetlands tends to be unstable and to suffer from drought and floods.

Keywords: agricultural intensification, lowland rice, cultivation practices, Uganda

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1. Introduction

In many countries in Sub-Saharan Africa (SSA), the consumption of rice has been increasing far more rapidly than domestic rice production due to rapid population growth and urbanization in the region (Africa Rice Center 2008). When the price of rice surged in 2007 and 2008, food insecurity among the poor became more serious (Ivanic and Martin 2008; Benson et al. 2008). Since rice is a major cereal crop that can improve food productivity in SSA, policies to enhance rice production are urgently needed not only for food security but also for income generation (Diao et al. 2008; Otsuka and Kijima 2010; Larson et al. 2010).

Uganda is one of the few countries in SSA in which domestic rice production has been increasing and where imports of rice have declined recently. Therefore, it is worth examining how Uganda was able to enhance rice production over the past 10 years. Until recently, rice production in Uganda had been conducted mainly in a few irrigation schemes in Eastern regions where rice production had been introduced by the Chinese in the 1970s. Although rice is not a traditional crop in Uganda, to meet the gap between domestic production and consumption, which has been increasing at a higher rate due to urbanization and rapid population growth, since 2003 the Ugandan government has been promoting rice production with support from donor agencies by introducing a new upland rice variety suitable for the African environment (the NERICA variety) and through a training program for extension workers. In addition, the Ugandan government has imposed a 75% tariff on imported rice to protect rice growers from competition with cheap imported rice and to give farmers an incentive to grow rice by making the price of rice relatively higher than that of other cereal crops.

All these policies should have partially accounted for the increase in rice production in Uganda. There is, however, another likely cause to explain this change. Until the late 1990s, many wetlands had been underutilized because upland farms had been relatively abundant. As the population has grown at an extremely high rate (the annual growth rate was 3.24% between

2000 and 2005), upland farms have become scarcer in most regions. As shown in Figure 1, rice production has been increasing rapidly since the late 1990s in Uganda. This increase is mainly due to the extension of the rice cultivation area (Figure 2). Productivity measured in terms of the average yield has been stagnant between 1 and 1.5 tons per hectare (Figure 3). Thus, the impressive increase in rice production in Uganda has been achieved without improving productivity.

Previous studies on upland rice production in Central and Western Uganda show that introduction of the NERICA variety has increased the rice cultivation area and has changed the upland farming system by replacing mainly maize (Haneishi et al. 2012; Kijima et al. 2008). It is not clear, however, how the lowland rice production area has been expanded. To fill this knowledge gap, in the present study, data has been collected for 600 households in 60 villages with access to wetlands in six districts in the East, North, Northeast, and Central regions. The estimation results show that the increase in population density in the upland farm areas pushes farmers to rice cultivation in the wetlands. It has also been found that better market access, which results in a higher producer price at the farm gate, and a secure tenure system in the wetlands encourages lowland rice production in Uganda.[1] Although the rice yield tends to be higher in plots with proper cultivation practices such as constructing bunds, leveling, and transplanting, the adoption of such practices does not enhance the yield once village fixed effects are controlled for. The results suggest that inadequate use of chemical fertilizer and unfavorable wetland conditions (prone to flooding and water shortages) account for the low productivity of rice cultivation in Uganda.

The rest of the paper is organized as follows. Section 2 describes the data used in this study and the characteristics of the sample households. Section 3 examines the area of expansion

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1. Lowland rice is rice grown on land that is flooded or irrigated. Upland rice is rice grown in dry soil. Wetlands are land areas that are saturated with water, either permanently or seasonally.

of rice production. In Section 4, the adoption function of rice cultivation practices and production functions are estimated. Section 5 presents conclusions.

2. Data and sample households

The data used in this study were collected in 2010 in collaboration with Makerere University. To cover different rice cultivation experiences and agro-ecological conditions, one district was selected from each geographical region (namely East, North, Northeast, and Central regions) where there are wetlands that can be used for rice cultivation. In each district, two sub-counties with active rice production and with access to wetlands were purposively selected. From these sub-counties, 60 LC1s (the lowest administrative unit in Uganda) were randomly drawn as sample communities. The number of LC1s selected per district is 15 in Lira district, 5 in Dokolo district, 15 in Butaleja district, 15 in Kamuli district, and 10 in Kumi district. In each LC1, 10 households were randomly sampled, and thus the number of sampled households is 600.

Table 1 shows the descriptive statistics of the sample communities and households. Eastern region (Butaleja district) has a relatively long history of rice cultivation because the irrigation scheme introduced by the Chinese is located in this region. In Central-East region (Kamuli district), lowland rice production began after 2000. In Northern (Lira/Dokolo district) and North-Eastern regions (Kumi district), there are still abundant cultivable areas in the uplands and there are larger wetlands. Traditionally, some of the wetlands are communal or government owned lands; they have been used as grazing land, openly accessed by community members. To show that rice is an attractive cash crop in Uganda, the last row of the upper panel indicates the price relative to maize, which is one of the major cash crops in most regions in Uganda. It was about 4.7 on average.

In the sample LC1s, 65% of the households grew rice in wetlands in 2009. The proportion is the highest in Butaleja district and the lowest in Dokolo district. The average size of a rice plot is 0.58 hectares. The average size of upland farms owned is 1.3 hectares, which shows that upland farming areas are no longer abundant when considering the average number of adult household members (3.5). In terms of assets, there are two measures: the current values of livestock (cattle, goats, sheep, chickens, pigs, donkeys, and ducks); and household assets (radios, bicycles, mobile phones, beds, chairs, motorcycles, vehicles, car batteries, and mosquito nets) owned at the beginning of agricultural production in 2009. Agricultural related assets are not included in household assets. Households in Dokolo and Kumi districts, where the community wetland area per household is larger than in the other districts, tend to own more livestock. Access to rice related training, whether offered by the government, NGOs, or donor agencies, is limited.[2] Only 12.6% of the sample households received training on rice cultivation. Thus, most of the rice-growing households in the sample areas learn how to cultivate rice via information sources such as neighbors and relatives.

3. Determinants of rice area expansion

In this section, the factors explaining the expansion of the rice cultivation area in wetlands are examined. For that purpose, it is important to understand the differences in cultivation in upland and wetland areas and the agro-ecological conditions in Uganda, where traditionally wetlands had been left unused for crop production. Partly due to the environmental protection policy of the Ugandan government, many wetlands were not used for cultivation before rice cultivation began. In the dry season, wetlands had been used as grazing land, while during the rainy season

2. In the data, there is no further information on training in terms of what kind of training was provided and who provided it.

local people were afraid of working in wetlands because of waterborne diseases. Especially when farmers do not have access to machines and draft animals usable in wetlands, land preparation in wetlands requires more labor than in upland farms. In the sample areas, such machines are not available. Although draft animals can be used when the water level is low, only 26% of the rice plots in the sample were ploughed by draft animals. Under such conditions, households may not have an incentive to utilize wetlands for cultivation as long as households have access to upland farms of sufficient size for crop production.

As the upland cultivation area accessed by households becomes smaller due to population growth, it is likely to be found that households intensify agricultural production by applying land-saving technologies such as the use of chemical fertilizer (Hayami and Ruttan 1985). It is possible, however, that households expand their cultivation area into wetlands, instead of investing in upland farms, when they have access to unused wetlands. Since the agro-ecological and socio-economic conditions are different across communities and households, whether to expand the cultivation area into wetlands or to intensify upland farms should depend on the costs and benefits of these two options.

Given the higher labor requirements of utilizing wetlands compared to upland farming, family labor availability can be a constraint on expanding the cultivation area into wetlands. In contrast, ownership of a bull can save labor inputs in upland farming, which may release family labor for cultivation in wetlands. Wetland accessibility decreases the cost of cultivation in wetlands, while wetland tenure insecurity decreases the benefit of using wetlands by increasing the risk of losing some of the outputs. The difference in tenure system is important in this setting since the wetlands owned by the government tend to be openly accessed.

Although some portions of the wetlands in the sample areas are used for purposes other than rice cultivation, such as grazing and vegetable production, rice accounts for the main portion partly because of its marketability and storability. Some may question why rice is not produced in upland farms if it is such an attractive crop. In the sample areas, upland rice production is not common due to a lack of sufficient rainfall for rice production (in this sample, only 36 households out of 600 grow rice in upland farms, and most of these are NERICA varieties which have a shorter maturity than traditional upland rice varieties). Since rice, including NERICA, grows well with abundant water, growing it in upland farms tends to perform worse due to the shortage of water compared to the wetlands. Even in the wetlands, production conditions are unpredictable (it is difficult for households to control the water level), and it is too risky for farmers to grow rice on a larger scale. In addition, farmers tend to produce traditional food crops for their home consumption since rice is a cash crop rather than a major staple food in Uganda. Thus, labor can be a constraining factor in expanding rice cultivation.

To examine the households' decision of whether and to what extent rice is grown in wetlands, we run two models: a probit model with a dependent variable of a dummy variable indicating whether a household grew rice in the last 12 months; and a Tobit model with a dependent variable of the proportion of wetland area under rice cultivation over the total cultivation area. Explanatory variables are the household and community characteristics shown in Table 2.

The estimation results are shown in Table 2. There are two specifications: columns 1 and 3 use a variable "the size of wetlands accessed by the community per household" as a proxy of wetland availability, while in columns 2 and 4, the wetland size separated according to the tenure system is used in order to test whether differences in the wetland tenure system have different affects on the decision to grow rice.

The coefficient of the size of upland farms owned is negative and significant in all columns, implying that the shortage of upland land for cultivation pushes farmers to grow rice in wetlands. As the wetland size that is available to the community increases, the probability that households grow lowland rice becomes higher. However, the size of openly accessed wetlands such as government owned wetlands negatively affects the decision to cultivate rice in wetlands, meaning that unless land tenure for the households is secure, households are less likely to grow rice in wetlands. The other community-level variables with significant coefficients are driving time to district town and average rainfall. These coefficients imply that households in communities with better market access and rice production conditions are more likely to grow rice in wetlands, which is as expected since rice is grown mainly as a cash crop and requires more water than traditional upland crops such as maize and cassava.

Other household characteristics affecting the probability of growing rice in wetlands are the number of adult family members, age of household head, bull ownership, and immigrant dummy. Since rice cultivation tends to be more labor intensive than upland crops, households with an older household head, few family members, and no draft animal may be constrained in growing rice in wetlands. A dummy variable of immigrant households takes a negative coefficient, which suggests that households whose origins are outside the community have limited access to wetlands. While some of these significant variables (immigrant dummy, number of female adults, and bull ownership) do not determine the intensity of rice growing in wetlands, education of household head turns significant in columns 3 and 4. These empirical results suggest that the increase in rice production by expanding the area under cultivation in communities with access to wetlands is explained partly by the decrease in upland farming area per capita.

4. Cultivation practices and rice yields

In this section, why the productivity of rice production in Uganda has been stagnant is examined in detail. Table 3 shows the characteristics of rice plots among sample households. As shown in Table 1, the number of observations in Dokolo district is small since fewer households grow rice in its wetlands. The average rice plot size is less than 0.4 hectares. The average yield is 2.5 tons per hectare, which is higher than the average rice yield in SSA. This high yield is, however, only achieved in Butaleja and Kamuli districts. In other districts, the average yield is less than 2 tons per hectare. These yield differences across districts may be explained by differences in the cultivation practices applied. In Kumi, Lira, and Dokolo districts, transplanting is rarely undertaken, meaning that seeds are broadcasted. It is known that the yield tends to be lower when seeds are broadcasted since the germination rate of the seeds becomes low and the resulting plant density is uneven over the cultivated area. Although leveling is critically important for water to be evenly stored over the rice plot, in these sample districts, less than 50% of plots conduct leveling. In Kumi and Lira/Dokolo districts, water control (constructing bunds and canals) and proper land preparation (leveling and puddling) are applied in only 30% of the rice plots.

The use of the improved variety seeds is not common in all districts (27% of the plots). Chemical fertilizer and herbicide are rarely used in all sample districts (1.2 kilograms of chemical fertilizer per hectare and 4% of rice plots with application of herbicide on average). The rice plots are located far away from the homestead (39 minutes on foot). This is especially the case for Butaleja district.

The bottom of Table 3 also shows the labor use on rice plots per season. The amount of labor used for rice cultivation is much higher than that observed in Asia. One reason could be because most of the sample households cultivate rice using manual labor, not machines. Another reason could be because quite a lot of labor hours are used in scaring away birds, which accounts for about 30% of the total labor.

Table 4 shows the adoption of technologies and the yield by the number of cultivation practices and technologies (such as transplanting, leveling/puddling, bunds/canal, fertilizer, and improved variety) that were applied to a given plot. Except in Butaleja and Kamuli districts, the number of such cultivation practices and technologies used is at most three. On one-third of rice plots in Kumi and Lira/Dokolo districts, none of the practices are applied. The bottom of the table shows the yield separately for the number of technologies adopted. The average yields across all sample districts increase as more technologies are adopted. However, this relationship does not seem to hold when yields with a different number of technologies adopted are compared within each district (figures in the same column).

Before examining the yield function, therefore, the constraints on farmers leading to their not adopting such cultivation practices are analyzed. Since the cultivation of lowland rice began recently in many parts of Uganda, households may not know about these practices. Thus, the availability of training related to rice production could have an impact on the adoption of cultivation practices. Even without training, farmers may learn proper cultivation practices through their own experience. It is also possible that those who know about these practices may not adopt them because applying these practices requires more labor inputs. For example, households who cannot hire labor due to credit constraints may not be able to adopt labor-intensive practices.

In order to examine the causes of this low application of proper cultivation practices more rigorously, the adoption functions of cultivation practices and improved variety are estimated using a community-level fixed effect model to control for unmeasured heterogeneities such as wetland water conditions. The dependent variable is an indicator variable taking unity if a practice is applied to a particular plot or not. In the case of chemical fertilizer, the amount of chemical fertilizer used in a particular plot is used as the dependent variable. The main explanatory variables are the availability of training on rice production at the village level, the size of upland farms owned, a dummy variable for whether or not households are credit constrained, and the number of adult household members. The other plot-level variables such as tenure system and plot size are also controlled.

Table 5 shows the estimation results. Columns 1-4 are adoption functions of transplanting, leveling, constructing canals, and improved variety, respectively, while column 5 is the input demand function for chemical fertilizer. Contrary to expectations, the availability of rice related training does not affect the probability of applying such cultivation practices. Rice cultivation experience significantly increases the probability of adopting the improved variety. The positive coefficient of the number of female adult household members in columns 1 and 5 suggests that the availability of female family labor is one of the constraints on applying transplanting and chemical fertilizer. When the rice plot is rented in, households are less likely to implement puddling and to conduct leveling/puddling. When households own rice plots and when the source of water for the rice plot is a stream, the probability of constructing bunds becomes higher. Households with smaller upland plots are more likely to conduct leveling and making bunds. None of the asset variables have significant effects on applying proper cultivation practices. The empirical results suggest that the ownership of the rice plot and the size of upland farms owned as well as access to a stable water source lead to adoption of proper cultivation practices.

In the rest of this section, why the rice yield has been stagnant in Uganda is examined by estimating the rice production function using an ordinary least squares (OLS) and stochastic frontier model. The dependent variable is rice yield per hectare at plot level. Regarding the explanatory variables, in addition to inputs commonly considered in production function estimation such as plot area size, fertilizer use, amount of seeds used, labor used, and their squared terms, the adoption of improved seed, application of the cultivation practices, and the availability of rice related training are included as explanatory variables.

Table 6 shows the production function estimation result. Columns 1 and 4 use only conventional input variables while columns 2 and 5 include district dummies, and in columns 3 and 6 the village fixed effects are controlled for. Similar to previous studies, the conventional inputs such as the amount of chemical fertilizer and seeds, use of improved variety, and labor inputs have positive associations with rice production in all specifications. Columns 1 and 3 show that the application of transplanting and leveling increases the rice yield, while in rest of the columns these variables no longer have significant effects on rice yields. This suggests that transplanting and leveling tend to be applied in better environments. Once these conditions are controlled for, the effects of applying the cultivation practices disappear. This suggests that these practices are not adopted because the rice yield is not effectively enhanced by the cultivation practices. This is probably explained by the fact that water in the wetlands tends to be unstable and to suffer from drought and floods. The results in all columns show that the availability of rice training at the village level does not increase rice yields. Since there is no information about what was taught in the training, it is difficult to know why the availability of training does not increase rice production.

5. Conclusions

This study examines the causes of increases in rice production through cultivation area expansion in Uganda using data covering major rice production areas with access to wetlands. The expansion of the area under rice cultivation in wetlands was mainly due to the push factor, meaning that as the size of upland farms owned decreases, the area under wetland rice cultivation increases. The size of wetlands at the village level increases the probability that households grow rice in wetlands, but does not significantly increase the proportion of the rice area over total cultivation areas. This is probably because there are still unutilized wetlands and the cultivation area can be expanded in the wetlands in our sample areas.

Although applying proper cultivation practices such as constructing bunds, leveling, and transplanting is considered to be critical in yield enhancement, especially for lowland rice cultivation, such cultivation practices are rarely adopted by the sample households. The rice production function estimation results show that these practices do not increase the yield significantly once the village fixed effects are controlled for. Since the water conditions in wetlands tend to be unstable and to suffer from drought and floods, the adoption of such cultivation practices may not lead to an increase in rice yields, which results in low adoption of proper cultivation practices. Therefore, in order to introduce Asian-type cultivation practices to significantly increase the rice yield, it may be necessary to introduce water management technologies.

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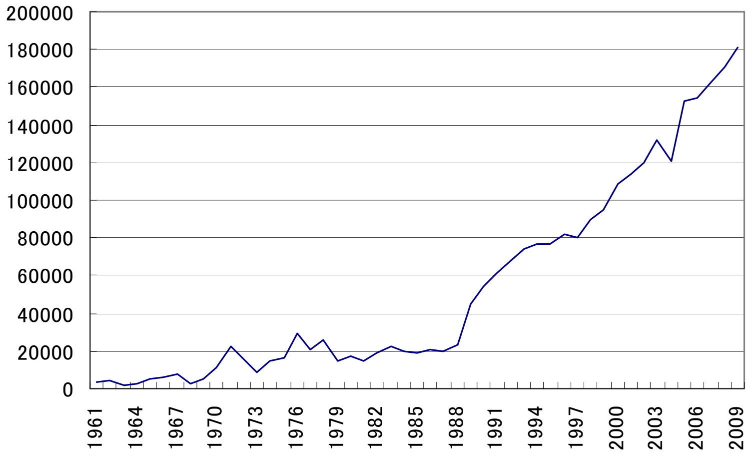
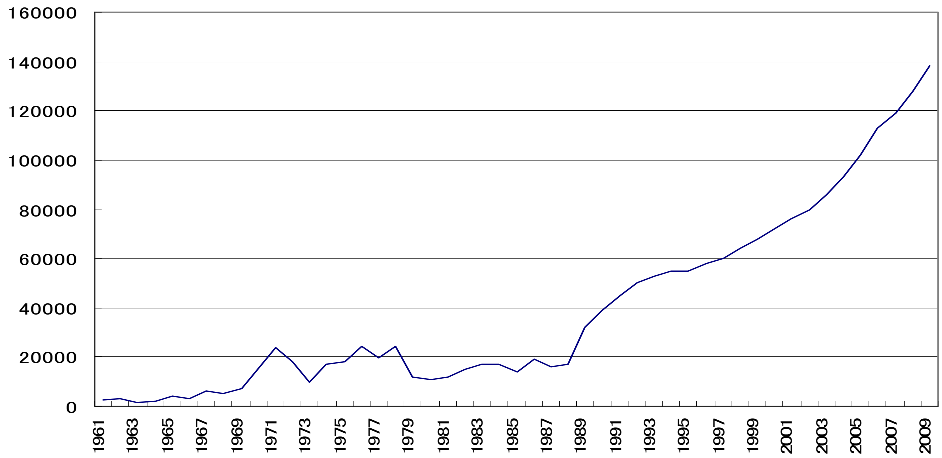
Figure 1. Rice production in Uganda (Tons)



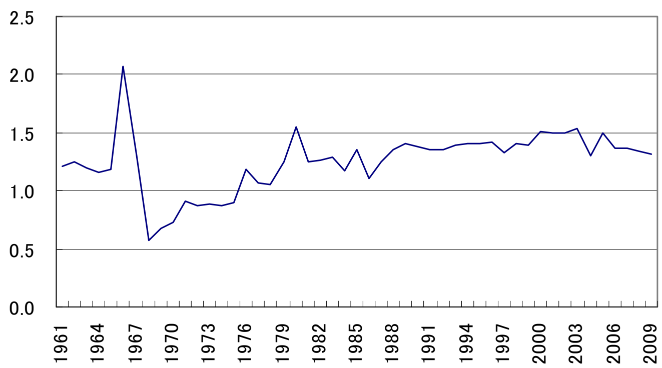
Source: FAO STAT, accessed on July 2, 2011

Figure 2. Rice area harvested in Uganda (Ha)



Source: FAO STAT, accessed on July 2, 2011

Figure 3. Average rice yield in Uganda (Ton/Ha)



Source: FAO STAT, accessed on July 2, 2011

Table 1. Descriptive statistics

	All	Kumi	Butaleja	Kamuli	Lira	Dokolo
LC1 level variables						
Average upland cultivated land area in LC1[a]	2.33	1.83	1.81	2.34	3.00	3.02
	(1.19)	(0.63)	(0.91)	(1.38)	(1.29)	(0.32)
Community wetland area per household (ha) [b]	29.96	115.9	13.71	1.268	14.49	39.26
(per household in nearby villages)	(65.42)	(121.1)	(17.53)	(1.748)	(10.70)	(39.52)
Land tenure of wetland is customary land [b]	0.22	0.61	0.00	0.04	0.31	0.42
	(0.41)	(0.49)	(0.00)	(0.13)	(0.45)	(0.49)
Land tenure of wetland is government owned [b]	0.01	0.30	0.00	0.00	0.21	0.00
	(0.29)	(0.46)	(0.00)	(0.00)	(0.39)	(0.00)
Years since rice was grown for the first time	17.87	19.26	29.35	15.95	10.13	6.208
in this LC1 [b]	(12.18)	(17.61)	(5.92)	(7.679)	(6.567)	(3.377)
Driving time from LC1 to nearest district	42.35	45.44	38.63	42.20	40.12	53.85
town (minutes) [b]	(14.15)	(8.826)	(15.33)	(10.21)	(14.28)	(19.90)
Average annual rainfall (mm) (district level) [c]	1471.6	1389.5	1404.4	1667.1	1485.5	1245.1
Rice-maize relative price (per kg) at	4.717	5.138	5.211	4.369	1.952	4.637
harvesting season [b]	(2.268)	(2.889)	(2.447)	(0.958)	(0.326)	(2.017)
Household level variables						
Rice growing household in 2009 dummy	0.650	0.633	0.896	0.688	0.504	0.229
	(0.477)	(0.485)	(0.307)	(0.465)	(0.502)	(0.425)
Household's lowland area under rice (ha)	0.58	0.37	0.65	0.47	0.73	0.72
in 2009 (only among growers)	(0.701)	(0.24)	(0.81)	(0.44)	(1.00)	(0.42)
Size of upland farms owned (ha)	1.32	1.28	0.70	0.96	2.05	2.33
	(1.49)	(1.33)	(1.02)	(1.31)	(1.65)	(1.71)
Household head moved from other LC1	0.167	0.067	0.118	0.278	0.176	0.146
(immigrant dummy)	(0.373)	(0.251)	(0.324)	(0.449)	(0.382)	(0.357)
Number of male adults (15-65)	1.767	2.056	2.049	1.535	1.504	1.792
	(1.230)	(1.433)	(1.464)	(0.982)	(0.980)	(1.071)
Number of female adults (15-65)	1.756	2.211	1.890	1.542	1.466	1.938
	(1.124)	(1.457)	(1.123)	(0.860)	(0.939)	(1.245)
Age of household head	44.60	44.69	46.74	41.41	45.53	45.09
	(14.11)	(12.51)	(13.71)	(13.21)	(16.35)	(12.97)
Years of education of household head	5.865	5.972	5.563	6.173	5.492	6.667
	(3.349)	(3.193)	(3.585)	(2.851)	(3.521)	(3.692)
Female headed household dummy	0.095	0.033	0.042	0.104	0.198	0.063
	(0.294)	(0.181)	(0.201)	(0.307)	(0.400)	(0.245)
Total size of land owned (ha)	1.65	1.49	1.25	1.25	2.28	2.65
	(1.71)	(1.62)	(1.48)	(1.52)	(1.88)	(1.72)
Value of household assets (USD)	75.06	77.17	77.18	75.51	64.17	93.14
(before rice production in 2009)	(73.76)	(71.46)	(78.19)	(70.82)	(68.75)	(84.04)
Value of livestock owned	276.84	427.24	232.1	144.1	309.2	439.3
(before rice production in 2009)	(326.85)	(380.04)	(300.5)	(204.0)	(331.0)	(390.5)
Own bull (dummy)	0.315	0.500	0.213	0.053	0.473	0.560
	(0.465)	(0.503)	(0.411)	(0.225)	(0.501)	(0.501)
Households with members of local organization	0.490	0.311	0.410	0.590	0.496	0.750
(dummy)	(0.500)	(0.466)	(0.493)	(0.493)	(0.502)	(0.438)
Households who received training (dummy)	0.126	0.111	0.118	0.028	0.260	0.104
	(0.332)	(0.316)	(0.324)	(0.165)	(0.440)	(0.309)

The first row for each variable is the mean and the number in parentheses is the standard deviation. [a] The variable is constructed using household-level data. For each household, the LC1-level average is calculated by excluding its household (non-self average or leave-out means). [b] The variable comes from a community questionnaire involving an interview with a group of 8-10 community members consisting of a community leader, key informants, male and female farmers, elders, and youths. [c] Rainfall data were obtained from the Department of Meteorology.

Table 2. Determinants of rice growing in 2009 (household level)

	Household grew rice in wetlands (dummy variable) Probit, dF/dX		Proportion of lowland rice area over total cultivated land Tobit, dF/dX	
	(1)	(2)	(3)	(4)
Household level variables				
Size of upland owned (ha)	-0.038	-0.037	-0.027	-0.026
	(2.25)*	(2.19)*	(3.26)**	(3.18)**
Household head moved from other LC1 (dummy)	-0.171	-0.166	-0.046	-0.043
	(2.58)**	(2.50)*	(1.45)	(1.36)
Number of male adults (15-65)	0.050	0.050	0.022	0.021
	(2.30)*	(2.30)*	(2.24)*	(2.22)*
Number of female adults (15-65)	0.035	0.033	0.007	0.007
	(1.59)	(1.51)	(0.70)	(0.67)
Age of household head (years)	-0.007	-0.007	-0.003	-0.003
	(4.06)**	(4.08)**	(3.99)**	(3.99)**
Years of education of household head	-0.013	-0.013	-0.006	-0.006
	(1.82)+	(1.86)+	(1.87)+	(1.91)+
Female headed household dummy	0.108	0.096	0.007	-0.000
	(1.40)	(1.22)	(0.16)	(0.00)
Value of household assets (thousand USD)	0.181	0.180	0.062	0.062
(before rice production in 2009)	(1.13)	(1.12)	(0.95)	(0.96)
Value of livestock (except bull) owned	0.029	0.017	0.032	0.027
(thousand USD) (before rice production in 2009)	(0.38)	(0.23)	(0.97)	(0.82)
Credit constraints dummy [a]	0.018	0.021	0.003	0.004
	(0.41)	(0.47)	(0.15)	(0.21)
HHs with members of local organization (dummy)	0.070	0.070	0.025	0.025
	(1.51)	(1.51)	(1.13)	(1.15)
Own bull (dummy)	0.153	0.160	0.030	0.031
LC1 level variable	(2.89)**	(2.99)**	(1.15)	(1.21)
Average wetland size (ha) per household	0.001		0.000	
	(1.93)+		(1.55)	
Average freehold wetland size (ha) per household		0.001		0.000
		(1.30)		(0.87)
Average customary wetland size (ha) per household		0.001		0.000
		(1.22)		(1.00)
Average government wetland size (ha) per household		-0.008		-0.005
		(1.82)+		(1.95)+
Driving time from LC1 to nearest district town	-0.003	-0.003	-0.002	-0.002
(minutes)	(1.70)+	(1.54)	(2.22)*	(2.09)*
Average annual rainfall (mm)	0.001	0.001	0.000	0.000
	(2.43)*	(1.81)+	(1.89)+	(1.26)
Rice-maize relative price at harvesting season	0.004	0.004	-0.000	-0.001
	(0.37)	(0.33)	(0.04)	(0.15)
Rice training available at LC1 (dummy)	-0.039	-0.049	-0.008	-0.012
	(0.73)	(0.90)	(0.32)	(0.46)
District dummies	Yes	Yes	Yes	Yes
Observations	577	577	577	577
Pseudo R-squared	0.19	0.20	0.41	0.43

[a] Credit constraint is defined if households applied for credit but did not obtain the amount they wanted or were refused, or if households needed credit but there was no access to credit or households did not ask because they were afraid of being refused. The numbers in parentheses are t-values.
+ significant at 10%; * significant at 5%; ** significant at 1%

Table 3. Lowland rice yield, cultivation practices, and labor use per hectare (plot level)

	All	Kumi	Butaleja	Kamuli	Lira	Dokolo
Number of lowland rice plots	533	64	226	124	111	8
Number of lowland rice plots with family labor data*	343	58	121	84	73	7
Size of lowland rice plot (ha)	0.38	0.41	0.35	0.30	0.50	0.77
	(0.45)	(0.26)	(0.35)	(0.22)	(0.76)	(0.43)
Yield (ton/ha)	2.51	1.79	3.31	2.44	1.55	0.79
	(1.68)	(1.32)	(1.60)	(1.44)	(1.52)	(0.36)
% of plots with:						
Transplant	59.4	2.7	94.3	68.3	5.7	0.0
Selecting seeds	77.5	90.4	80.6	91.0	50.4	27.3
Leveling/puddling	83.0	43.8	94.7	91.6	61.0	36.4
Bunds/canals	65.3	30.1	90.5	23.4	73.2	36.4
Improved seeds	26.9	1.4	31.2	37.7	25.2	9.1
Stream as a water source	63.4	67.1	76.0	74.3	18.7	27.3
Chemical fertilizer application (kg/ha)	1.22	0.0	1.9	0.0	1.5	0.0
% of plowing by hand hoe	73.9	17.1	91.8	92.6	52.1	72.7
% of herbicide use	4.0	0.0	1.7	4.1	10.1	0.0
Walking time from homestead to lowland plot (minutes)	38.7	24.7	58.2	17.3	27.4	25.5
Labor use on rice plot (man-days/ha)*	490.8	641.7	441.5	570.9	391.5	438.4
	(324.2)	(384.8)	(255.8)	(333.2)	(310.4)	(411.7)
Land preparation (clearing, plowing, making bunds, maintaining canals, leveling, puddling)	131.5	98.8	116.9	177.6	143.1	137.9
	(116.9)	(101.4)	(73.8)	(153.3)	(145.2)	(107.0)
Crop establishment (sowing, preparing seedlings, making nursery beds, transplanting)	41.8	5.2	41.0	87.6	28.9	33.6
	(58.2)	(11.9)	(31.9)	(107.1)	(36.3)	(40.7)
Crop care (weeding, applying chemicals)	75.2	118.6	45.6	72.3	86.4	69.7
	(101.5)	(111.5)	(43.5)	(60.5)	(101.5)	(77.1)
Harvesting/threshing	68.6	209.9	35.0	81.9	72.9	48.3
	(88.2)	(295.3)	(34.3)	(73.9)	(86.5)	(25.5)
Post harvest (hauling, drying, bagging)	28.9	25.1	50.8	15.7	12.3	17.7
	(41.1)	(38.8)	(48.9)	(22.6)	(22.4)	(30.4)
Bird scaring	144.9	205.9	139.7	206.7	63.1	73.9
	(155.8)	(169.5)	(132.0)	(159.0)	(105.1)	(67.0)

Source: Household survey

* Family labor use is only available for one plot per household. The numbers in parentheses are standard deviations.

Table 4. Combinations of technologies adopted and yield (plot level)

	All	Kumi	Butaleja	Kamuli	Lira/ Dokolo
Number of technologies adopted (% of plots)					
5	3.1	0.0	7.6	0.0	0.0
4	15.3	0.0	26.6	5.4	0.0
3	30.9	0.0	54.4	30.5	4.5
2	24.4	13.7	6.8	46.1	39.6
1	14.1	50.7	1.9	12.0	21.6
0	12.2	35.6	2.7	6.0	34.3
Yield (ton/ha) with					
5 technologies	4.65	---	4.65	---	---
	(1.76)		(1.76)		
4 technologies	3.49	---	3.56	1.97	---
	(1.39)		(1.37)	(0.55)	
3 technologies	2.91	---	3.06	2.59	1.55
	(1.54)		(1.63)	(1.14)	(0.75)
2 technologies	2.08	1.71	2.92	2.46	1.46
	(1.61)	(1.59)	(1.15)	(1.61)	(1.49)
1 technology	1.77	1.94	---	2.06	1.43
	(1.44)	(1.29)		(1.54)	(1.54)
No technologies	1.61	1.61	---	2.33	1.57
	(1.45)	(1.27)		(1.05)	(1.58)

Technologies: Transplanting, leveling/puddling, bunds/canal, fertilizer, and improved variety.

Table 5. Adoption of cultivation technologies (LC1 fixed effects model)

	Transplanting	Puddle/ leveling	Bunds/ canal	Improved variety	Fertilizer (kg/ha)
	(1)	(2)	(3)	(4)	(5)
Availability of rice training at LC1 level	-0.012	-0.005	-0.014	-0.037	-0.882
	(0.97)	(0.28)	(0.64)	(1.40)	(2.66)**
Value of livestock owned (except bull) (thousand USD)	0.000	0.000	0.000	-0.000	0.001
	(0.14)	(0.72)	(1.36)	(1.14)	(1.55)
Value of household assets owned (thousand USD) (before rice production in 2009)	0.000	-0.000	-0.000	-0.000	-0.000
	(1.15)	(1.32)	(1.61)	(1.28)	(0.28)
Own bull (dummy)	0.015	-0.032	-0.006	0.035	0.193
	(0.60)	(0.84)	(0.13)	(0.65)	(0.29)
Walking time from home to rice plot (minutes)	-0.000	0.000	-0.000	0.002	0.007
	(0.59)	(0.33)	(0.11)	(4.04)**	(0.91)
Years of lowland rice cultivation	-0.000	0.001	0.001	0.005	-0.060
	(0.35)	(1.32)	(0.52)	(3.35)**	(1.16)
Lowland rice plot size (ha)	-0.002	-0.002	0.042	-0.011	-0.103
	(0.09)	(0.07)	(1.10)	(0.23)	(0.18)
Plot owner (dummy)	0.031	0.006	0.085	0.062	0.228
	(1.09)	(0.15)	(1.68)+	(1.04)	(0.30)
Tenant of plot (dummy)	0.019	-0.100	-0.081	-0.115	-0.318
	(0.64)	(2.23)*	(1.51)	(1.82)+	(0.40)
Water source is stream	0.027	-0.004	0.077	0.023	0.582
	(1.15)	(0.12)	(1.87)+	(0.47)	(0.96)
Head's years of education	-0.002	0.003	0.005	0.007	-0.180
	(0.72)	(0.68)	(0.99)	(1.11)	(2.33)*
Head's age	0.002	0.000	0.002	-0.000	-0.085
	(1.69)+	(0.08)	(0.97)	(0.22)	(3.38)**
Female headed household	-0.050	-0.046	-0.017	0.011	-0.981
	(1.09)	(0.67)	(0.21)	(0.12)	(0.81)
Number of males aged 15-64	-0.009	-0.018	-0.008	-0.027	-0.509
	(1.11)	(1.44)	(0.51)	(1.54)	(2.29)*
Number of females aged 15-64	0.019	0.018	0.040	0.002	0.829
	(1.98)*	(1.30)	(2.34)*	(0.09)	(3.30)**
Immigrant household dummy	0.023	-0.063	0.036	-0.035	0.583
	(0.72)	(1.34)	(0.64)	(0.53)	(0.70)
Size of upland owned (ha)	-0.012	-0.024	-0.026	-0.014	-0.024
	(1.57)	(2.10)*	(1.95)+	(0.90)	(0.12)
Credit constrained	-0.033	0.044	-0.050	0.033	-0.070
	(1.70)+	(1.51)	(1.45)	(0.80)	(0.14)
Risk of confiscation of wetland plot [a]	-0.014	0.134	0.054	0.013	0.123
	(0.59)	(1.59)	(1.22)	(0.25)	(0.19)
Observations	498	498	498	498	498
R-squared	0.05	0.07	0.08	0.11	0.12

[a] Subjective measure taking unity if household believes there is a risk of confiscation of wetland plots.
The numbers in parentheses are t-values. + significant at 10%; * significant at 5%; ** significant at 1%

Table 6. Production function (ton/ha)

	OLS			Stochastic	Frontier	Model
	Base model (1)	Base + district dummies (2)	Base + village fixed effects (3)	Base model (4)	Base + district dummies (5)	Base + village fixed effects (6)
Availability of rice training at LC1 level	-0.002	0.031	-0.124	-0.002	0.031	-0.124
	(0.02)	(0.29)	(0.97)	(0.02)	(0.30)	(1.09)
Chemical fertilizer (kg/ha)	0.110	0.103	0.080	0.110	0.103	0.080
	(2.25)*	(2.11)*	(1.70)+	(2.30)*	(2.16)*	(1.83)+
Chemical fertilizer squared	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
	(2.20)*	(2.12)*	(1.69)+	(2.24)*	(2.17)*	(1.90)+
Improved variety dummy	0.377	0.370	0.177	0.377	0.370	0.177
	(2.04)*	(1.96)+	(0.87)	(2.08)*	(2.01)*	(0.98)
Seed (kg/ha)	0.011	0.009	0.010	0.011	0.009	0.010
	(3.47)**	(2.98)**	(3.02)**	(3.54)**	(3.05)**	(3.40)**
Seed squared	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(1.16)	(0.76)	(0.71)	(1.18)	(0.78)	(0.80)
Labor (man-days)	0.000	0.000	0.001	0.000	0.000	0.001
	(1.30)	(1.63)	(1.75)+	(1.33)	(1.67)+	(1.97)*
Labor squared	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.06)	(0.30)	(0.22)	(0.07)	(0.31)	(0.24)
Transplanting dummy	0.953	0.393	0.004	0.953	0.393	0.004
	(5.23)**	(1.32)	(0.01)	(5.33)**	(1.36)	(0.01)
Puddle/Leveling dummy	0.376	0.246	0.208	0.376	0.246	0.208
	(1.70)+	(1.04)	(0.77)	(1.73)+	(1.07)	(0.86)
Bund/canal dummy	-0.088	-0.104	-0.335	-0.088	-0.104	-0.335
	(0.50)	(0.52)	(1.48)	(0.51)	(0.54)	(1.66)+
Land (plot size ha)	-0.275	-0.235	-0.281	-0.275	-0.235	-0.281
	(1.65)	(1.41)	(1.62)	(1.68)+	(1.44)	(1.82)+
District dummies	No	Yes	Yes	No	Yes	Yes
Village fixed effects	No	No	Yes	No	No	Yes
Observations	330	330	330	330	330	330
R-squared	0.34	0.35	0.27			
Log-likelihood				-569.7	-565.9	-516.1

The numbers in parentheses are t-values. + significant at 10%; * significant at 5%; ** significant at 1%

Abstract (in Japanese)

要約

ウガンダでは過去 10 年間に米の生産が急速に増加しているが､米の平均単収については依然として低いままである。本論文では、湿地にアクセスのある 600 の農家を対象とした家計調査データを使用し、この単収増を伴わない米の生産増がどのような要因によって説明できるかを検証する。米の生産を行うかどうかに関する回帰分析の結果によると、氾濫水位より高い土地（upland）の耕作地が不足するに伴い､低い湿地（lowland）での稲作を行う確率が高くなることが分かった。また、単収を増加させると考えられる栽培技術（畔造成、均平化、適切な栽培密度による移植）の採用率が低く、これが低単収の原因の一つと考えられるが、時間とともに変化せず、観測・測定されない村に固有な特質をコントロールすると、これらの栽培技術が単収を有意に増加させないことが生産関数の推計により示された。安定的な水量を確保できない湿地では、栽培技術の採用が単収増加につながらないため、これらの技術が採用されていない可能性を示唆している。

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Working Papers from the same research project

"An Empirical Analysis of Expanding Rice Production in Sub-Sahara Africa"

JICA-RI Working Paper No. 25

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

Yoko Kijima, Yukinori Ito, and Keijiro Otsuka