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Exploration of rainfed rice farming in Uganda based on a nationwide survey: Regionality, varieties and yield

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Using a nationwide survey of rice growing farmers in Uganda, this study examined how farmers grow rice under rainfed conditions in various agro-climatic zones, and how rainfed rice cultivation performs in terms of yield, and what factors determine the level of rice yield. The study found that Nerica 4 and Supa were the two major varieties planted by rainfed rice farmers, the former in upland and the latter in lowland. High seeding rate, low fertilizer-chemical application and high labor intensity characterized rainfed rice cultivation in Uganda, though distinct regionality existed in fertilize-chemical application and labor intensity. The high marketed ratio of rice produce also characterized rice farming. The estimation of yield functions revealed that rainfall, the amount of seeds and fertilizers applied, lowland and small farmers were positive determinants of rice yield per hectare, that the potential for high yield existed in western regions of the country, and that there were some minor lowland rice varieties that performed better than popular Nerica 4 and Supa. The estimation also revealed that rice plots under the traditional tenure systems yield less, and those under the leasehold system yield more, than those under the formalized freehold and private mailo systems.

Key words: Ago-ecological zone, factor share, input intensity, land tenure, lowland, rainfall, rice disposal, rice income, upland, yield function

INTRODUCTION

Rice is not a traditional staple crop in Uganda as well as in other East African countries, but it is a new crop that has experienced ‘rice boom’ since the turn of the century when a series of NERICA (New Rice for Africa) varieties were introduced (Haneishi et al., 2011). In spite of increasing importance of rice as a staple food in people’s diet and as an income source of farmers, however, research on what has been going on at the grassroot level is dearth. In the case of Uganda, on one hand, the two rounds of agricultural household survey recently implemented by the government in 2005/2006 and 2008/2009 (UBOS, 2007, 2011) for the first time paid attention to rice and collected data on rice production in the country, without any details at the field level. On the other hand, some researchers reported field level realities in rice farming in some details based on farmer-interview surveys conducted in some sample rice growing areas, without showing an overall picture of rice farming in the country (Kijima et al., 2006, 2008, 2011; Lodin et al., 2009; Fujiie et al., 2010). Between these lies an information gap that this paper tries to fill up by presenting the results of a nationwide survey of rice

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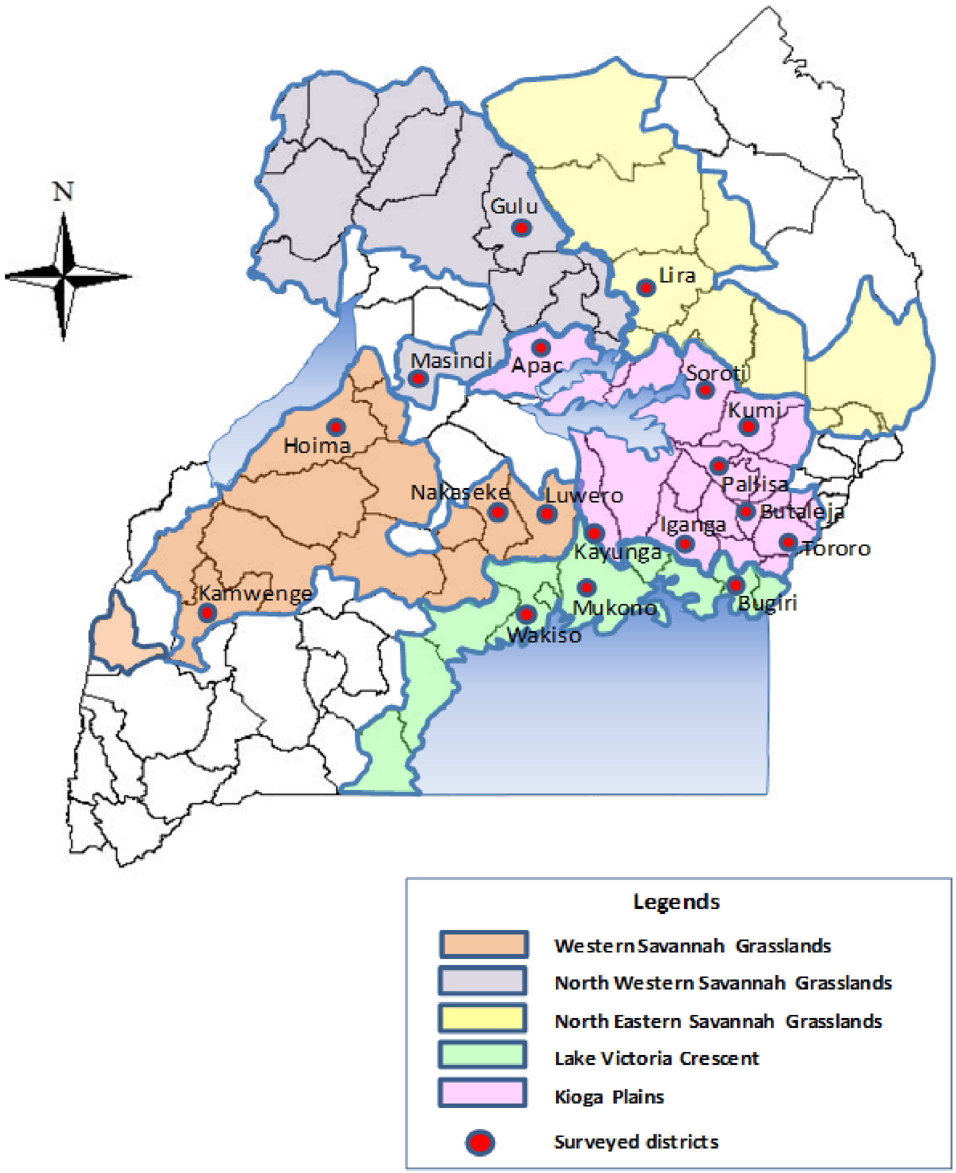

Figure 1. Agro-ecological zones in Uganda and surveyed districts.

growing farmers in Uganda. Following Haneishi et al. (2011), which gave an overview as to how rainfed rice farming evolved in Uganda, how diverse it was in different regions of the country, and what categories of farmers adopted it, this paper looks into how farmers in Uganda grow rice under rainfed conditions in various agro-climatic zones, how rainfed rice cultivation performs in terms of yield, and what factors determine the yield.

MATERIALS AND METHODS

The data used in this paper was collected by a nation-wide survey on rice growing farmers conducted by National Crops Resources Research Institute (NaCRRI) in collaboration with the Africa Rice Centre (ARC). Sample farmers from whom we obtained information were drawn by applying the following stratified random sampling: (1) We grouped rice growing areas into five regions, that is, North, East far, East near, Central and West; (2) selected randomly three rice growing districts in each sample region; (3) selected randomly two rice growing sub-counties in each sample district; (4) selected randomly two rice growing parishes in each sample sub-county, and (5) selected randomly 20 rice growing farm households in each sample parish. A total of 1,267 farmers were interviewed, and excluding those with missing and / or unreliable information, the data of 1,014 farmers who grew rice either in rainfed upland or in rainfed lowland were used in analysis.

The locations of our sample districts are shown in Figure 1 and the numbers of our sample farmers by region and district are presented in Table 1. In this paper, we look into the regionality in rice farming in terms of agro-ecological zones: Western Savannah Grasslands (WSG), North Western Savannah Grasslands (NWSG), North Eastern Savannah Grasslands (NESG), Lake Victoria Crescent (LVC) and Kioga plains (KP). This order of the zones is

Table 1. Numbers of sample farm households and rice plots, and rainfall, by region and district.

Agro-ecologicalzone[1)]	No. of farmers	No. of rice plots	Rainfall in 2007-08 (mm) [2)]		
			July-Dec. 2007	Jan.-June 2008	Total
WSG	196	270	934	580	1,513
Luwero[3)]	49	70	1,041	805	1,847
Hoima	73	124	880	467	1,347
Kamwenge	74	76	880	467	1,347
NWSG	150	173	735	512	1,247
Gulu	82	96	1,096	515	1,611
Masindi	68	77	374	508	882
NESG:	67	92	1,010	509	1,518
Lira	67	92	1,010	509	1,518
LVC	198	279	897	677	1,573
Mukono [4)]	71	87	1,041	805	1,847
Wakiso	63	73	752	548	1,300
Bugiri	64	119	735	861	1,596
KP	403	485	702	592	1,294
Apac	66	83	1,010	509	1,518
Butaleja[5)]	20	43	735	861	1,596
Iganga	82	120	504	677	1,180
Soroti	76	76	655	502	1,157
Kumi	78	82	655	502	1,157
Pallisa	81	81	655	502	1,157
Total	1,014	1,299	855	574	1,429

[1)] Agro-ecological zones: Western Savannah Grasslands (WSG), North Western Savannah Grasslands (NWSG), North Eastern Savannah Grasslands (NESG),Lake Victoria Crescent (LVC) and Kioga Plains (KP), arranged in the order of the dominance in rainfed upland rice cultivation relative to rainfed lowland rice cultivation among the sample farmers. [2)] The rainfall from July 2007 to December 2008.Data are of the Meteorological Department of Uganda. The rainfall of districts where there is no weather observatory is substituted for by the rainfall of the most adjacent district. [3)] Include a part of Nakaseke district. [4)] Include a part of Kayunga district. [5)] Include a part of Tororo district.

the order of the degree that upland rice cultivation dominates (Haneishi et al., 2011), and the zones are arranged in this order in the tables that follow in this paper.

The survey was conducted between August and November 2009 using two sets of questionnaire. The first questionnaire set included questions on rice cultivation in the 2007 second season and the 2008 first season and the second questionnaire set included questions on plots planted to non-rice crops. Although there are a few irrigation schemes in Uganda with irrigated areas of about 5,000 ha, including non-functional ones, farmers cultivating rice under irrigated conditions are not included in our sample in order to focus on rainfed rice farming, which has been spreading rapidly in mainly upland ecosystems since the introduction of NERICA varieties in the early 2000s.

Since one of the major purposes of this paper was to show the regionality of rainfed rice farming in Uganda, no sophisticated statistical methods, beyond simple statistical tests for sample means (t-test and multiple comparison) and humble regression analyses were used. Throughout the paper, the significance levels for these statistical tests adopted were the 5% level or higher. For multiple mean comparisons, both Scheffe and Tukey tests were tried out and the more conservative test, that is, less rejections of the null hypothesis of equal means at the 5% significance level, was adopted. For identifying the determinants of rice yield, rice yield functions of the following linear formwere estimated by applying the robust regression method:

$$Y = \beta_0 + \sum_{1}^{k} \beta_i X_i + u$$

where Y = rice yield (kg ha^{-1}), X_i = explanatory variables, u = error term and β's are parameters to be estimated. The details of explanatory variables are explained when the estimation results are presented.

RESULTS AND DISCUSSION

Yield

Rice yield per hectare of the sample farmers is shown in Table 2. For the entire sample, the average rice yield per ha was 1.8 t in the 2007 2^{nd} season, 1.9 t in the 2008 1^{st} season and 1.8 t for the average of the two seasons. Reflecting the fact that rainfall was more than the required level of 500 mm per season (NaCRRI, undated)

Table 2. Rice yield per ha by season, by land type andby agro-ecological zone[1].

Parameter	2007 2nd season		2008 1st season		Differrence[2]	2007-08 average[3]	
	Yield (t ha^{-1})	CV (%)	Yield (t ha^{-1})	CV (%)		Yield (t ha^{-1})	CV (%)
All	1.8	89	1.9	82	ns	1.78	76
Land type							
Upland	1.7	74	1.7	85	ns	1.66^{a}	73
Lowland	1.8	96	2.0	80	*	1.87^{b}	77
Agro-ecological zone							
WSG	2.1	93	2.2	72	ns	2.12^{a}	67
NWSG	1.7	74	1.6	78	ns	1.57^{b}	74
NESG	1.5	95	1.9	109	ns	1.63^{ab}	85
LVC	2.0	81	2.1	86	ns	1.98^{a}	77
KP	1.5	87	1.7	77	ns	1.58^{b}	75

[1] For 1299 plots. CV stands for the coefficient of variation. [2] T-test for the mean difference between the 2007 2nd and the 2008 1st seasons; *=significant at the 5% level, ns=not significant. [3] For plots which were planted to rice in the both seasons, the yields are simple averages over the two seasons, and for plots which were planted to rice only in one of the two seasons, the yields of the season are taken. The yields followed by the same alphabet are not statistically different at the 5% level.

in both the seasons for all the agro-ecological zones (Table 1), there was no statistically significant difference in the yield between the two seasons not only for the entire sample but also in the yield by land type and by agro-ecological zone, except for lowland for which the yield in the 2008 1st season was significantly higher than in the 2007 2nd season. In this study, unless otherwise noted, we focus our attention on the average yield of these two seasons

Compared to earlier studies, the yield levels of our sample farmers were lower than those of rainfed upland farmers in central and western Uganda found by Kijima et al. (2006, 2008, 2011) and in central Uganda by Miyamoto et al. (2012), but higher than those of rainfed upland farmers in northern Uganda by Fujiie et al. (2010). The UBOS Agricultural Household Survey of 2008/09 gives the rice yield per ha of 2.5 t for the entire farmers growing rice in the country, including both rainfed and irrigated cultivation, but this is the average over 1.6 t for Western, 1.7 t for Northern, 0.8 t for Central and 3.6 t for Eastern regions (UBOS, 2011). Except Eastern region where irrigated rice cultivation dominates, the yield levels of our sample farmers in 2007/08 are comparable to or higher than those in 2008/09 reported by UBOS.

Reflecting unstable growing conditions inherent in rainfed cultivation, the variation in rice yield was very large: Even for the 2007-08 averages, the variation measured by the coefficient of variation (CV) was as high as 76% for the entire sample (Table 2). For the variation within a season, the highest variation is found in NESG for the 2008 2nd season, which was 109%. Even with such large variations, the yield difference between upland and lowland was statistically significant. For yield level, the agro-ecological zones were divided into two groups with statistically significant differences: High-yield zones consisting of WSG and LVC and low-yield zones of NWSG and KP. NESG is included in both groups because of its large yield variation.

Varieties

Varieties that rainfed rice farmers planted are summarized in Table 3. Although farmers used various rice varieties, there were two prominent varieties; Nerica 4 for upland and Supa for lowland. Nerica 4 was planted on 64% of total upland rice plots and Supa on 50% of total lowland rice plots. Other varieties of some importance were Sindano, Superica, Nerica 1 and 10 for upland and Kaiso and Nerica 4 for lowland. Compared to upland, lowland found more number of varieties. Reflecting differences in the weights of upland and lowland among the agro-ecological zones, the diffusion of varieties had strong regional biases: Nerica 4 in the upland dominating zones and Supa for the lowland dominating zones.

Within such a broad pattern, however, some more differences are observed among the zones. Of the upland dominating zones, the concentration on Nerica 4 was more distinct in WSG than in NWSG, and the variety of second importance was Superica in WSG and Sindano in NWSG. Of the lowland dominating zones, the concentration on Supawas distinct in NESG and KP but not so in LVC, and Kaisowas a relatively important variety in NESG and LVC. It should be noticed that LVC, and KP at a much lesser extent, had variety lists very different from other zones, in which other lowland varieties, including such varieties as Benenego, Kyabukooli and

Table 3. Rice varieties planted by land type and by agro-ecological zone, and yield per haby variety, 2007-08 [1)].

Varieties	All	Land type (%)		Agro-ecological zone (%)					Yield [2)] (t ha^{-1})
		Up-land	Low-land	WSG	NWSG	NESG	LVC	KP	
Nerica 4	32	64	7	69	53	20	26	9	1.8^{a}
Supa	29	2	50	0	2	51	10	61	1.5^{a}
Kaiso	7	1	11	0	0	16	19	4	2.2^{b}
Sindano	6	8	4	0	40	4	0	1	1.5^{a}
Superica	5	8	4	16	1	0	5	3	2.3^{ab}
Nerica 1&10	4	9	1	9	3	7	3	3	1.6^{ab}
Other lowland varieties	13	2	21	3	1	0	30	14	2.3^{b}
Other upland varieties	4	7	2	2	1	2	7	5	1.6^{ab}
Total	100	100	100	100	100	100	100	100	1.8
(No. of plots)	1,299	559	740	270	173	92	279	485	1,299

[1)] For 1,299 plots. [2)] 2007-08 average yield. The yields followed by the same alphabet are not statistically different at the 5% level.

Pakistan, which were rarely found in other zones, took large shares.

According to the yield level, rice varieties are grouped into two: High-yield-variety group including Kaisoand 'other lowland varieties' and low-yield-variety group include Nerica 4, Supa and Sindano. Superica, Nerica 1 and 10 and 'other upland varieties' are included in both groups because of their large yield variations. The average yield per ha of high-yield-variety group was 2.2 t, while that of low-yield-variety group was 1.6 t, with the difference of 0.6 t per ha. To what extent such differences in rice yield among varieties were due actually to the variety *per se* shall be analyzed at the end of this paper, together with other factors such as land type, agro-ecological zone, production input and land tenure.

Production inputs

Seeds, fertilizers and chemicals

Amount of seeds, fertilizers and chemicals (herbicides) applied by sample farmers are summarized in Table 4. The average quantity of seeds applied per hectare was 89 kg for upland and 96 kg for lowland, with no statistical difference between them. This level of seed intensity is nearly twice as much as the recommended level of 50 kg ha^{-1} (20 kg ac^{-1}; NaCRRI, undated), but fairly comparable to the level for rainfed upland rice cultivators found in an earlier study (Miyamoto et al., 2012). Eighty five percent of rice farmers take seeds from their own produce, the original sources of which are fellow farmers (60%), public sources such as donor organizations that implement rice promotion projects (20%) and other sources including the purchase of companies' seeds (20%).

It has been observed that few farmers in Uganda apply fertilizers and chemicals in rice cultivation (Kijima et al., 2006, 2008, 2011; Fujiie et al., 2010). It is the case for our sample farmers as well. The percentage of plots applied with fertilizers was 14% for upland and 7% for lowland. The same percentage for chemicals (herbicides) was 15 and 12%, respectively. The average quantity applied by the farmers who applied them was 53 to 59 kg ha^{-1} for fertilizers and 6 to 7 L ha^{-1}for herbicides, the levels of which were comparable to those of rainfed upland rice farmers in central Uganda (Miyamoto et al., 2012). The most popular fertilizer was urea, applied by 53% of fertilizer users, followed by DAP and NPK with the share of 25 and 7%, respectively. For herbicides, 50% of herbicide adopters used Butanyl 70, 15% 2,4-D, 11% Satunil and 9% Weed Master. It should be noted that for upland, no significant yield difference was observed between farmers who applied fertilizers or herbicides and those who did not, but for lowland, fertilizer or herbicide adopters attained significantly higher yields than non-adopters (Table 4).

Not only the number of farmers who used fertilizers or herbicides was few but also their distribution had clear regional biases (Table 5). Most of fertilizer or herbicide adopters were found in LVC and WSG, and in NWSG at much lesser extent, while very few or no adopters were found in NESG and KP. It is interesting to observe that although the use of herbicides was more popular than the use of fertilizers in these fertilize-herbicide using zones, farmers who applied herbicides tended to apply fertilizers as well or *vice versa*.

Labor

Rice is a labor intensive crop. Some previous studies support a hypothesis that rice is a pro-smallholder crop (Kijima et al., 2008; Lodin et al., 2009; Miyamoto et al., 2012). A major source from which this pro-smallholder characteristic is derived is the labor-using nature of rice cultivation. Table 6 that summarizes labor inputs for rice production per hectare is consistent with these earlier findings. For the entire sample, the average labor

Table 4. Average amount of seeds, fertilizers and herbicides applied, 2007-08 [1)].

Parameter	Number of plots		Quantity applied	Yield
	no.	(%)	(kg ha^{-1})	(t ha^{-1})
Seeds				
Upland	559		89[a]	1.7 [a]
Lowland	740		96[a]	1.9[b]
Fertilizers				
Upland	559	100		
Notapplied	481	86	0	1.6[a]
Applied	78	14	59	1.7[a]
Lowland	740	100		
Not applied	691	93	0	1.8[a]
Applied	49	7	53	2.6[b]
Herbicides			**L ha^{-1}**	
Upland	559	100		
Not applied	473	85	0	1.6[a]
Applied	86	15	6	1.8[a]
Lowland	740	100		
Not applied	653	88	0	1.8[a]
Applied	87	12	7	2.7[b]

1) For 1,299 plots. The means followed by same alphabet are not statistically different at the 5% level.

Table 5. Percentage of plots applied with fertilizers and /or herbicides by agro-ecological zone, 2007-08.

Parameter	Total plots (no.)	Plots applied with fertilizer (%)	Plots applied with herbicide (%)	Plots applied with both (%)
WSG	270	14	24	12
NWSG	173	6	8	5
NESG	92	0	0	0
LVC	279	19	31	14
KP	485	5	1	1
Total	1,299	10	13	6

intensity was 332 person-days ha^{-1}. Comparing to other rice growing regions in the world, such a level of labor intensity can be said highly intensive (Barker et al., 1985). Tasks that absorbed a lot of labor were land preparation (50 days), weeding (80 days), harvesting and threshing (60 days) and bird scaring (90 days). The patterns of labor use by task were quite similar between upland and lowland and so were the dependency rates on hired labor which were about one-third for both land types.

However, labor intensity varied greatly from a region to another (Table 7). The agro-ecological zones were clearly demarcated into highly labor intensive zones (WSG and LVC), medium labor intensive zone (KP) and less labor intensive zones (NWSG and NESG). The labor intensity of the highly intensive zones was more than 400 person-days, more than twice as high as that of the less intensive zones, though the labor intensity of 200 person-days ha^{-1} in the less intensive zones is still high according to the international standard. Such large differences in labor intensity between the highly and less intensive zones were brought about mainly by the differences in labor needs for land preparation and bird scaring. In the less intensive zones, including KP, the use of cattle plowing in land preparation was fairly common (Musiitwa and Komutunga, 2001) and land preparation by tractor was found in some parts of these zones. In contrast, in the highly intensive zones, land preparation was done fully manually using hand hoes and farm hatchet. It appears that bird damages were less serious in the less intensive zones, not including KP, than in the highly intensive zones.

Table 6. Labor inputs for rice production per ha,by task, 2007-08 [1)].

Parameter	Upland		Lowland		Average	
	days ha^{-1}	% hired	days ha^{-1}	% hired	days ha^{-1}	% hired
Clearing	18	39	12	38	15	39
Slash and burn [2)]	9	40	6	44	7	42
Plowing	40	35	25	34	31	35
Seeding / transplanting	24	23	15	28	19	26
Seed guarding	11	38	5	39	7	40
First weeding	45	26	45	24	45	25
Second weeding	30	28	32	26	31	27
Third weeding	6	48	8	45	7	47
Chemical application	6	47	5	69	6	59
Bird scaring	77	30	96	38	90	34
Harvesting	36	23	42	24	39	24
Threshing	20	25	19	26	19	25
Drying	6	21	6	24	6	22
Transport	7	30	12	35	10	33
Total	333	30	328	32	332	31

[1)] For 1,014 farmers for whom data are available. [2)] Include residue spreading.

Table 7. Total labor inputs per ha by agro-ecological zone and by variety, 2007-08[1)].

Parameter	Upland	Lowland	Average
		days ha^{-1}	
Zone			
WSG	418	415	418 [a]
NWSG	206	138	196 [b]
NESG	247	225	232 [b]
LVC	506	403	432 [a]
KP	246	363	349 [c]
Variety [2)]			
Nerica 4	382	-	382 [a]
Supa	-	363	363 [a]

[1)] For 1,014 farmers for whom data are available. Means followed by the same alphabet are not statistically different at the 5% level. [2)] Nerica 4 planted to lowland (n=46) and Supa planted to upland (n=5) are excluded for small number of observations.

Table 7 also provides labor intensity by variety, for most popular Nerica 4 and Supa. Nerica 4 is an early maturing variety that needs 120 days before harvest, while Supa needs 150 days to be harvested, one month longer than Nerica 4. In spite of a large difference in the duration for rice plants being in the fields, there was no significant difference in the labor requirements between these varieties.

Disposal of rice output

Rice produced by farmers is sold out to the market, consumed at home and kept as seeds for following seasons (Table 8). Reflecting the fact that rice is a cash crop for farmers, the percentage share of rice sold out to the market was as high as 70% for the entire sample. In addition, some amount of rice was kept at home for future sale seeking a better price in the market. Therefore, the share of rice consumed at home was at most 24 and 6% was kept as seeds. Such a pattern of rice disposal is consistent with the pattern found in UBOS (2011).

The share of rice output sold out was significantly higher for upland farmers than for lowland farmers. Among the agro-ecological zones, the propensity to sell

Table 8. Disposal of rice output by land type andby agro-ecological zone, 2007-08 [1)].

Parameter	Kept as seeds (%)	Kept at home[2)] (%)	Sold out (%)			Total (%)
			In paddy	In milled rice	Total	
Land type						
Upland	6	22	55	17	72[a]	100
Lowland	6	26	25	44	68[b]	100
Zone						
WSG	5	16	63	16	79[b]	100
NWSG	5	24	51	20	71[a]	100
NESG	8	21	69	3	72[ab]	100
LVC	6	32	13	49	62[c]	100
KP	5	26	25	44	69[a]	100
All	6	24	37	33	70	100

[1)] For1,057 plots for which data are available. The percentage shares of total sold out followed the same alphabet are not statistically different at the 5% level. 2) Obtained as residual. Include stored for future sale as well as consumed at home.

was highest in WSG, suggesting that the nature of rice as a cash crop was highest there. The lowest propensity to sell was found in LVC, which is not consistent with the findings by UBOS (2011) that farmers in the central region dispose of a quite large share of their rice output in the market. This anomaly may be explained by the large share of rice output kept at home in LVC, which should include a bulk of rice that farmers store for future sales.

Another observation in Table 8 is about the form farmers sell the rice output. For the entire sample, the quantity of rice produce sold in the form of paddy rice was slightly larger than the quantity sold in the form of milled rice. However, there was a contrasting pattern in this respect between upland and lowland: Upland rice farmers tended to sell their rice more in paddy and the opposite was the case for lowland rice farmers. Among the agro-ecological zones, rice was sold by farmers mostly in the form of paddy in WSG, NWSG and NESG and the other way around in LVC and KP. Such contrasting patterns may suggest that rice milling services were better developed in the zone with a longer history of rice cultivation such as KP or the zone with closer proximity to the large urban markets such as LVC than in the zones with a shorter history of rice cultivation and situated far from the market centers such as WSG, NESG and NESG.

Production structure and income

The cost structure of and farmers' income from rice production are estimated in Table 9. Rice output is evaluated at the farm-gate before milling process and factor payments include accordingly factor inputs spent in the production process from land preparation to transporting paddy output to farm-gate. In case rice output needs to be evaluated, we assume UGX 1,000(US$ 0.60) per kg for the price of paddy rice. All paid out costs, that is, the costs for current inputs and hired labor, are valued at prices prevailing in the respective markets during the study period. Family labor inputs are evaluated at their respective market wage rates. For fixed capital, such as foe and other farm instruments, and land, no imputation is made, so that the returns to these inputs are included in farmers' operator surplus.

For the entire sample, the factor share of current inputs was 7%. Therefore, the gross value-added ratio was 93%, indicating that rice cultivation generated UGX 2.07 million (US$ 1,300) of gross income for every hectare planted to rice. Labor took the largest factor share of as much as 70%.Subtracting costs for current inputs and labor from the gross value of output, 23% was left to farmers as operator's surplus, which consisted of returns to land and fixed capital and profit. Farmers' income from rice production, obtained by subtracting paid-out costs from the gross value of output, was UGX 1.44 million (US$ 850) per hactare, or 65% of gross output. These factor shares of and farmer's income from rice production obtained from our sample farmers are remarkably similar to those reported in Kijima et al. (2008). Reflecting the higher yield per hectare, operator's surplus and farmer's income were larger for lowland rice farmers than for upland rice farmers, but the production structure was essentially the same for upland and lowland rice cultivation.

Determinants of rice yield

Finally, we examined what factors affect rice yield per hectare by estimating the yield function. For explanatory variables, the factors explained thus far in this paper and in Haneishi et al. (2011) were tried out; production in puts

Table 9. Factor payments, factor shares and farmers' income in rice production per hectare, 2007-08 [1)].

Parameter		ALL		Upland		Lowland	
		UGX000	%	UGX000	%	UGX000	%
Rice output	1	2,217	100	2,012	100	2,365	100
Factor payment							
Current inputs	2	149	7	152	8	148	6
Seeds		123	6	120	6	126	5
Fertilizers		10	0	16	1	6	0
ides		16	1	16	1	16	1
Labor	3	1,559	70	1,613	80	1,604	68
Family		935	42	968	48	962	41
Hired	4	624	28	645	32	642	27
Operator's surplus	5=1-2-3	509	23	246	12	613	26
Farmer's income	6=1-2-4	1,444	65	1,214	60	1,576	67

1) For 1,014 farmers. The official exchange rate for July 2007 to June 2008 was US$ 1.00 = UGX 1,700 on average.

(seeds, fertilizers, chemicals and labor), rainfall (total rainfall for the period from July 2007 to June 2008), land types (upland), farm sizes (large farmer), agro-ecological zones (LVC), varieties (Nerica 4), and land tenure systems (owner). Of these variables, production inputs and rainfall are continuous variables, and all the rest are dummy variables, for which the bases, that is, the categories set to be zero, are shown in the parentheses above.

The robust regression method was applied to two sets of observations; one consisting of the entire sample of 1,299 observations, and the other that was a sub-set of the entire sample consisting of the observations for which the information on land tenure system of farmers' rice plots was available (n = 632). The robust regression method was adopted in order to deal with the heteroscedasticity in the residuals. The results of the estimation are summarized in Table 10 for the two sets of observations and for the explanatory variables that give regression coefficients statistically significant at the 5% level or higher. Note that among the production inputs tried out, chemicals and labor did not give any significant coefficient so that they are not included in the regression equations shown in Table 10.

First, Regression [1] was look at for the entire sample. It reveals that rainfall was a significant determinant of yield; an increase in annual rainfall of 1 mm increased rice yield by about 0.6 kg ha^{-1}. This means that an increase in rainfall of 1 mm per season increased rice yield by about 1.2 kg ha^{-1}. Although it is a matter of course for rainfed rice cultivation that rainfall is a critical determinant of yield, our result is the first attempt to quantify its impact in Uganda using farm-level data.

Of the variables related to production inputs, seeds and fertilizers gave significant positive impacts on the unit yield. An increase of 1 kg ha^{-1} of seeds resulted in an increase in rice yield of about 6 kg ha^{-1}, which is fairly comparable to the finding of Miyamoto et al. (2012) for rainfed upland farmers in central Uganda. In the case of fertilizer, a 1 kg ha^{-1} increase in the application brought about an increase in the yield of about 8 kg ha^{-1}. Farmers who used fertilizers applied about 55 kg per ha (Table 4), of which urea took the largest share of 53%. Even if we assume that all the fertilizers used were urea, an increase in nitrogen application of 1 kg ha^{-1} resulted in an increase in rice yield of about 17 kg ha^{-1}. Since the prices of paddy and nitrogen were UGX 1,000 (US$ 0.60 kg^{-1}) and UGX 5,000 (US$ 3.00) kg^{-1}, respectively, the application of fertilizer increased profits substantially. As a nitrogen response to rice yield, however, this rate of response is less than the nitrogen response found by Miyamoto et al. (2012).

The yield of lowland plots was significantly higher than that of upland, by about 0.2 t ha^{-1}. This result was obtained under the condition that other factors, such as rainfall, production inputs, size of farmer, region and variety planted, were controlled. This result, therefore, confirms that, *ceteris paribus,* rainfed lowland, because of its better capacity to sustain soil moisture, offers a better growing condition for rice than rainfed upland. The coefficient of small famer dummy is positive and significant, indicating that the yield of small farmers was higher than that of large farmers by about 0.2 t ha^{-1}. This result provides an additional evidence to support the proposition that rice is a crop of pro-smallholder nature (Kijima et al., 2008).

Table 10. Results of robust estimation of yield function [1].

Explanatory variable	N=1,299		N=632 [2]	
	[1]		[2]	
	Coef.	**Prob.**	**Coef.**	**Prob.**
Continuous variables				
Rainfall (mm $year^{-1}$)	0.602	0.001	0.675	0.000
Seeds (kg ha^{-1})	5.65	0.000	6.64	0.002
Fertilizers (kg ha^{-1})	7.88	0.000	7.51	0.000
Dummy variables:				
Lowland	243	0.008	277	0.012
Small farmer	165	0.027	271	0.008
WSG	573	0.000	575	0.004
NWSG	380	0.006		
Kaiso	420	0.039		
Sindano	-343	0.036		
Other lowland varieties	542	0.000		
Mailo/Customary tenure			-247	0.011
Leaseholder			885	0.007
Intercept	381	0.123	465	0.087
R^2 (adjusted)	0.106		0.160	

[1] Yield (kg ha^{-1}) is regressed on the explanatory variables. [2] A sub-sample consisting of observations for which the information about land tenure of the rice plots is available.

Among the agro-ecological zones, the yield was significantly higher in WSG and NWSG than in other zones, showing a good potential for growing rainfed rice in these upland dominating zones (Haneishi et al., 2011). It should be reminded that on average rice yield was highest in WSG, but lowest in NWSG (Table 2). When other factors, such as rainfall, type of land and variety, were controlled, rice yield in NWSG was estimated to be significantly higher than in other zones except for WSG.

Among varieties, Kaiso, Sindano and‘ other lowland varieties’ had significant coefficients, negative for Sindano and positive for the other two. Not only‘ other lowland varieties’ but also Kaiso are lowland varieties mostly planted to lowland (Table 3). Such results seem to indicate that the yield performance of rainfed lowland cultivation in which low-yielding Supa dominates could be improved by introducing Kaiso and ‘other lowland varieties’ and the cultivation practices associated with these varieties. For upland rice varieties, no superior one in terms of yield performance was found. Nerica 4, the major upland variety, performed significantly better than Sindano, but cannot be distinguished from other upland varieties in terms of the unit yield. Being relatively high yielding (though not statistically significant) in the ‘low-yield-variety group’ which consists of upland varieties (Table 3), it is critical for enhancing the yield performance of rainfed upland cultivation to increase the yield of Nerica 4 in the average farmers’ fields to the level attained in advanced farmers’ and experiment stations’ fields through improving the cultivation practices.

Regression [2] for the smaller sub-set of the entire sample gives quite similar results as Regression [1] for rainfall, seeds, fertilizers, lowland, small farmer and WSG, indicating that the sub-set shares essentially the same regression structure as the entire sample has (Table 10).Important results revealed by Regression [2] are that rice yield per hectare was significantly less for the plots under mailo/customary tenure systems, and significantly more for the plots under leasehold tenure system, than the plots under freehold/private mailo tenure systems. This finding is contrary to the finding by Place and Otsuka (2002) in that they found no difference in productivity in crop farming among different tenure systems.

For the inefficiency of the traditional tenure systems relative to the formalized tenure systems, we do not have any information at hand that decisively explains why it arises. It might be due to the difference in how clearly the ownership of land is defined: Under the traditional customary tenure and mailo systems, it is loosely defined being associated with communities, clans and families, while it is more clearly defined as a property right of individual persons under the formalized tenure systems such as freehold and private mailo. It must be a research issue of top-priority to clarify the mechanism that brings about this inefficiency, since its implication, that is, the modernization of traditional tenure systems may work in favor for improving productivity in crop farming, should have a far-reaching importance not only for rainfed rice farming in particular but also for crop farming in general.

For the better efficiency of the leasehold system over the owner-operator (freehold and private mailo) system, too, we do not have a decisive explanation. Theoretically, these two systems are predicted to have the same production efficiency (Hayami and Otsuka, 1993). A possible reason for the better efficiency of the leasehold system may be sought in the fact that, under the 'rice boom,' many farmers, and quite a few people with non-farm professions, wanted to start rice farming by renting land from other farmers under the leasehold system (Haneishi et al., 2011); they may possess some advantages over ordinary farmers in such respects as farming technology, entrepreneurship and capability to raise capital funds. This point, however, is also left for future studies to be elucidated more precisely.

Conclusions

Using a nationwide survey of rice growing farmers in Uganda, we examined in this paper how farmers grow rice under rainfed conditions in various agro-ecological zones, how rainfed rice cultivation performs in terms of yield, and what factors determine the yield. We found that the average yield per ha was 1.8 t ha^{-1} for the entire sample, 1.7 t ha^{-1} for rainfed upland and 1.9 t ha^{-1} for rainfed lowland, the difference between the land types being statistically significant. Nerica 4 and Supa were the two major varieties planted by rainfed rice farmers, the former in upland and the latter in lowland. High seeding rate, low fertilizer and chemical application and high labor intensity characterized rainfed rice cultivation in Uganda, though distinct regionality existed in fertilizer and chemical application and labor intensity, reflecting differences in agro-climatic conditions, soil fertility and traditional farming technology, such as land preparation with draft animals. The high marketed ratio of rice produce also characterized rice farming in that rice was an important cash crop for farmers. On average, the gross value-added ratio of rice production was 93% and the farmers' income ratio was 65%.

The estimation of yield functions revealed that rainfall, the amount of seeds and fertilizers applied, lowland and small farmers were positive determinants of rice yield per ha, that the potential for high yield existed in Western Savannah Grasslands and North Western Savannah Grasslands, and that Kaiso and some minor lowland rice varieties revealed better yield performance among lowland varieties than such popular varieties as Nerica 4 and Supa. It also revealed that rice plots under the traditional tenure systems yield significantly less, and those under the leasehold system yield significantly more, than rice plots under suchformalized land tenure systems as freehold and private mailo.

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Abbreviations: ARC, The Africa Rice Center; **CV,** coefficient of variation; **KP,** Kioga Plains; **LVC,** Lake Victoria Crescent; **NaCRRI,** National Crops Resources Research Institute; **NERICA,** new rice for Africa; **NESG,** North Eastern Savannah Grasslands; **NWSG,** North Western Savannah Grasslands; **WSG,** Western Savannah Grasslands.

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