［*Jpn. J. Agric. Econ.* Vol.22, pp.106-111, 2020］

The Adoption of Upland Rice by Lowland Rice Farmers and Its Impacts on Their Food Security and Welfare in Madagascar

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The objective of this paper is to examine the impacts of newly adopted upland rice cultivation on lowland rice farmers' food security and welfare. Using cross-sectional data collected from randomly selected 600 farm households in Vakinankaratra region of Madagascar, this study reveals that the adoption of upland rice cultivation has a positive impact on their food security by substantially increasing total rice production per capita. It also increases households' food consumption and total consumption per capita. These results imply that upland rice cultivation should receive more attention from policy makers as a feasible instrument for farmers to increase rice production.

Key words: upland rice, technology adoption, impact assessment

1. Introduction

Rice is the most fundamental staple food for people in Madagascar and the main income source for rural households as well. Sharma and Razafimanantsoa (2016) introduces statistics showing that rice provides 41.9% of the total generated agricultural income of farm households and rice consists of more than half of the total calorie intake for rural households. Hence, the improvement of rice production should be closely related to the welfare of rural households.

Generally, crop production is improved through either yield improvement or land expansion. In the context of Madagascar, the expansion of lowland rice fields is almost impossible due to lowland scarcity and population increase. In addition, the adoption of yield enhancing technologies has remained at low level due to liquidity constraints, high labor requirement, and unstable weather condition (for example, Harvey *et al*., (2014), Minten, Randrianarisoa, and Barrett (2007), and Moser and Barrett. (2003)).

However, a noteworthy change in rice production is currently taking place in the central highland zone of the island. An increasing number of farmers are adopting upland rice cultivation which is conducted on naturally well-drained fields without water retention on the surface. In Madagascar, except for a few regions in eastern part of the island, upland rice cultivation used to be almost negligible in terms of production volume and planted area. In the early 2000s, new varieties developed by a series of collaborated research program of CIRAD[1)] and FOFIFA[2)] enabled upland rice cultivation in the central highland zone where no suitable upland rice variety had existed due to the cold temperature (a review is available in Raboin *et al*. (2014)). In addition, NERICA[3)] varieties which are more tolerant against drought and more competitive against striga, a parasitic, seriously harmful weed, than conventional varieties began to be promoted. NERICA varieties provided farmers in drier part of the central highland zone with a chance to have better and stable harvest.[4)] As of 2019, 17 improved varieties of upland rice have been officially introduced to the central highland zone.[5)]

It is true that the newly introduced upland rice varieties have caused the expansion of upland cultivation in the central highland of Madagascar.

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1) The French Agricultural Research Centre for International Development
2) The National Center for Applied Research and Rural Development of Madagascar
3) NERICA stands for New Rice for Africa.
4) Roughly speaking, in central part of the central highland zone lying at a high altitude cold temperature is the constraint and FOFIFA/CIRAD varieties are exclusively dominate, while in western part of the central highland zone lying at a relatively lower altitude dryness is the constraint and NERICA varieties are more suitable.
5) The catalogue is available at https://www.dp-spad.org/content/download/4375/32703/version/1/file/POCHVAR.pdf (accessed on October 10, 2019). However, identifying a variety to its scientific names in the farmers' fields is not realistic because many different local names have been generated and used by farmers.

However, considering that few farmers had grown upland rice before the introduction of the new varieties, this study focuses on the impact of the adoption of "upland rice cultivation" rather than the adoption of any particular rice variety or varieties. In this sense, this study differs from existing studies, which analyze the impact of the adoption of particular upland rice varieties, such as NEIRCA (e.g. Kijima, Sserunkuuma, and Otsuka (2006), Kijima, Otsuka, and Sserunkuuma (2008) and Sakurai *et al*. (2014)).[6)]

More importantly, unlike in many sites in Sub-Saharan Africa where upland rice has been introduced, most Malagasy farmers grow lowland rice as traditional staple food and adopt upland rice cultivation as supplemental rice production. In particular, we observe an interesting contrast between the rapid expansion of upland rice practice and the slow progress of lowland rice intensification. However, empirical studies about upland rice are still few. The motivation of this paper is to contribute to filling this gap.

2. Research Question and Hypotheses

The main goal of this study is to examine the impacts of the adoption of upland rice cultivation on farmers who grow lowland rice. This study firstly investigates the determinants of upland rice cultivation. Then, it estimates the impacts of upland rice cultivation on households' food security and welfare.

Regarding the food security, three indicators are used. Total rice production per capita is the main indicator. It is expected that upland rice has a positive impact on it since upland rice is supposed to be supplementary to lowland rice, but it may not be the case if it substitutes for lowland rice production. The quantity of rice purchased in each month from January to March is another indicator. In Madagascar, these three months are generally recognized as lean months before the main harvest from lowland starts in April. Rice price is the highest in these three months in a year. If upland rice harvested a few weeks earlier than lowland rice is for home consumption, it will reduce the quantity of rice purchased in the lean period. Furthermore, the quantity of rice consumed in a week is also used as an indicator of food security.

As the welfare indicators, the value of consumption in the last one month is used. Intuitively, upland rice cultivation should have a positive impact on welfare since it provided supplemental income. However, it may not be true in the following two cases. First, income from upland rice is negative if the paid-out costs for upland rice cultivation such as hired labor and fertilizer are higher than its value. Second, total income does not increase or even decrease if farmers reduce the production of other crops and/or reduce labor supply to off-farm/non-agricultural employment.

3. Analytical Framework

In this study, with cross-sectional data collected in non-experimental setting, a probit model is used to identify the determinants of upland rice cultivation. Then, the impact of upland rice cultivation is analyzed using propensity score matching to address endogeneity. This study employs Kernel matching methods in order to maximize the sample size as well as precision of the analysis. Bootstrapping method is applied to estimate the standard error.

4. Data and Descriptive Statistics

Data for this study was collected through 2 steps. Firstly, a census survey was conducted in 60 villages in 13 communes across 3 districts in Vakinankaratra region from December 2017 to January 2018. The 60 villages are about 50% of the total villages in the 13 communes, and were selected intentionally to have an even geographical distribution within each commune. Then, based on the household list created from the census data, 10 households that grow lowland rice were randomly selected from each of 60 villages as sample households for main survey. The main survey was conducted to the total of 600 households from June to August 2018 and collected detailed household level information via interview: it includes demography, agricultural input and output, monthly transaction (sales and purchases) of rice, monthly expenditure of food and non-food items, weekly food consumption, and non-agricultural/off-farm activities. Out of the 600 households, 34 households are dropped

6) In many countries in Sub-Saharan Africa, NERICA has been introduced as a new upland crop where few farmers had experience in upland rice cultivation. Thus, what was really adopted is not a new upland "rice variety" but a new upland "crop." In this sense, the situation is the same as our study site in Madagascar.

Table 1. Descriptive statistics

Variables	Mean of all samples	Mean of non-upland rice growers	Mean of upland rice growers	Difference of the means[1]	
Household characteristics					
Number of household members	4.99	4.78	5.11	-0.33	*
Household with male head (%)	89.75	86.87	91.30	-4.44	*
Age of household head	46.23	47.33	45.64	1.69	
Household head's literacy in French (%)	62.72	65.66	61.14	4.51	
Number of adult members (15 years old or above) in household	3.05	2.97	3.10	-0.12	
Land Endowment					
Number of parcels	3.64	3.32	3.81	-0.48	***
Total area of parcels (ha)	0.75	0.45	0.92	-0.47	***
Total area of lowland parcels (ha)	0.31	0.22	0.36	-0.13	***
Total area of upland parcels (ha)	0.45	0.23	0.56	-0.34	***
Total area of lowland parcels per capita (ha)	0.067	0.055	0.075	-0.019	**
Total area of upland parcels per capita (ha)	0.098	0.057	0.120	-0.064	***
Irrigation condition of lowland (%)	69.58	79.86	64.04	15.82	***
Subjective evaluation of lowland plot soil fertility weighted by plot size (1-3)[2]	2.15	2.12	2.17	-0.045	
Subjective evaluation of upland plot soil fertility weighted by plot size (1-3)[2]	1.92	1.89	1.92	-0.029	
Farming Characteristics					
HH[3] experienced weather-related production shocks in lowland rice (%)[4]	64.84	58.08	68.48	-10.40	**
HH[3] experienced weather-non-related production shocks in lowland rice (%)[4]	20.67	9.09	26.90	-17.81	***
Other characteristics					
Any HH[3] member is engaged in off farm employment (%)	61.84	67.68	58.70	8.98	**
Any HH[3] member is engaged in non-agricultural employment (%)	35.51	43.43	31.25	12.18	***
Livestock (Log of total value per capita)	2.91	3.08	2.82	0.26	*
Asset (Log of total value per capita)	2.94	3.19	2.80	0.38	***
Distance from the national road (10km)	0.58	0.56	0.59	-0.03	
Food security and welfare indicators					
Total rice production per capita (kg)	264.04	208.93	293.69	-84.76	***
Rice consumption in last 7 days (kg/capita)	2.28	2.35	2.24	0.12	
Total value of food items consumed in the last one month (10^3MDA/capita)[5]	51.48	50.45	52.04	-1.60	
Total value of non-food items consumed in the last one month (10^3MDA/capita)[5]	15.13	12.34	16.63	-4.29	**
Aggregated value of items consumed in the last one month (10^3MDA/capita)[5]	66.62	62.79	68.68	-5.89	
Number of Observations	566	198	368	-	-

Note:1) *, **, and *** indicate that the means are different at the significance level of 10%, 5%, and 1%, respectively.
2) Evaluation is based on three-scale category: low=3, average=2, and high=1.
3) HH stands for household.
4) "Experienced" is defined as having at least one shock in the last 10 years.
5) MDA stands for Malagasy Ariary. 1 USD = about 3275 MDA on July 18, 2018.

from the analyses: 4 households are due to incomplete data and 30 households have no upland plot to adopt upland rice cultivation.

Table 1 presents the descriptive statistics of the remaining 566 sample households. The mean size of households is around 5 people. The mean of household heads' age is 46 years old. On average, a household has 3 to 4 parcels whose total area is less than 1 ha. By agroecology, mean landholding of a household is 0.31 ha in lowland and 0.45 ha in upland.

Among the sample households, 65% of them have experienced production shocks in lowland rice due to weather related events such as cyclones and low temperature at least once in the last 10 years, and 20% of them have experienced weather-non-related production shocks in lowland rice such as crop disease and insect attack.

Among 566 households, 65% of them grew upland rice in the main cropping season of 2017/2018, which is the same percentage as found in the census survey. The mean comparison between upland rice growers and non-growers shows significant differences in many variables. With respect to household's characteristics, upland rice growers have significantly larger household size. In terms of land endowment, total area of lowland parcels, that of upland parcels, and the sum of them are significantly larger among the upland rice growers. In the meantime, upland rice growers are less likely to have irrigated lowland.

As for income source, upland rice growers are less

Table 2. Determinants of upland rice cultivation[1]

Variables	(1)		(2)	
Household characteristics				
Number of household members	-0.01		-0.01	
Sex of household's head (=1 if male)	0.02		-0.00	
Age of household head	-0.00		-0.00	
Household head's literacy in French (=1 if the head can read French)	-0.01		0.09	***
Number of adult members (15 years old or above) in household	0.00		0.01	
Land Characteristics				
Size of lowland parcels per capita (ha)	0.02		-0.01	
Size of upland parcels per capita (ha)	1.22	**	0.61	
Irrigation condition of lowland (=1 if irrigated)	-0.15	***	0.03	
Subjective evaluation of lowland plot soil fertility weighted by plot size (1-3)[2]	0.03		-0.01	
Subjective evaluation of upland plot soil fertility weighted by plot size (1-3)[2]	0.07		0.07	
Farming Characteristics				
HH[3] experienced weather-related production shock in lowland rice (=1 if yes)[4]	0.10	**	0.06	
HH[3] experienced weather-non-related production shocks in lowland rice (=1 if yes)[4]	0.19	***	0.17	***
Other Characteristics				
Any of household member has non-agricultural income source (=1 if yes)	-0.07	*	-0.02	
Log of total value of livestock per capita	0.03		0.03	*
Log of total value of asset per capita	-0.09	***	-0.07	***
Distance from paved road (10km)	0.04		0.13	**
Commune dummy variables				
Belazao	NA		0.34	**
Antanimandry	NA		0.36	**
Betafo	NA		Reference	
Soavina	NA		0.40	***
Antohobe	NA		0.52	***
Mahaiza	NA		-0.01	
Ambohimasina	NA		0.13	
Ambohimanambola	NA		0.39	***
Inanantonana	NA		0.37	***
Ankazomiriotra	NA		0.49	***
Mandoto	NA		0.38	***
Antambao Ambary	NA		0.11	
Vinany	NA		0.78	***
Number of observations	566		566	

Note:1) Coefficients show marginal effects. *, **, and *** indicate significance level at 10%, 5%, and 1%, respectively.
2) Evaluation is based on three-scale category: low=3, average=2, and high=1.
3) HH stands for household.
4) "Experienced" is defined as having at least one shock in the last 10 years.

likely to have family members engaged in off-farm and/or non-agricultural employment. In addition, values of livestock and assets are significantly smaller for upland rice growers. With respect to food security and welfare indicators, rice production per capita and total value of non-food items consumed in the last one month are significantly larger for upland rice growers.

5. Results

1) The determinants of upland rice cultivation

Table 2 shows the results of probit regression. Unobservable factors at the commune level are captured as commune fixed effects by commune dummy variables in the second column.

The most salient is that the upland rice adoption is significantly affected by the commune effects. By comparing the first column and the second column, it is interpreted that the availability of upland, the lack of irrigation in lowland, weather-related risk in lowland, and the opportunities of non-agricultural earning are commune level factors affecting upland rice cultivation rather than household level ones. Moreover, unobservable commune level effects such as the presence of NGOs, farmers' formal associations, and farmers' informal network that promote upland rice cultivation may also be working.

As for household-level variables, French literacy of household head and weather-non-related shock experiences have significant influence on the adoption. While the former is common finding in the literature of technology adoption, for example Kijima, Otsuka, and Sserunkuuma (2011) and Olufunmilola, Bamire, and

Ogunleye (2017) in the case of NERICA adoption, the latter has not been identified in existing literature and is considered to be our contribution.

2)Impact of upland rice cultivation

Common support conditions for propensity score matching estimation are shown in Figure 1 and Figure 2 for the cases of without and with commune dummies respectively. Kolmogorov-Smirnov distance measure of distributions of propensity score is 0.4063 for the former and 0.5620 for the latter. Thus, because the commune dummies worsen the common support condition, the model without commune dummies is used in propensity calculation and consequent analysis imposing common support. We also confirm that there is no statistically significant difference in the mean of each variable after matching (results are not shown).

The result of impact assessment is given in Table 3, which indicates upland rice cultivation improves households' food security through the increase in the total rice production. This result is consistent with the typical explanation that upland rice is a supplemental production to lowland rice, rather than a substitute for lowland rice. Moreover, this analysis provides quantitative evidence that the upland rice plays an important role through the increase of 75.75kg of rice production per capita, which is not negligible as both income source and food. As for household's consumption, the result shows that upland rice cultivation significantly increases household's consumption level, particularly consumption of food items as hypothesized.

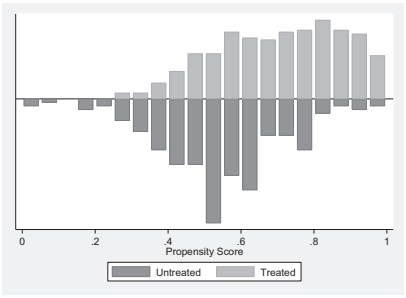

Figure 1. Common support without commune dummy

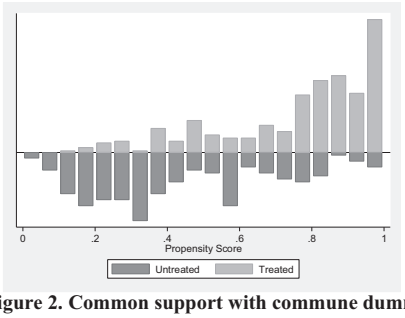

Figure 2. Common support with commune dummy

However, none of the other variables related to rice purchasing behavior in lean months are significantly affected. It implies that households do not use the additional rice production to cope with the food shortage in the lean months.

Moreover, upland rice cultivation does not affect the amount of rice consumption at the time of interview (i.e. after harvest of main rice production), although it significantly increases the value of monthly food consumption in the same period as already shown. We do not have direct evidence, but the contrasting results may imply that additional rice production from upland contributes to the consumption of other food than rice, probably via purchasing.

Robustness check was conducted by using another matching method, nearest-neighbor matching, and similar results were obtained.

6. Conclusion

Upland rice cultivation has rapidly become popular in the central highland zone of Madagascar. Regarding the upland rice cultivation as a new technology that is successfully adopted by rural farm households, this paper provides empirical evidence of the impact of the upland rice cultivation. The results imply that the upland rice cultivation enhances food security and improving households' welfare.

This study suggests that the upland rice is worth receiving more attention from policy makers because it is a realistic instrument for small-scale farmers to increase rice production. Promoting upland rice cultivation to low adoption areas is recommended.

The major limitations of this study are as follows. First, the endogenous factors may not be perfectly controlled in the presented framework. Thus, the construction of a panel dataset is expected to redirect the analysis of this study.

Second, variables for households' consumption and rice purchasing behaviors are constructed based on data only from January to June. Thus, data covering all months may provide a new insight.

Table 3. Impact of upland rice cultivation[1]

Dependent Variables	Unit	Coefficients[1]	
Food Security			
Total rice production per capita	Kg/capita	75.75	*
Quantity of rice consumed in the last 7 days	Kg/capita	0.00	
Quantity of rice purchased in January	Kg/capita	1.30	
Quantity of rice purchased in February	Kg/capita	-0.15	
Quantity of rice purchased in March	Kg/capita	-0.56	
Total quantity of rice purchased during January and March	Kg/capita	0.59	
Welfare			
Total value of food items consumed in the last one month[2]	10^3MDA/capita	5.08	**
Total value of non-food items consumed in the last one month[2]	10^3MDA/capita	2.86	
The aggregated value of items consumed in the last one month[2]	10^3MDA/capita	7.95	**
Number of observations		566	

Note: 1) * and ** indicate significance level at 10% and 5%, respectively.
2) MDA stands for Malagasy Ariary. 1 USD = about 3275 MDA on July 18, 2018.

In addition, future study will be expected to explore profitability and risk of upland rice cultivation in comparison with those of lowland rice cultivation and those of other crops like maize and cassava. Such studies will provide answers to questions such as "Which is better for farmers, intensifying lowland rice production or further expanding upland rice fields?" and "What is the optimal mixture of those crops?"

Acknowledgement

This study is part of FyVary Project, one of SATREPS projects.

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