Case 4:

Extensification and Intensification Process of Rainfed Lowland Rice Farming in Mozambique

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Abstract

This paper explores the extensification and intensification process of rice production in Mozambique's dominant rice ecology, i.e., rainfed lowland area. Our household-level data show that the potential of extensification is not fully exploited, as only 41% of the cultivable lowland is used for rice. The lack of power predominantly constrains rice area expansion. High potential also exists in land intensification as indicated by the average yield of 2.5 t/ha among the top 25% of rainfed farmers. Intensification through technology adoption and intensive crop care (i.e., Boserupian process) seems to be emerging among the farmers reaching their rice land limits.

Keywords: Green Revolution, rice, Sub-Saharan Africa

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Introduction

Rice consumption in Mozambique has been increasing rapidly from 86 thousand tons in 1990 to 519 thousand tons in 2010 at an annual growth rate of 8.6% (USDA 2011). This is a faster growth rate than the three other major cereals: maize (5.5%), wheat (7.4%), and sorghum (4.7%) (USDA 2011). Meanwhile, local rice production has stagnated since then, resulting in a rapid increase in rice imports. Facing the trend of rising rice prices in the world market, high priority has been placed on the development of the domestic rice sector in the country. For example, under the initiative of the Coalition for African Rice Development (CARD), the country has drafted a national development strategy emphasizing the modernization of the sector (CARD 2011).

About 90% of the rice area is classified under rainfed lowland ecology in Mozambique (Seck et al. 2010), while irrigated ecology accounts for only 3%. Although the potential of the latter agro-ecology is very high according to analysis of the Chokwe irrigation scheme by Kajisa and Payongayong (2011), it is not easy to realize a massive increase in irrigated area in the short-term. Hence, a major contribution to the increase in rice production should come from rainfed lowland ecology.

However, our knowledge on rice farming and rice farmers in rainfed lowland areas is limited. A few exceptions include Agrifood Consulting International (2005) and Zandamela (2008), in which they describe rice farming in this agro-ecology that is characterized as the use of a traditional variety with little fertilizer input on small farms. This is useful to understand the current prevailing farming practices. For the country's rice sector development, however, what we need to know is whether there is potential in this area beyond the current level of production and how the development process will start.

This paper attempts to identify the potential of and constraints on production increase in rainfed lowland areas in Mozambique, using household-level data collected in Zambézia and Sofala in 2008. These two provinces consist of about 65% of the rice area of the country (Ministry of Agriculture 2005). In line with Boserup (1965), which discussed the transformation process to modern farming, our analyses shed light on the process from two angles: by area expansion and/or by land intensification (or yield improvement). Since Mozambique exploits less than 20% of the area suitable for rice production (Agrifood Consulting International 2005), our analyses start with identification of the factors underlying rice area expansion. Then, secondly, we examine the determinants of land productivity because some farmers have already achieved high yields by modernizing their practice even under rainfed conditions. In other words, we try to detect the emergence of the Boserupian process (intensification with modern technologies) for the farmers who have already reached their rice land limit (Boserup 1965). Through analyses with these two approaches, we discuss what constraints hinder farmers in achieving their potential in our study area and what kind of policy interventions could be effective to remove the constraints.

1. Rice in Mozambique

Similar to other African countries, a shift in consumer preference to rice – as a result of an increase in urbanization and the convenience of preparing rice meals – has been rapidly increasing rice demand in Mozambique (Hossain 2006). Figure 1 shows a rapid increase in consumption since 1990. It also shows that in response to this increase, production grew initially at 12.1% annually from 1993 to 1998, but that growth has stagnated since then. As shown in Figure 2, the growth of production in this period was largely attributed to area expansion resulting from the re-settlement of rural populations after the peace agreement in 1992, rather than yield increases (Zandamela 2008). Paddy yield has stagnated at around 1 t/ha for the last three decades. Therefore, once the re-settlement was completed, production growth lost its momentum at the end of the 1990s. The result was a rapid increase in rice imports as indicated by the widening gap between consumption and production in Figure 1.

Rice in Mozambique is produced mostly under rainfed lowland ecology (Table 1) where the farmers follow traditional cultivation practices. The seed varieties commonly used are either traditional varieties or old improved varieties developed in the 1960s or 1970s (Agrifood Consulting International 2005).[1] Only 2.5% of the rice farmers use fertilizer, 5.2% use pesticides, 11% use animal traction, and 25% use some mechanization on farms with an average size of 1.28 hectares (Agrifood Consulting International 2005). Similar to some other African countries, rice is a cash crop for Mozambican farmers. Among rainfed lowland areas, Zambézia and Sofala are the two major provinces in the

1. The names of the traditional varieties are Chupa, Chibica, Agulha, Faia, Mmima, and Muaia Muriangani. Old improved varieties include C4, ITA312, and Limpopo.

country (Table 1).

2. Data

The International Rice Research Institute (IRRI) conducted a household survey in 2008 for the agricultural season 2007-08, covering the period from September 2007 to August 2008. The survey was conducted in parallel with the National Agricultural Survey of 2008 (*Trabalho de Inquérito Agrícola* 2008 (hereafter, TIA08)) in collaboration with the Department of Statistics within the Directorate of Economics of the Ministry of Agriculture.

TIA08 is a nationally representative dataset covering all provinces. Based on the TIA08 survey, 33 villages in 9 districts out of 151 villages in 17 districts in Zambézia and Sofala are identified as rice-growing villages (Figure 3). TIA08 has sampled about 8 households in each village, generating a sample of 248 farmers from 33 villages. IRRI has additionally conducted a detailed rice survey for these sample farmers. Of them, 197 farmers produced rice in the 2007-08 season.

3. Summary statistics and research issues

Table 2 shows summary statistics on rice farming and household characteristics of the data set. Paddy yield is merely 1.1 t/ha, which is lower than other African countries with the same agro-ecological conditions, where most of them achieved about 2 t/ha (Seck et al. 2010). It does not, however, mean that all of them are low productivity farmers. The top 25% of the farmers achieved an average yield of 2.5 t/ha, which is an attractive yield level under these agro-ecological conditions. This means that the potential exists but only 25% of the farmers have currently realized it. Important research questions are what type of farmer has achieved high yield and how we can close the yield gap.

The table shows that only 1% of the area cultivated use modern varieties with no application of any kinds of chemical inputs. Improved rice farming practices such as construction of bunds and transplanting are observed to some extent, but still less than half the farmers have adopted these practices. In terms of power sources, either tractors or animals are seldom used; indicating rice farming is largely done manually. Careful examination of each factor reveals the strategies for productivity improvement.

The table also shows that only 41% of their cultivable lowland is used for rice cultivation on average, indicating the potential of area expiation for production increase. Household size is 5.23 on average and the number of working members is 2.23. The household size is not so different from the Asian standard. Different from Asia, however, is that there are few landless rural households in Mozambique. In this regard, Mozambique faces more serious labor constraints than Asia for rice farming. At the same time, animals or machines are seldom used. Therefore, the lack of power could be one of the bottlenecks for area expansion.

In the study area, the proportion of female-headed household is 26%, and the average schooling of household members is 2.92 years. These socio-economic factors are also considered as possible determinants in the analyses.

4. The determinants of rice cultivated area

Methodology

We investigate the determinants of the rice cultivated area by a framework akin to Skoufias (1995). If the markets function perfectly, the level of inputs including the size of the cultivated area is determined solely by the output price, the quality of land, technology, a farmer's farming ability (these four items as the determinants of marginal return), and input prices (as the determinant of marginal cost) but not by factor endowments and wealth of the farmer. Therefore, a significant influence of the endowments would indicate this factor cannot be acquired from the market and becomes a constraint for the optimal use of the inputs. In this section we try to identify the constraints on the optimal use of the lowland area for rice cultivation by examining the influence of the household-level resource endowments, controlling the influence from land quality, technology, ability and prices as much as possible.

The dependent variable we use is the rice cultivated area in hectares. Of the explanatory variables, the resource endowments of a household are understood by landholding size of the lowland area, the number of working age members, and the number of owned draft animals. Farming ability may be understood by the age of the household head, the average years of education over household member, the participation in agricultural training, and the gender of the household head. The agricultural training variable also includes access to technologies. We run linear and quadratic models where the latter model includes squared terms of the household variables except the female head dummy. Price effects are captured by village-level variables on price and market access. Our model includes rice price (milled rice equivalent), access to seed markets, access to fertilizer markets, access to credit markets, the existence of tractor rental markets, and the existence of animal rental markets in a village. To understand the access to markets in general we also include the variable for access to paved roads and the variable indicating access to roads throughout the year (i.e., non-seasonal access). The variables for market access would also include the access to technologies. The other important price variables are male and female wage rates. Unfortunately, however, such variables are missing in many villages in our data set. Hence, we use the average proportion of non-agricultural workers as the proxy.

Because our data are about one fifth left-censored (no rice cultivation) observations, we use the Tobit model for the estimation. We run the Tobit model with district fixed effects and village fixed effects. The former includes village-level variables in order to explore how the village-level variables on price and market access affect the proportion of the rice cultivated area. The latter is estimated in order to completely control village-level effects because some important village-level prices like wage rates are not fully available in our data set. We also expect that land quality can be controlled as a village fixed factor. In this regard, the village fixed effect models add statistical confidence to our influence on the household-level resource endowment.

Descriptive Analysis

For descriptive analysis, to have some idea on what kind of farmers are approaching their land limit, instead of cultivated land size, we classify the farmers based on the proportion of rice area into three groups: (1) no rice cultivation, (2) below-median proportion, and (3) above-median proportion at the median of 33%. By group, Table 3 shows the household- and village-level characteristics. First of all, it is difficult to find some systematic pattern between no rice farmers and rice farmers. One possible reason could be that the farmers in this group include those who have decided not to cultivate simply because their lowland is not suitable for rice cultivation.

Meanwhile, we can observe a few discernible features between the below-median group and the above-median group. First, the labor endowment measured by the number of working members per hectare of land is larger among the above-median group. Second, although there are no tractor owners in our sample, we observe there are draft animal owners only in the above-median group. Consistent with this, in the above-median group, we observe more villages with draft animal rental markets, although the difference is small. These imply that the lack of power is one of the bottlenecks for area expansion. Third, it appears that the rice area increases with average schooling years, which may include farm management abilities. Fourth, although we expect that profitability is a major incentive for rice area expansion, the table shows that the rice price is almost the same over the three groups.

Regression Analysis

Table 4 shows the estimation results of the determinants of the rice cultivated area. A key finding is that a positive and significant coefficient of labor endowment in both models indicates that the greater the labor force is in a household, the larger the land the household uses for rice cultivation. As expected in previous discussions, this suggests that farming households cannot hire as many agricultural laborers as they wish and that the lack of power is a major constraint to rice area expansion.

Being consistent with this finding, the existence of animal rental markets in a village contributes to area expansion, as indicated by its positive and significant coefficient. Since the number of owned draft animals is insignificant, even the farmers who do not own animals seem to be able to use animals for agriculture as long as the rental market exists in the village. Although a tractor is another important power source, the existence of its rental market is not statistically significant. Note that most of the tractors available in our study area are four-wheeled tractors, which are not suitable for the land preparation of small rice plots. Hence, our results may simply imply that the existing types of tractors are not effective for rice cultivation. Two-wheeled hand tractors are more commonly used in many rice producing countries. Our results might change if such tractors become locally accessible.

Average schooling years are not significant. Existing empirical studies on the impact of education on agricultural performance have found that a basic level of education is sufficient to acquire the benefits of modern agricultural practices (Feder et al. 1985; Foster and Rozenzweig 1996). However, given that its mean value is merely 2.9 years, its impact may not be large enough to affect farming practices.

5. The determinants of yield

Descriptive Analysis

Table 5 shows land use, rice technologies, and household- and village-level characteristics of the sample of 197 rice farmers by rice yield group, where the average yield ranges from 294 kg/ha for the bottom group, to 809 kg/ha for the middle, and to 2,200 kg/ha for the top. Two variables on land use shed light on two key issues of land productivity. First, the size of the cultivated area shows an inverse relationship with yield. This feature is commonly observed in South Asia partly because factor markets are distorted and large landholders have to manage their farms by themselves even when renting out is a better option (Otsuka 2007). Since Mozambique used to follow a socialist system, the private ownership of farm land has not yet been fully established and doubt still exists on the credibility of official land titling. Under such circumstances, land rental transactions could be inactive, resulting in an inverse relationship.

Second, in order to identify the households already facing their land limit for rice cultivation, we generate a dummy variable that takes the value one when the proportion of the rice area is 100%. The table indicates a high yield is more likely to be observed when land is already fully utilized and the size of the cultivated area is small, implying that, even in Mozambique's rainfed areas, some farmers may have already entered into the stage of land intensification through land productivity improvement.

Being consistent with this conjecture, the adoption of a modern variety (ITA 312) is observed only among the top yield group.[2] Furthermore, the adoption rate increases from 0.03 to 0.11 if we limit the sample of this group to the full land utilizing farmers, which we may regard as an intensification effort. Meanwhile, there is no clear pattern in the adoption of local varieties. The use of other modern inputs such as chemical fertilizer and other chemicals is zero for all, indicating the use of these inputs is not yet an available option for productivity improvement. The table also shows the level of adoption of improved practices recommended by local agronomists (i.e., the construction of bunds, flatness of plots (as a result of leveling), transplanting (against direct seeding), timely seeding/transplanting, and the number of seedlings per hill) does not show a clear association of them with the

2. ITA 312 was developed by the International Institute of Tropical Agriculture (IITA) in Nigeria. It has the yield potential of 5 to 6 t/ha in farmers' fields.

yield.[3] Regarding power use, the use of draft animals for land preparation looks positively associated with the yield, although the use of tractors does not have any association presumably due to the inappropriate size of that technology as we have discussed in the previous section.

The table also shows household- and village-level characteristics. Among them, it is reasonable to observe that the participation in agricultural training, rice price (at a village market), and the existence of draft animal rental markets are positively associated with the rice yield. A positive association of rice price with the yield is an interesting contrast to the case of rice area expansion for which price has no impact. This implies that the area expansion is strictly constrained by the labor endowment of the household (highly significant in the regression analysis) even when the rice price is attractive for more expansion, while the intensification constraint may be less strict and thus there is room to proceed along that path when the price becomes more attractive.

Regression Analysis

We estimate a kind of reduced form yield function that can be expressed as a function of a household's resource endowment (exogenous at least in the short-term). A key explanatory variable is either the proportion of rice area or the full cultivation dummy to capture the emergence of the Boserupian process. Since these variables are possibly endogenous, we use the instrumental variable approach where the explanatory variables in the quadratic model of our rice area function are used for identifying instrumental variables (IVs). Table 6 shows the estimation results with village fixed effects. As additional explanatory variables, we include household characteristics used in the previous model. The diagnostic tests support the use of IV.

First of all, the IV result with a full land utilization dummy has a positive and significant coefficient, indicating the emergence of intensification for farmers facing rice land limits, although the result is not robust across the models. Secondly, a negative and significant coefficient of the size of cultivated area indicates a very strong inverse relationship. It also shows that the owning of draft animals is important for productivity improvement, although we cannot deny a reverse causality.

Having identified who achieves high yields, we now explore how

3. Timely seeding / transplanting is crucial in Mozambique in order to avoid yield loss due to cold weather in winter.

they achieve high yields. To explore this issue, we estimate a structural form of yield function. However, the estimation of this form entails the endogeneity problem of explanatory variables. Although one possible solution is the use of the IV method, we were not able to find appropriate identifying IVs as most of the variables that affect input and technology adoption also affect the yield directly. Therefore, we use this form simply to draw implications about associations among the yield, the input levels and the technology adoption. In order to supplement this approach, we also estimate a reduced-form yield function, which can be expressed as a function of a household's resource endowment (exogenous at least in the short-term) and village-level variables (exogenous to a household). In addition, the reduced-form technology adoption function will be estimated for the technologies that were identified as influential in the structural form estimation. Combining all the results, we discuss what factors encourage/constrain technology adoption and how they eventually determine the yield.

The structural form regression results (Table 7) show that those who achieve high yield tend to use modern rice technologies such as a high yielding variety (ITA 312) and animal power. Although the causality issue between adoption and yield still remains, this may imply the Boserupian process is emerging with the adoption of modern technologies.

Table 8 shows the estimation results of the reduced form regressions with district fixed effects or village fixed effects. The result shows that the adoption of ITA 312 is positively influenced by the age of the household head and the existence of a credit market in the village. The former may capture the effect of experience in farming. The existence of a credit market would help the cash-constrained farmers who would like to purchase seeds from the markets. Moving now to the next adoption function, the use of draft animals for land preparation is promoted when a farmer owns more draft animals. Moving now to the yield function, among the significant determinants in previous functions, the number of owned draft animals is still statistically significant. In the yield function, the rice price becomes highly significant, although it does not affect any adoption. The price effect may be directly related to farmers' efforts to realize more careful farm management for higher earnings as rice is a cash crop in Mozambique.

6. Conclusion

About 90% of the rice area is under rainfed lowland ecology in Mozambique (Seck et al. 2010). Observing increasing rice consumption in the country, this paper investigated the potential of and constraints on rainfed lowland rice farming in Mozambique, using data from Zambézia and Sofala provinces. The data show that the potential is not fully exploited as only 41% of the cultivable lowland is used for rice. Our regression analysis indicates that the lack of power is the predominant constraint to rice area expansion. There are few landless people in the country to supplement the lack of manpower of farming households. Besides, under rainfed conditions, the labor demand peaks coincide with the rainfall pattern and hence it is difficult to rely on exchange or hired labor among the rice farmers. Hence, the development of the labor markets cannot be an effective solution. The alternative is to seek a substitution of animal or machine power for manpower. In fact, our regression analysis shows that the existence of animal rental markets could contribute to an increase in the rice area proportion. Statistical evidence is not found on mechanization. However, this does not necessarily mean the ineffectiveness of mechanization because our result relies on data where four-wheeled tractors are commonly used. Two-wheeled tractors are more commonly used in other rice-producing countries. Taking this into account, it is worth considering the potential of small-scale mechanization as a way to relax the constraint of the lack of power.

Our analysis also shows that some farmers are already approaching their rice land limit and moving from an extensification stage toward an intensification stage (i.e., Boserupian process). The intensification has high potential for production increases as indicated by an average yield of 2.5 t/ha among the top 25% of farmers in the rainfed area where the yield of about 2 t/ha is still an attractive yield. The intensification process has just started and thus the evidence is still limited to clearly identify the determinants and constraints. Nevertheless, according to our analysis, the use of modern varieties and draft animals seems to contribute to a yield increase. In this regard, firstly, it is worth devoting efforts to developing modern varieties that fit the country's rainfed agro-climatic conditions. Secondly, to tackle the lack of power, it is worth investigating further the role of draft animals and small-scale mechanization for intensification. As found in the case study of the Chokwe irrigation scheme, modern inputs such as chemical fertilizer would be important factors for yield increase even in the rainfed area if the irrigation conditions were as reliable as in the areas with modern irrigation systems (Kajisa and Payongayong 2011). We also find that a price signal is an important stimulus for intensification. The reduction of marketing margins through the development of a rice marketing system could contribute to the production increase through intensification. Investigation into the rice marketing system is beyond the scope of this paper, which we will leave for our future research.

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Table 1: Area of rice production in 2005 and agro-ecology by province

Province	Area of rice production in 2005 (000ha)	Proportion (%)	Predominant agro-ecology in major rice provinces
Niassa	5.9	2	
Cebo Delgado	38.2	14	Rainfed lowlands/Uplands
Nampula	28.1	10	Rainfed lowlands/Uplands
Zambézia	158.2	57	Rainfed lowlands
Tete	1.6	1	
Manica	3.2	1	
Sofala	24.9	9	Rainfed lowlands
Inhambane	6.0	2	Rainfed lowlands/Uplands
Gaza	11.8	4	Irrigated
Maputo	0.4	0	Rainfed lowlands
Total	278.3	100	

Source: TIA 2005 for area and proportion. Zandamela et al. (1994) referred in Agrifood Consulting International (2005) for agro-ecology.

Table 2: Summary statistics on rice farming and household characteristics in rainfed lowland areas in Zambézia and Sofala in 2008

Variable	Mean	Std. Dev.
Features of rice farming		
Paddy yield (kg/ha)	1095	1019
Paddy yield of top 25% (t/ha)	2500	1044
Land holding size – total (ha.)	1.60	1.34
Land holding size – lowland (ha.)	0.76	0.85
Proportion of rice area (%)	41	29
Share of modern variety (%)	1	10
Chemical fertilizer use (kg/ha)	0.00	
Use of other chemicals (kg/ha)	0.00	
Share of plot w/bund (%)	45	50
Share of transplanting farmers	29	45
Share of HHs using machinery for land prep. (%)	3	16
Share of HHs using animals for land prep. (%)	2	14
Household characteristics		
HH size	5.23	2.26
No. of working members	2.23	0.87
Age of HH head	39.08	12.26
Proportion of female-headed HHs	0.26	0.44
Average schooling years	2.92	1.95
Obs.	197	

Table 3: Household- and village-level characteristics by proportion of rice area

	No rice	<Median*	>Median*
Prop. of rice area (%)	0.0	18	64
HH-level characteristics			
Landholding (Lowland) (ha)	0.38	1.00	0.53
No. of working members/ha	3.54	1.42	3.94
Ave. educ. (years)	2.44	2.71	3.15
No. of tractors owned	0.00	0.00	0.00
No. of draft animals owned	0.00	0.00	0.06
Head age (years)	41.6	39.3	38.6
Female head (dummy)	0.31	0.23	0.28
No. of non-ag. income earners	0.45	0.56	0.38
Ag. training participation (dummy)	0.0	0.02	0.002
Village-level characteristics			
Rice price (milled eq.) (MT/kg)	13.4	13.4	13.3
Road access (paved) (dummy)	0.19	0.31	0.27
Road access (non-seasonal) (dummy)	0.78	0.91	0.81
Seed market access (dummy)	0.61	0.63	0.69
Fertilizer market access (dummy)	0.00	0.02	0.04
Credit access (traders) (dummy)	0.10	0.05	0.06
Draft animal rental mkt. (incl. non-rice) (dummy)	0.06	0.04	0.08
Tractor rental mkt. (incl. non-rice) (dummy)	0.29	0.12	0.20
Obs.	51	95	102

Median=33

Table 4: Estimation results of the determinants of rice area

	Dependent var.: rice cultivated area (ha.)			
	Tobit and district fixed effects		Tobit and village fixed effects	
	Linear	Quadratic	Linear	Quadratic
HH-level determinants				
Landholding (Lowland)	0.0730	0.0441	0.0324	-0.0418
	(0.0502)	(0.119)	(0.0513)	(0.117)
Lowland area size sq.		0.00963		0.0241
		(0.0319)		(0.0309)
No. of working age members	0.141***	-0.122	0.155***	-0.151
	(0.0487)	(0.138)	(0.0504)	(0.135)
No. of working age members sq.		0.0364*		0.0424**
		(0.0198)		(0.0195)
Ave. educ.	0.00868	0.0220	0.00131	-0.0244
	(0.0224)	(0.0564)	(0.0228)	(0.0571)
Ave. educ. Sq.		-0.00151		0.00431
		(0.00829)		(0.00830)
Head age	0.00237	0.0416***	0.00296	0.0524***
	(0.00314)	(0.0154)	(0.00314)	(0.0156)
Head age sq.		-0.000438**		-0.000561***
		(0.000171)		(0.000176)
Female head	-0.00771	-0.0622	0.0175	-0.0294
	(0.0916)	(0.0928)	(0.0970)	(0.0961)
Prop. of ag. training participation	-0.157	-0.701	-0.0643	-0.202
	(0.518)	(1.905)	(0.502)	(1.843)
Prop. of ag. training participation sq.		0.476		0.0627
		(2.113)		(2.045)
No. of draft animals	0.00216	-0.0151	0.0441	0.0264
	(0.0980)	(0.0960)	(0.0959)	(0.0929)
Village-level determinants				
Rice price (village mkt.)	-0.0124	0.0356		
	(0.0135)	(0.109)		
Rice price sq.		-0.00146		
		(0.00358)		
Av. proportion of non-ag. workers	0.0848	-0.653		
	(0.161)	(0.663)		
Av. proportion of non-ag. workers sq.		0.738		
		(0.622)		
Road access (paved)	-0.142	-0.187		
	(0.189)	(0.250)		
Road access (non-seasonal)	-0.110	-0.159		
	(0.146)	(0.146)		
Seed market access	0.0460	0.0580		
	(0.105)	(0.105)		
Fertilizer market access	0.729**	0.0840		
	(0.341)	(0.640)		
Credit access (trader)	-0.244	-0.254		
	(0.192)	(0.195)		
Animal rental mkt.	0.420*	0.519**		
	(0.233)	(0.233)		
Machine rental mkt.	0.106	0.134		
	(0.177)	(0.222)		
Constant	-0.146	-0.816	-0.106	-0.584
	(0.335)	(0.896)	(0.249)	(0.384)
Pesuido R squared	0.095	0.119	0.147	0.181
Observations	248	248	248	248

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
51 left-censored obs. at 0.

Table 5: Land use, rice technologies and household- and village-level characteristics by three rice yield groups

	Bottom	Middle	Top
Paddy Yield (kg/ha)	294	809	2200
Land use			
Cultivated area in the sample parcel (ha)	0.48	0.37	0.23
Full utilization of land for rice (dummy)	0.15	0.05	0.14
Modern Inputs			
Use of modern variety (dummy)			
ITA312	0.00	0.00	0.03
Use of local variety (dummy)			
Chupa	0.00	0.02	0.03
Nene	0.18	0.15	0.08
Cabo	0.14	0.09	0.14
Manda	0.03	0.02	0.06
Chemical fertilizer (kg/ha)	0.0	0.0	0.0
Use of herbicide/insecticide (%)	0.0	0.0	0.0
Improved Practice			
Plot w/bund (dummy)	0.52	0.41	0.43
Flat plot (dummy)	0.83	0.89	0.86
Transplanting (dummy)	0.27	0.32	0.28
Direct seeding month (Month-week)	Nov. 4th	Nov. 4th	Nov. 4th
Transplanting month (Month-week)	Jan. 2nd	Jan. 2nd	Jan. 2nd
No. of seedlings per hill	2.2	1.9	2.1
Power use			
Animal use for land prep. (dummy)	0.00	0.02	0.05
Tractor use for land prep. (dummy)	0.02	0.05	0.02
HH-level characteristics			
Lowland area size (ha)	0.58	0.77	0.93
No. of working age members/ha	3.8	2.2	2.3
Ave. educ. (years)	2.9	2.9	2.9
No. of tractors owned	0.0	0.0	0.0
No. of draft animals owned	0.0	0.0	0.1
Head age (years)	37.9	38.7	40.7
Female head (dummy)	0.32	0.23	0.23
No. of non-ag. income earners	0.53	0.36	0.51
Ag. training participation (dummy)	0.00	0.004	0.023
Village-level characteristics			
Rice price (milled eq.) (MT/kg)	12.4	13.0	14.7
Road access (paved) (dummy)	0.30	0.21	0.35
Road access (non seasonal) (dummy)	0.79	0.90	0.87
Seed market access (dummy)	0.55	0.70	0.75
Fertilizer market access (dummy)	0.02	0.02	0.06
Credit access (traders) (dummy)	0.06	0.06	0.05
Draft animal rental mkt. (incl. non-rice) (dummy)	0.00	0.08	0.11
Tractor rental mkt. (incl. non-rice) (dummy)	0.21	0.09	0.17
Obs.	66	66	65

Table 6: Estimation results of paddy yield function

	Dependent var.: paddy yield (kg/ha) Village Fixed Effect			
	OLS	IV	OLS	IV
Proportion of rice area [a)]	312.4	1,214		
	(294.2)	(1,037)		
Full land utilization (dummy) [a)]			415.2	1,272*
			(264.0)	(763.5)
Cultivated area [a)]	-642.3***	-1,392***	-643.2***	-1,022***
	(196.1)	(433.4)	(190.5)	(304.8)
Landholding (lowland)	84.43	196.4	79.37	145.3
	(96.30)	(144.0)	(92.25)	(97.87)
No. of working age member/ha	11.45**	3.890	10.88**	5.897
	(5.258)	(6.338)	(5.257)	(5.512)
Ave. educ.	58.47	47.04	57.95	48.64
	(41.10)	(40.80)	(40.85)	(38.60)
Head age	8.262	11.16*	8.859	11.61**
	(6.104)	(5.970)	(6.098)	(5.812)
Female head	-68.96	-83.11	-57.18	-24.80
	(181.3)	(179.1)	(180.8)	(182.2)
Ag. training participation	859.8	944.7	784.9	709.9
	(855.9)	(821.8)	(850.9)	(787.4)
No. of draft animals /ha.	125.5**	111.5**	137.8***	155.1***
	(49.83)	(48.00)	(49.93)	(49.69)
Constant	414.3	388.5	531.8	662.7
	(491.0)	(594.1)	(474.8)	(471.2)
Endogeneity test (Durbin)	4.86		4.42	
	[0.09]		[0.11]	
Endogeneity test (Wu-Hausman)	1.95		1.77	
	[0.15]		[0.17]	
First-stage F for prop. rice area or full cult.		3.09		2.33
		[0.00]		[0.03]
First-stage F for cultivated area		10.11		10.11
		[0.00]		[0.00]
Overidentification test (Sargan)		6.64		5.61
		[0.24]		[0.34]
Overidentification test (Basmann)		5.27		4.42
		[0.38]		[0.50]
Observations	197	197	197	197
R-squared	0.370	0.332	0.375	0.331

a) possible endogenous variable. Identifying IVs are the explanatory variables in the quadratic village fixed effect model in Table 4
Standard errors in parentheses; p-values in brackets
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Estimation results of paddy yield function (structural form)

	Dependent var.: paddy yield (kg/ha)		
	Village Fixed Effect		
	OLS	OLS	OLS
Proportion of rice area	101.6		
	(284.8)		
Full land utilization (dummy)		245.9	
		(265.3)	
Cultivated area	-708.5***	-721.6***	
	(185.1)	(181.0)	
Plot with bund	148.7	144.8	95.67
	(155.2)	(154.9)	(161.0)
Use of ITA 312	2,317***	2,240***	2,447***
	(721.6)	(716.3)	(731.7)
Use of Chupa	623.4	545.8	680.8
	(582.1)	(587.7)	(605.4)
Use of Nene	-249.7	-270.9	-223.2
	(236.7)	(237.4)	(246.4)
Use of Cabo	-187.2	-213.7	-60.91
	(254.4)	(255.6)	(262.6)
Use of Mamia	-92.12	-99.29	-52.51
	(284.4)	(283.4)	(295.6)
Use of Manda	641.0	662.1	920.7*
	(461.2)	(459.0)	(470.2)
Use of tractor for land preparation	-284.3	-252.1	-523.6
	(478.6)	(479.0)	(494.3)
Use of animal for land preparation	1,006*	1,020*	952.4*
	(519.9)	(518.3)	(540.8)
Transplanting (against direct seeding)	-77.21	-88.80	-111.2
	(185.2)	(184.6)	(192.4)
Constant	1,262***	1,294***	1,054***
	(177.0)	(144.1)	(135.1)
Observations	197	197	197
R-squared	0.377	0.380	0.316

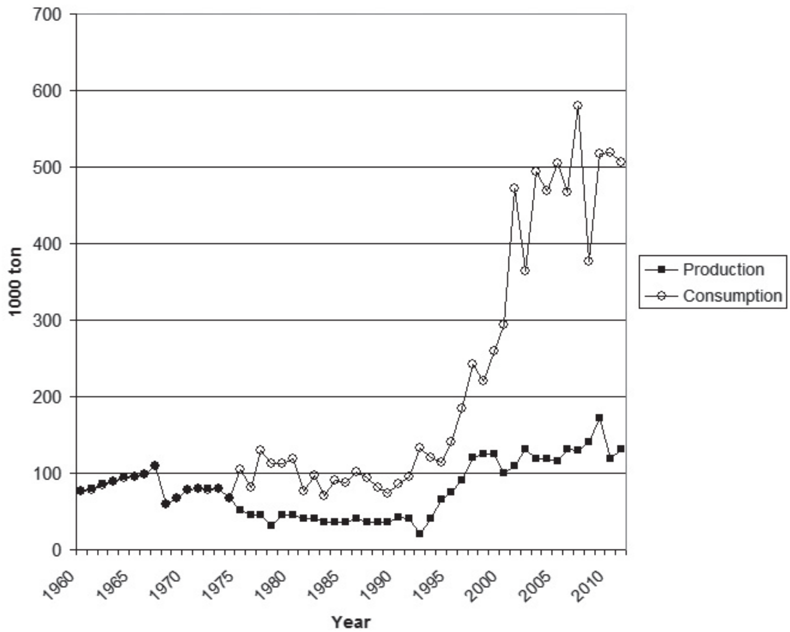
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: Estimation results of paddy yield function and technology adoption function (reduced form)

VARIABLES	Use of ITA 312 (dummy)		Use of animal (dummy)		Yield (kg/ha)	
	District Fixed Effects	Village Fixed Effects	District Fixed Effects	Village Fixed Effects	District Fixed Effects	Village Fixed Effects
HH-level variables						
Landholding (Lowland)	-0.0107	-0.0108	-0.00384	-0.00480	71.31	36.77
	(0.00952)	(0.0102)	(0.0112)	(0.0123)	(89.44)	(93.12)
No. of working age members/ha	0.000258	0.000106	-0.000350	-0.000427	17.54***	17.91***
	(0.000505)	(0.000549)	(0.000594)	(0.000662)	(4.739)	(5.006)
Ave. educ.	0.000412	-0.000198	0.00164	0.00345	33.79	62.22
	(0.00432)	(0.00461)	(0.00508)	(0.00556)	(40.57)	(42.03)
Head age	0.00147**	0.00151**	-0.000733	-0.000840	3.609	5.926
	(0.000637)	(0.000682)	(0.000750)	(0.000824)	(5.988)	(6.227)
Female head	-0.00996	-0.0273	-0.0331	-0.0484**	32.47	-20.16
	(0.0180)	(0.0202)	(0.0212)	(0.0244)	(169.2)	(184.2)
Ag. training participation	-0.0222	-0.0119	0.00463	-0.000823	717.0	876.3
	(0.0945)	(0.0962)	(0.111)	(0.116)	(888.0)	(877.4)
No. of draft animals/ha	-0.000235	0.000448	0.0404***	0.0417***	113.4**	134.4***
	(0.00545)	(0.00560)	(0.00641)	(0.00676)	(51.18)	(51.08)
Village-level variables						
Rice price (village mkt.)	6.68e-05		-0.00124		68.36***	
	(0.00272)		(0.00320)		(25.55)	
Av. proportion of non-ag. workers	-0.0178		0.0141		-275.8	
	(0.0322)		(0.0379)		(302.8)	
Road access (paved)	-0.0105		0.0158		617.6*	
	(0.0378)		(0.0444)		(354.8)	
Road access (non-seasonal)	0.00418		-0.0132		423.8	
	(0.0299)		(0.0352)		(280.8)	
Seed market access	-0.0122		0.0151		86.03	
	(0.0212)		(0.0250)		(199.4)	
Fertilizer market access	0.0306		-0.0355		253.7	
	(0.0674)		(0.0793)		(632.7)	
Credit access (trader)	0.0765*		-0.0101		-99.17	
	(0.0403)		(0.0474)		(378.2)	
Animal rental mkt.	0.00605		0.0819		245.1	
	(0.0482)		(0.0567)		(452.9)	
Machine rental mkt.	-0.0150		-0.0195		-353.2	
	(0.0360)		(0.0424)		(338.1)	
Constant	-0.0293	-0.0343	0.0627	0.0607	-805.0	401.2
	(0.0536)	(0.0339)	(0.0631)	(0.0410)	(503.5)	(309.5)
Observations	197	197	197	197	197	197
R-squared	0.099	0.168	0.369	0.387	0.227	0.327

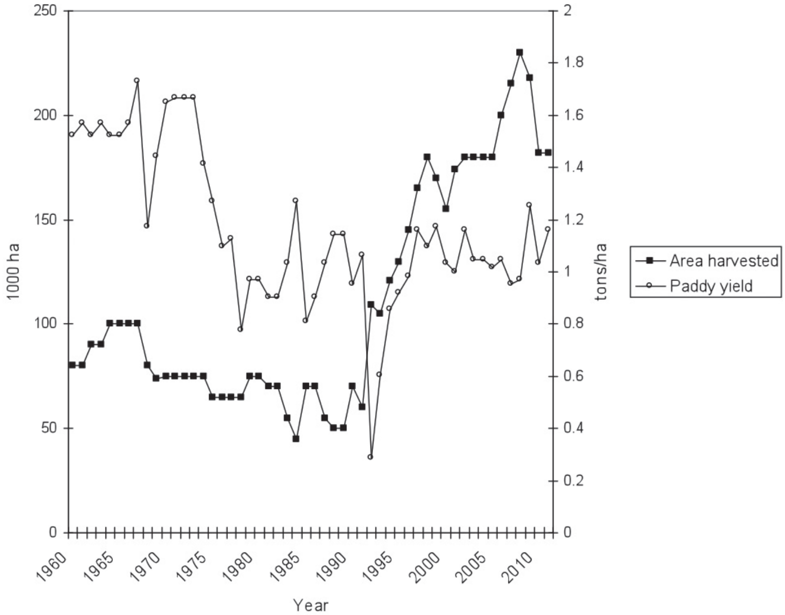
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 1: Production and consumption of rice (milled) in Mozambique from 1960 to 2011



Source: USDA PS&D Online downloaded from http://worldfood.apionet.or.jp/index-e.html.

Figure 2: Area harvested and paddy yield in Mozambique from 1960 to 2011



Source: USDA PS&D Online downloaded from http://worldfood.apionet.or.jp/index-e.html.

Figure 3: Map of survey province and districts 1960 to 2011