SAGA

Strategies and Analysis for Growth and Access

SAGA Working Paper
June 2006

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Strategies and Analysis for Growth and Access (SAGA) is a project of Cornell and Clark Atlanta Universities, funded by cooperative agreement #HFM-A-00-01-00132-00 with the United States Agency for International Development.

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Invited panel paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-18, 2006

June 2006

Acknowledgements: We thank Luc Christiaensen, Christine Moser, Lalaina Randrianarison and Eliane Ralison for useful discussions. This work has been made possible by support from the World Bank and from the United States Agency for International Development (USAID), through grant LAG-A-00-96-90016-00 to the BASIS CRSP, the Strategies and Analyses for Growth and Access (SAGA) cooperative agreement, number HFM-A-00-01-00132-00. The views expressed here and any remaining errors are the authors' and do not represent any official agency.

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Abstract

This study explores the constraints on agricultural productivity and priorities in boosting productivity in rice, the main staple in Madagascar, using a range of different data sets and analytical methods, integrating qualitative assessments by farmers and quantitative evidence from panel data production function analysis and willingness-to-pay estimates for chemical fertilizer. Nationwide, farmers seek primarily labor productivity enhancing interventions, e.g., improved access to agricultural equipment, cattle and irrigation. Shock mitigation measures, land productivity increasing technologies and improved land tenure are reported to be much less important. Poorer farmers have significantly lower rice yields than richer farmers, as well as significantly less land. Estimated productivity gains are greatest for the poorest with respect to adoption of climatic shock mitigation measures and chemical fertilizer. However, fertilizer use on rice appears only marginally profitable and highly variable across years. Research and interventions aimed at reducing costs and price volatility within the fertilizer supply chain might help at least the more accessible regions to more readily adopt chemical fertilizer.

JEL Subject Codes: O1, O3, Q12

1. Introduction

Recent research suggests that improvement in the productivity of staple food crops, especially rice, offers a key lever for alleviating rural - as well as urban - poverty in Madagascar (Minten and Barrett, 2006). The crucial question remains how best to advance that objective. This study explores the constraints on agricultural productivity and priorities in boosting productivity in rice, the main staple in Madagascar, using a range of different data sets and analytical methods. We pay particular attention to differences across regions and the income distribution, and we focus especially on exploring why chemical fertilizer uptake rates appear so low.

The structure of the paper is as follows. Section 2 discusses the data and descriptive statistics. In section 3, we discuss farmers' self-reported constraints that limit agricultural and rice productivity. This qualitative analysis provides preliminary results we then corroborate in section 4 using plot-level panel data to estimate the marginal rice productivity and yield elasticities with respect to the primary inputs in Malagasy rice systems, as well as a key indicator of the type of rice production method employed and climatic shocks suffered. Then, in section 5, we look in more detail at chemical fertilizer use, a crucial driver for increased productivity in other rice economies and an input for which the marginal gains to the poor are substantially greater than to the rich. Section 6 briefly concludes.

2. Data and descriptive statistics

We use several different types of data. First, in section 3, we exploit data from three nationally representative surveys: the 2001 and 2004 household surveys (the

Enquête Permanente auprès des Ménages, or EPM) and the 2004 commune survey, fielded at the most local level of government administration in the country. Each of these three surveys includes qualitative assessments of constraints to agricultural and rice productivity.

Those productivity constraint questions from the nationally representative surveys are quite comparable to similarly worded ones in more detailed household surveys fielded in 2002 and 2003 by the USAID BASIS CRSP project of Cornell University. Both surveys were run three to four months after the main rice harvest in two different highlands regions: the Vakinankaratra region of Antananarivo province and the rural communes surrounding the city of Fianarantsoa in the eponymous province. Farmers in both areas have a long experience in rainfed and irrigated rice production. The 2002 data were gathered through a comprehensive survey collecting information at the plot and household level. The same farmers were visited in 2003 using a very similar questionnaire to facilitate analysis of interannual household- and plot-level dynamics. Comparison with the nationally representative survey data allows us to triangulate in order to check the robustness of our results across different surveys, methodologies and samples. The BASIS data also allow us to tie the analysis of productivity constraints to quantitative estimation of production functions and of willingness-to-pay for chemical fertilizers, in sections 4 and 5, respectively, as those data are only available in the BASIS survey modules.

The depth and breadth of rural poverty in Madagascar is starkly reflected in the BASIS data. Our welfare indicator is 2002 per capita household income, computed as the sum of the consumption and sales of agricultural commodities and livestock and non-agricultural and wage income. 2002 average annual per capita incomes vary significantly across the income distribution (Table 1), from almost 30,000 Ariary (equivalent to $25 US) for the poorest quintile to a bit more than ten times as much for the richest quintile (quintile 5). This difference is driven by both relatively and absolutely more off-farm income – off-farm income represents 54% of the richest quintile versus 30% for the poorest quintile – as well as agricultural income that is almost eight times higher for the richest quintile. Off-farm earnings are strongly related to educational attainment and proximity to town-based employment. Rice production overwhelmingly dominates all other land uses and sources of agricultural income across the income distribution. Hence the importance of studying rice productivity as a central feature of improving rural livelihoods in Madagascar.

Per capita paddy rice production corresponds to only one third (2002) to one half (2003) of the national average consumption of 110 kg of white rice (170 kg of paddy) per capita per year among the lowest income quintile. These poorest households typically complement own rice production with purchases, especially during the pre-harvest lean season. The two richest quintiles produce more than average consumption and most of the households in these categories are likely net sellers of rice. However, market participation is not sufficient to smooth consumption over the year and this especially so for the poorest households as the self-reported length of the lean period drops significantly from the poorest to the richest quintile, from almost six months to less than four months.

These descriptive statistics signal how closely food security, income and rice production are linked in the rural highlands of Madagascar and thus the importance of rice productivity to household welfare in these villages. Differences in agricultural income across the income distribution arise both due to greater productivity among the richer households as well as larger cultivated land area. The poorest households' average rice yields are 22% to 35% lower than the richest quintile in 2002 and 2003, respectively, while they cultivate roughly half as much land (and land in rice). Variation in other inputs is similarly pronounced, with the ratio of agricultural equipment owned by the richest to poorest quintile equal to roughly 10, and livestock holdings 60-70% higher among the richest quintile. Partly this reflects substitution between labor – used more intensively on poorer farms' plots – and capital. But it likely also reflects binding constraints that limit access to critical agricultural inputs, as we explore further.

As to have a better sense of our yield data, we first look descriptively at paddy yields dynamics over the two years (Table 2). We divided the plots in high and low yielding plots for the two years, depending if yields were below or above 2,5 tons per hectare, about the national average (Faostat). About three quarters of the plots stayed in the same category in the two years: 22% in the low productivity category and 52% in the high productivity category. One quarter of plots changed categories: 13% of the plots moved from low to high productivity and 12% vice-versa. We thus note quite some variation over such a short-time period.

3. Qualitative analysis on constraints to increased productivity

The 2001 national household survey asked farmers about the biggest constraints they faced to improved agricultural productivity. The same question was asked in the 2004 national household survey, based on a different sampling frame and with a bigger sample.

Respondents had to rank options from ‘not important’ to ‘very important’. The results are presented in Table 3 ordered in decreasing percentage of households that identified the constraint as ‘quite’ or ‘very’ important.

Answers were strikingly consistent between the two surveys, three years apart and with a different sample. The most and least frequently cited constraints were common to both surveys. Access to agricultural equipment, access to cattle for traction and transport and access to labor are ranked among the top four constraints in both surveys. Access to land was the second most cited constraint in the 2001 EPM but omitted from the 2004 version, while access to irrigation was second most cited in the 2004 EPM but lacked a direct analog in the 2001 national household survey. The clear pattern in these answers is that inputs that complement labor and boost its productivity are most limiting in farmers' opinion.

The second most important set of constraints in the 2004 EPM relates to shocks associated with plant disease, drought and flooding. More than half of all households report these constraints to be ‘quite’ or ‘very important’. By contrast, less than 40 percent of households identify land tenure insecurity or the siltation of land as important constraints and these are more commonly identified as not a constraint on agricultural productivity. While secure property rights are in general an important determinant for soil investment and thus higher productivity (Feder and Feeny, 1991), tenurial security does not appear to farmers to be a serious impediment to agricultural productivity in rural Madagascar, a finding consistent with results elsewhere in sub-Saharan Africa (Migot-Adholla et al., 1991) and with recent quantitative analysis in Madagascar (Jacoby and

Minten, 2006). This contrasts with renewed emphasis on land titling by the government and some international donors in Madagascar.

The same qualitative questions were used as to get at the constraints for increased rice production more specifically. In the 2003 BASIS household survey, one randomly selected rice plot was chosen for each household and respondents were asked to identify the main constraint to increased rice productivity on that particular plot and to rank twelve different potential constraints. The commune survey of 2004 asked focus group in each of the 300 communes the same question and to do the same ranking.

As reported in the top panel of Table 4, the commune survey rankings are broadly consistent with the results of the EPM national household surveys. The biggest constraints were, again, labor productivity boosting factors: access to better irrigation, agricultural equipment, and livestock to work the land. Second came shock mitigation, concerning plant disease and flooding, especially. The least widespread constraints concerned land tenure security and silting of land.

The BASIS survey responses by rice growing households in the densely populated highlands differ noticeably from the nationally representative commune and household survey results. In this setting, land intensification technologies play a far more prominent role as a limiting constraint on rice productivity than at the national level. Access to cattle for manure is ranked first and access to agricultural inputs such as fertilizer is ranked fourth, where both of these fell at or below the median rank in the nationally representative surveys. These indicators of demand for land intensification technologies are ranked higher than access to labor, agricultural equipment or cattle for working the land. Climatic shocks are also considered less important in the highlands of

Madagascar, presumably because these areas are less frequently and severely hit by cyclones than coastal areas. However, when we look only at the EPM data for households from Antananarivo province (the highland region in which most of the BASIS respondents live), the same pattern emerges: access to cattle for manure and to inputs become the top constraints. This underscores the spatial heterogeneity of constraints to improved agricultural productivity, as perceived and reported by farmers, consistent with the Boserupian hypothesis that land intensification is most in demand where population densities are greatest.

4. Production function analysis

Farmers' self-reported productivity constraints are informative, but only up to a point. We supplement those findings with rice production function analysis based on the plot-level BASIS survey panel data. Using a generalized quadratic functional form to allow for a second-order approximation to the true underlying production function and controlling for fixed effects[1], we estimate the expected marginal physical productivity of each factor, computed at the mean value for each other input in each quintile of the 2002 income distribution. This enables us to explore the possibility of heterogeneity in marginal response across the income distribution, providing some insight as to how constraints on productivity vary between poorer and richer farmers.

Table 5 summarizes the elasticity and marginal productivity estimates. The results show that rice productivity is relatively sensitive to labor availability, with an average

[1] A test of the null hypothesis that labor use is exogenous to output is not rejected. Labor use was instrumented by family size and family composition, households' agricultural assets (e.g., plows and ox carts), access to draught oxen, and participation in non-agricultural or off-farm employment activities. A Hausman test favors a fixed effects specification over a random effects model.

elasticity of 0.35. One additional hour of work would result in an increase of 0.65 to 1.06 kg of rice yield depending on the income quintile. Evaluated at the average paddy price in 2002, this physical marginal return corresponds to a marginal value product of 1,040 Ariary[2] for the poorest households, about 25% lower than the prevailing wage rate at the site of the surveys, and to 1,700 Ariary for the wealthier households, almost 20% higher than the average agricultural wage rate.[3]

Total landholdings and the value of agricultural equipment did not have a statistically significant impact on rice productivity, on average. The estimated elasticities with respect to agricultural equipment are consistently low across the income distribution, in contrast to farmers' self-reported constraints to productivity growth. But the effect of increased cultivated area on yield exhibits an interesting pattern as one moves from poorer to richer households. The long-observed inverse farm size-yield relation (Benjamin, 1995; Barrett, 1996; Lamb, 2003) appears to hold only for the poorest farmers, while for richer farmers, yield is increasing in cultivated area, likely reflecting that among the rich there are both small, part-time farmers who are relatively unproductive as they depend primarily on off-farm earnings and larger, full-time farmers who are relatively productive (Barrett et al., 2005).

We find positive effects of improved rice production technology on yields. We use the age of the rice plant at transplanting as a proxy for use of improved production

[2] These marginal value products were computed based on 8 hours of work per day and a price of paddy rice of 200 Ariary per kg.

[3] By its direct effect of draft power for plowing and transportation and its indirect effect for manure supply, an extra cattle increases expected rice yields by an average of 0.9 kg per are, for an estimated yield elasticity of 0.06. Richer households enjoy a 40% higher expected return than do poorer households. While the richer households might have more cattle in absolute numbers, livestock density per hectare is actually lower on richer farms (Table 1), potentially explaining the larger returns per unit land in the highest income quintile. However, the estimated coefficients are not significant at conventional statistical levels.

methods; for example, transplanting seedlings at 7-14 days old is a central part of the promising System of Rice Intensification (SRI) package of techniques.[4] The effect of adopting improved rice production methods is greatest for the poorest two income quintiles.

Rice production appears quite sensitive to climatic shocks. The estimation results indicate that expected yields decrease by 34% and 10% for the poorest and the richest household, respectively, when struck by flooding or drought. The adverse effect of a climatic shock on the poorest (second poorest) income quintile is roughly three (two) times greater than on the richest quintile. While the poor and rich farmers suffer shocks with equal frequency (Table 1), poorer farmers appear more vulnerable to climatic shocks, likely due to less shock mitigation capacity due to their limited ability to invest in risk avoidance measures (e.g., pumps or irrigation), in hiring labor to replace flooded plants, etc.

Finally, estimated yield elasticities with respect to chemical fertilizer are statistically significant and nearly 30% greater for the poorest quintile than for the richest quintile. This suggests that the effective cost of fertilizer is higher for the poor than for the rich, whether due to liquidity constraints, volume discounts, or other factors. We return to an analysis of chemical fertilizer use and demand in section 5.

[4] SRI uses no purchased inputs but relies on a suite of agronomic adjustments: very early transplanting and wide spacing of seedlings, frequent weeding, and controlling the water level to allow for the aeration of the roots during the growth period of the plant, i.e., no standing water on the rice field (Moser and Barrett, 2003; Barrett et al., 2004).

5. Mineral fertilizer use patterns and willingness to pay

The June 2006 Africa Fertilizer Summit of African heads of state, held in Abuja, Nigeria, underscores the importance currently placed on stimulating fertilizer uptake as a central plank of agricultural development strategies in sub-Saharan Africa. This is as true in Madagascar as in the rest of the sub-continent. In this section, we therefore look more closely at mineral fertilizer input use patterns, average and estimated marginal productivity effects, and willingness-to-pay estimates based on our survey data.

Mineral fertilizer use is uniformly low in rural Madagascar, with only about 30 percent of the BASIS farmers applying any fertilizer and average application rates among users amounting to only 0.40 kg per are in 2002, and 0.21 kg per are in 2003. These rates fall far below the average for other low-income rice producing countries such as Vietnam, Nigeria or Mali. A simple unconditional comparison of plots that received mineral fertilizer and those that did not reveals a 20% difference in average rice yields – an increase of 4.5 kg/are – suggesting substantial gains to mineral fertilizer application. The production function estimation results from the previous section imply a marginal output of 4.1 kg/are,[5] with poorer farmers exhibiting a statistically significantly higher estimated marginal return from chemical fertilizer than do richer farmers (Table 4).

So why is fertilizer use so low, especially among the poor who stand to benefit most from increased fertilizer application in Malagasy rice systems? The most likely explanation is the excessive cost of fertilizer. The chemical fertilizer (NPK) to paddy price ratio in Lac Alaotra region, the rice basket of Madagascar – for which we have data available and where input and output prices are typically quite similar to the highlands –.

[5] These estimates are consistent with previous work in this area (e.g., Bernier and Dorosh, 1993). The slightly greater estimated marginal effect, relative to average yield effect, reflects the highly skewed nature of the fertilizer application data.

varies considerably across years, between 2.6 and 7.0 from 2000-2004 (Figure 1), the high point occurring during the presidential crisis when the country teetered on the brink of civil war. Using the estimated marginal return of 4.1 kg paddy per kg of fertilizer (Table 4), the ratio of the value of marginal output over the cost of fertilizer varied between 1.6 (in 2000) and 0.6 (in 2002). So fertilizer use on rice appears profitable on average.

However, given the greater likelihood of flooding and droughts on rice fields, households may consider the risk of fertilizer application too high on these fields. In an overview of fertilizer incentives facing African farmers, Yanggen et al. (2002) argue that the ratio of the value of marginal output over fertilizer cost must be at least 2, preferably 3, in order to be attractive to small farmers, given risk, seasonal credit constraints, and other factors limiting uptake and effective profitability. Tellingly, we estimate this ratio to never have reached 2 in these five years. This suggest that highlands and Lac Alaotra rice farmers find chemical fertilizer only marginally profitable, which may explain the limited uptake in rural Madagascar.

These ratios contrast sharply with similar estimates from other rice producing countries, especially in Asia. For example, the ratio of urea over paddy prices in 2001 (based on the data of Faostat) was below 2 in India and Pakistan, less than half the level observed in Madagascar at that time. This difference in ratios explains to a large extent why Malagasy farmers less frequently use fertilizers – and apply less fertilizer when they use any – than do their counterparts in other rice economies. The favorable ratio in Asian countries is due in large measure to the much lower prices of fertilizer, which is often locally produced and/or subsidized.[6] Moreover, yield responses vary, often depending on varieties and soil types, and appear to be much higher in Asia too.

We further investigate the demand for chemical fertilizer via willingness-to-pay analysis. In the 2003 BASIS survey, households were asked about their current use and perceived benefits of chemical fertilizer.[7] Then farmers were offered the opportunity to accept, refuse or remain undecided about fertilizer purchase at one of 8 randomly assigned prices, following the dichotomous choice format popularized in environmental economics (Mitchell and Carson, 1989). As is standard in the literature, uncertainty/indecision was included as a refusal in our analysis.

As shown in Figure 2, willingness to pay for fertilizer appears quite responsive to price beyond an atypically low range. For example, a price increase from 400 to 700 Ariary per kg would reduce the estimated percentage of households willing to buy fertilizer from 83% to 30%. Using the results of a parsimonious model where the acceptance dummy was regressed on an intercept and the logarithm of the price, median willingness to pay is estimated at about 575 Ariary per kg or roughly 0.50$/kg, the mean price observed in the highlands. Yet only 30% of farmers actually use fertilizers, reflecting some combination of hypothetical bias and spatial variation in prices, since fertilizer prices are lowest in the highlands and Lac Alaotra regions typically.

[6] For example, retail fertilizer prices (e.g, urea) in India ($0.21/kg) and Pakistan ($0.29/kg) are significantly lower than the prices in rural areas of Madagascar's highlands ($0.50/kg) (Prices for India and Pakistan are out of the Faostat database for the year 2002).

[7] Only two-thirds of the households thought that the use of chemical fertilizer was beneficial on rice fields. This might underscore the need for extension to communicate more clearly and broadly how to use chemical fertilizer to improve rice output.

Interestingly, these willingness-to-pay answers suggest that almost all Malagasy farmers would use chemical fertilizers if prices were similar to those in Asian rice economies.[8]

While unfavorable price ratios might explain partly the low chemical fertilizer use, other factors likely play a role as well. Given the deficient or non-existent extension system,[9] farmers are often not aware of the recommended quantity, timing or mode of utilization of chemical fertilizer, and therefore opt not to risk fertilizer use. The local varieties that are widely used in Madagascar are also more sensitive to the disease pyriculariose when they are used in combination with fertilizer than in the absence of chemical fertilizer application (Andriatsimialona, 2004). Unless fertilizer is used together with improved varieties, pay-offs might thus be too low to attract farmer interest.

6. Conclusions

Improvement in staple crop, especially rice, productivity appears a powerful way to alleviate rural - as well as urban - poverty in Madagascar (Minten and Barrett, 2006). In this paper, we study constraints on increased productivity and variation in marginal input productivity and yield elasticities across the rural income distribution. Integrating qualitative assessments by farmers and quantitative evidence from panel data production function analysis and willingness-to-pay estimates for chemical fertilizer, we find several consistent patterns. Nationwide, farmers seek primarily labor productivity enhancing

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[8] We also estimated a more comprehensive model that included the bid level, household characteristics, proxies for shocks over the last ten years, beliefs about fertilizer use and constraints on rice productivity, and village dummies. The results illustrate the internal consistency in household responses. Farmers who believe that fertilizer are beneficial for rice production, are more likely to accept the fertilizer purchase bid. Few other variables are significant. The more the household is involved in off-season cash crops, the more likely it will accept the bid, probably as profitability on these crops is typically higher than on rice. Older heads of households are less likely to accept. No other variables proved statistically significant. Results of this regression are available from the authors by request.

[9] In the 2004 national household surveys, it was estimated that about 7% of the farmers had contact with an extension agent prior to the year of the survey.

interventions, e.g., improved access to agricultural equipment, cattle and irrigation. Shock mitigation measures, land productivity increasing technologies and improved land tenure are reported to be much less important. These priorities vary by region, however. Farmers in the more densely populated highlands rate access to manure and other land-intensifying agricultural inputs, such as chemical fertilizer and improved irrigation highest in terms of expected rice productivity improvements. These results are consistent with the induced innovation theory (Hayami and Ruttan, 1985) and caution against a ‘one size fits all’ approach to agricultural development policy for the country as a whole.

Poorer farmers have significantly lower rice yields than richer farmers, as well as significantly less land. Estimated productivity gains are greatest for the poorest with respect to adoption of improved rice production practices, climatic shock mitigation measures and chemical fertilizer. However, fertilizer use on rice appears only marginally profitable and highly variable across years. Our willingness-to-pay estimates suggest that fertilizer demand is highly price sensitive, suggesting that low fertilizer uptake in rural Madagascar largely reflects prices beyond the reach of most farmers, especially poorer ones. If fertilizer prices were at the levels seen in Asian economies – less than 50% of the price in Madagacar – our estimates suggest that a significantly higher number of farmers would purchase and apply chemical fertilizer. It thus seems that research and interventions aimed at reducing costs and price volatility within the fertilizer supply chain might help at least the more accessible regions to more readily adopt chemical fertilizer. Fertilizer use, shock mitigation and relieving binding labor constraints faced by Malagasy farmers appear the key elements of a strategy to increase rice productivity, food security and incomes in rural Madagascar.

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Table 1: Farm characteristics by income level

			Per capita income quintile in 2002											
			Quintile 1		Quintile 2		Quintile 3		Quintile 4		Quintile 5		Overall	
			Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.
Income - welfare measures														
Per capita annual income	ariary	2002	28,680	10,001	54,695	6,428	86,552	10,610	128,144	19,722	334,275	306,853	116,724	165,111
Per capita agri. income	ariary	2002	20,212	9,758	36,199	14,079	54,984	22,561	77,234	31,373	155,645	96,184	64,337	63,609
Length of lean season	month	2002	5.95	2.52	5.42	2.50	5.66	2.40	4.58	2.76	3.88	2.86	5.18	2.69
Paddy rice production														
Production per capita	kg	2002	61	39	92	54	142	99	196	113	375	397	163	209
		2003	83	50	108	71	141	115	190	111	352	306	166	176
Average yield	kg/are	2002	21.3	16.9	26.7	17.3	23.5	16.6	29.6	18.5	28.9	21.9	26.4	18.9
		2003	25.8	18.4	26.8	16.4	23.9	17.2	28.2	17.9	31.4	19.8	27.5	18.3
Total cultivated rice area	ares	2002	39.46	27.97	37.35	37.15	50.83	43.47	59.10	62.13	72.26	75.38	48.20	52.29
		2003	31.13	31.48	38.74	39.83	50.44	42.90	59.45	61.92	72.07	75.62	48.83	52.87
Production factors and shifters														
Total agricultural land area	ares	2002	76.49	80.95	82.50	79.99	135.18	107.53	160.28	156.97	161.76	143.92	119.68	119.31
		2003	79.02	82.82	83.93	72.74	134.03	106.58	160.62	156.90	161.57	142.43	120.37	119.01
Value of agr. equipment	ariary	2002	8,568	27,054	47,916	109,001	27,761	67,720	58,760	108,427	85,990	125,487	42,896	94,556
		2003	11,258	32,566	49,301	108,864	29,132	69,100	59,957	109,567	86,943	126,625	44,484	95,479
Number of cattle & cows	no	2002	1.78	2.13	2.09	2.42	1.54	1.95	2.33	2.34	2.98	3.46	2.10	2.50
		2003	1.64	2.17	2.31	3.46	1.53	1.74	2.17	2.32	2.90	2.93	2.07	2.60
Total labor use	hours/ar	2002	23.4	12.4	17.7	10.2	15.5	9.6	15.5	10.1	13.7	9.7	17.2	10.9
		2003	19.0	11.9	15.5	8.9	13.5	9.1	14.8	10.1	11.6	7.1	14.9	9.9
Age of transplanted plants	days	2002	49.25	17.82	49.02	16.92	48.40	14.95	44.20	16.32	38.26	16.55	45.85	17.02
		2003	44.92	14.13	13.93	12.22	42.63	10.51	40.82	12.63	42.02	13.34	42.87	12.68
Mineral fertilizer users	1=user	2002	0.24	0.42	0.36	0.48	0.32	0.47	0.25	0.43	0.28	0.45	0.29	0.46
		2003	0.23	0.42	0.36	0.48	0.22	0.42	0.25	0.44	0.41	0.49	0.30	0.46
Mineral fertilizer use	kg/are	2002	0.86	4.36	0.51	1.52	0.09	0.21	0.11	0.33	0.44	1.54	0.40	2.20
(for users only)		2003	0.16	0.73	0.16	0.35	0.09	0.30	0.18	0.70	0.48	1.24	0.21	0.76
Drought	1=yes	2002	0.14	0.35	0.15	0.36	0.18	0.39	0.14	0.35	0.12	0.33	0.15	0.35
		2003	0.15	0.36	0.13	0.33	0.13	0.34	0.12	0.33	0.11	0.31	0.13	0.33
Flooding	1=yes	2002	0.13	0.33	0.13	0.33	0.11	0.32	0.07	0.26	0.10	0.30	0.11	0.31
		2003	0.07	0.25	0.07	0.26	0.07	0.26	0.07	0.26	0.11	0.31	0.08	0.27

Table 2: Yield transition matrix

			Yield in 2003*		Overall
			Low	High	
Yield in 2002*	Low	Number of observations	166	95	261
		% of observations	22%	13%	35%
		Average yield in 2002	14.7	14.8	14.8
		Average yield in 2003	14.5	39.4	19.5
	High	Number of observations	92	389	481
		% of observations	12%	52%	65%
		Average yield in 2002	35.9	46.7	43.9
		Average yield in 2003	17.7	46.2	37.5
Overall		Number of observations	258	484	742
		% of observations	35%	65%	100%
		Average yield in 2002	18.6	36.1	26.3
		Average yield in 2003	15.3	44.5	27.6

* Low yields: less than 2,5 tons/ha; high yields: equal to or more than 2,5 tons/ha

Table 3: Farm households' reported constraints on improved agricultural productivity

	Percentage of households that state this constraint is … important			
Variables	not	a bit	quite	very
Constraints to overall agricultural productivity				
EPM 2001, 2470 agricultural households				
Access to agricultural equipment	19	18	27	35
Access to land	27	19	29	25
Access to cattle for traction and transport	24	23	29	24
Access to labor	22	28	30	20
Access to credit	36	19	23	22
Degradation of irrigation infrastructure due to environmental problems	29	31	22	18
Access to agricultural inputs (e.g. fertilizer)	34	26	19	21
Access to cattle for fertilizer	42	23	19	16
Land tenure insecurity	44	26	22	8
Silting of land	46	29	18	7
EPM 2004, 3543 agricultural households				
Access to agricultural equipment	11	14	32	43
Access to irrigation	13	21	29	37
Access to cattle for traction and transport	16	20	35	29
Access to labor	17	22	37	24
Avoid droughts	20	19	27	34
Access to agricultural inputs (e.g. fertilizer)	24	20	26	30
Phyto-sanitary diseases	19	25	30	26
Avoid flooding	25	20	26	29
Access to cattle for fertilizer	28	22	25	25
Access to credit	31	23	22	24
Silting of land	33	29	23	15
Land tenure insecurity	38	24	23	15

Table 4: Farm households' reported constraints on improved rice productivity

Variables	Percentage of households that state this constraint is … important			
	not	a bit	quite	very
Constraints to rice productivity				
Commune survey 2004, 290 communal focus groups				
Access to better irrigation systems	3	12	27	58
Access to agricultural equipment	4	19	27	50
Access to livestock for traction and transport	8	22	27	43
Access to credit	16	24	23	37
Avoid losses due to plant diseases	11	31	24	34
Avoid floods	16	26	22	36
Access to improved seeds	13	29	21	37
Access to labor	17	27	26	30
Access to chemical fertilizer	29	29	20	22
Access to livestock for manure	26	32	20	22
Avoid silting	22	36	21	21
Avoid droughts	48	15	12	25
Land tenure	27	37	23	13
Basis Crsp survey, 2003, 316 agricultural household in highlands				
Access to cattle for manure	5	6	13	76
Access to better irrigation	5	14	20	61
Access to credit	11	8	37	44
Access to agricultural inputs (e.g., fertilizer)	4	17	35	44
Access to labor	10	15	40	35
Access to agricultural equipment	20	15	26	39
Access to cattle for transaction and transport	28	11	25	36
Avoid losses due to plant diseases	19	23	42	16
Avoid droughts	22	23	27	28
Avoid floods	24	37	25	14
Insecure property rights	59	11	14	16
Avoid silt	34	38	21	7

Table 5: Plot-level panel data estimates of marginal returns to rice production inputs

		Per capita income quintile in 2002						F-test
		Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	Overall	p-value
Total cultivated area	Additional kg of paddy per are	0.02	0.03	0.04	0.05	0.07	0.04	
	Doubling area: Yield increases by	*3.8%*	*6.8%*	*14.2%*	*21.8%*	*34.7%*	*16.2%*	
Labor	kg of paddy per hour	0.65	0.84	0.85	0.89	1.06	0.86	***
	Doubling labor: Yield increases by	*36.4%*	*36.9%*	*34.5%*	*34.8%*	*31.8%*	*34.9%*	
Value of agr. equipment	Kg of paddy per hour	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	
	Doubling ag. equipement: Yield increases by	*-0.2%*	*-1.4%*	*-1.4%*	*-1.9%*	*-2.7%*	*-1.5%*	
Number of cattle	kg of paddy per unit of cattle	0.75	0.72	0.79	1.01	1.16	0.89	
	Doubling number of cattle: Yield increases by	*3.8%*	*5.5%*	*3.8%*	*6.0%*	*10.4%*	*5.9%*	
Chemical fertilizer	Kg of paddy per kg of fertilizer	4.23	4.12	4.31	4.29	3.74	4.14	***
	Doubling fertilizer use: Yield increase by	*5.1%*	*3.7%*	*1.0%*	*1.6%*	*4.0%*	*3.2%*	
Age of plants (technology)	kg of paddy per day	-0.02	-0.03	0.00	0.00	0.03	0.00	**
	Doubling age: Yield decrease	*-2.5%*	*-4.0%*	*-0.3%*	*0.1%*	*2.9%*	*-0.7%*	
Climatic shocks	Yield changes in kg/are if shocks	-12.94	-8.66	-5.99	-5.2	-4.27	-7.43	***
	% change on yield if shocks	*-34.4%*	*-23.0%*	*-16.8%*	*-13.4%*	*-10.1%*	*-19.6%*	

F-test is used to check the significance for each variable. If tests jointly, at least one of the coefficient estimates differs from zero; ***, * indicate significance level at the 1% and 10% level

Source: BASIS CRSP 2002, 2003 surveys

Figure 1: Cost - benefit ratios for chemical fertilizer and paddy

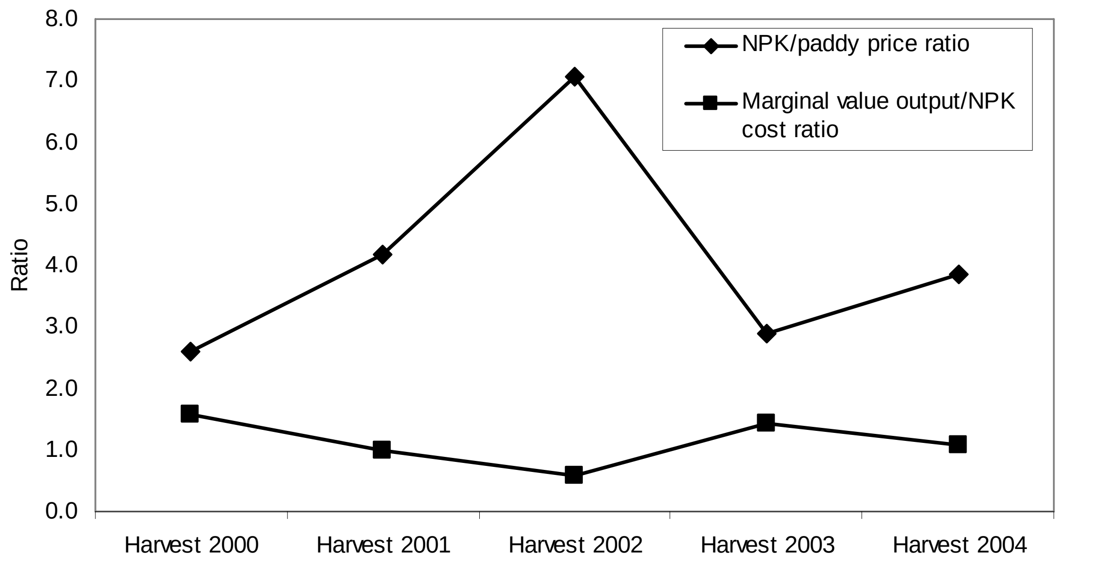

Figure 2: Demand for chemical fertilizer by price level