Cost reduction in rice production: an approach at the farm level in Brazil

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Technology generation and the adoption of preferred production practices are not ends in themselves. Rather, the ultimate goal is unit cost reduction or an increase in total factor productivity to enhance community welfare.

Agricultural progress in Brazil has resulted from high investment in technological change. Agriculture serves many purposes in the Brazilian economy, including production of food and energetics for import substitution (Homem de Melo, 1983).

Recent studies on technology implementation and adoption and investment in agricultural research have shown that new technologies such as those for both irrigated (Avila, 1981; Irias *et al.*, 1989) and upland rice (Texeira, Yokoyama and Seguy, 1989) and soybeans (Ayres, 1985) and wheat (Ambrosi and da Cruz, 1986) have not only influenced the growing pattern of agricultural production but also resulted in high rates of return to the Brazilian economy.

The problems that persist within different sectors of the economy – rural versus urban, commercial versus traditional agriculture, rich and poor among social classes and regions, formal versus informal economic activities together with commercial agriculture, greater agro-industrial demand, higher concentrations of consumers in large cities and low labour concentration per area in the rural sector – reinforce the need for technological improvements, mainly in the area of food crops. This is particularly evident in the case of rice, an important food for both rich and poor, as well as a commercial, mechanized crop with high agro-industrial potential.

The impact of new technological practices on these problems, the distribution of benefits from investment in agricultural research and the extent to which technological improvements lessen inequalities must all be accounted for.

Socio-economic research on rice and beans at EMBRAPA (Brazilian Agricultural Research Enterprise)/CNPAF (National Research Centre for Rice and Beans) aims to supplement agricultural research with information on general aspects of production, consumption characteristics of different groups of farmers and the impact of technology on the society. It is recognized that newly developed upland rice varieties, alternative production systems incorporating soil management techniques, crop rotation practices and appropriate soybean and maize varieties have great potential to promote more sustainable production systems, including those for rice.

The impact of technology on household socio-economic conditions and socio-economic characterization must be assessed to understand how beneficiaries may be affected. Analysis of cost and of the gains in productivity resulting from technology adoption are usually undertaken. On-farm research provides information on technology adoption rates and important socio-economic factors. Follow-up studies analysing cost structures and the impact of specific technologies on income over a given period of time must be implemented.

In this study an attempt is made to describe general socio-economic characteristics and determinants of production and yields, technology adoption and factors affecting cost structures at the farm level.

THE DATA

Two sets of on-farm data were collected. The first sample was chosen to account for size of production (small farms with less than 9 ha of planted rice and large farms with more), production systems (irrigated versus upland and swampland) and tenancy (landowner and otherwise) (Table 1). It includes rice farms in the states of Minas Gerais (136 cases), Maranhão (14 cases) and São Paulo (seven cases). Other variables were included for stratification, such as the planting procedure (manual or mechanized) and planting systems, usually characterized as direct fallow or seedlings for irrigated areas.

TABLE 1 **Sample distribution of rice farmers by size, production system and tenure**

State	Large (area >9 ha)						Small (area <9 ha)						Total					
	IR		SW		UP		IR		SW		UP		IR		SW		UP	
	L	NL	L	NL	L	NL	L	NL	L	NL	L	NL	L	NL	L	NL	L	NL
SP	1	-	-	-	1	1	-	-	1	-	3	-	1	-	1	-	4	1
GO*	-	-	-	-	7	1	-	-	-	-	-	-	-	-	-	-	7	1
MT	-	-	-	-	44	4	-	-	-	-	-	-	-	-	-	-	44	4
MS	-	-	-	-	22	3	-	-	-	-	-	-	-	-	-	-	22	3
MA	2	-	-	-	2	-	-	-	-	-	4	6	2	-	-	-	6	6
MG	26	2	10	1	40	1	36	11	45	5	-	-	62	13	55	6	40	1
Total	29	2	10	1	116	10	36	11	46	5	7	6	65	13	56	6	123	16

IR - irrigated; - swamps; UP - upland; L - landowner; NL - not landowner.
*For technology a larger sample of 248 farmers was analysed.

The second sample consisted of randomly selected large-scale upland rice farms in central Brazil (256 cases in Goiás, 41 in Minas Gerais, 48 in Mato Grosso and 25 in Mato Grosso do Sul) (Table 1). Farmers were characterized with respect to hectarage under cultivation and technology in use. Additional qualitative aspects and farmers' reactions to new technology were also emphasized. The two samples were independently analysed in this study for the strong differentiation of socio-economic characteristics. For the cost and production analysis of upland rice farms, a subsample of 64 farms from sample 2 was selected. Consistent data on factor use and factor prices were not available for all farms surveyed in the second sample.

TECHNOLOGY GENERATION AND ADOPTION

Research conducted on rice at CNPAF has emphasized improvement of upland varieties. Research is currently being conducted on varietal improvement for irrigated systems and on evaluation of the specialized *varzeas* (swampland) environment. Ten upland rice varieties with improved disease-resistance and also one variety for irrigated systems have been released based on cooperative work with state research agencies. These have proved to be more productive than traditional varieties in most instances. The improved average productivity of the varieties released by CNPAF, however, is often related to other technological improvements, such as inexpensive blastdisease control, and soil management practices, including deep ploughing and fertilization.

Alternative production systems for upland rice were developed involving specific cultural practices, crop rotation and use of the new rice varieties. Preparing soil by first incorporating residues of the previous crop, followed by deep ploughing and involving crop rotation (legume-grass) has been reported to be an adequate method of controlling weeds. These technologies for either improving yields or minimizing costs of production constitute important results from research that was originally implemented by different institutions in other parts of Brazil even before the organization of EMBRAPA.

FARMERS' CHARACTERISTICS AND TECHNOLOGY ADOPTION

For the first sample, farmer characterization was mentioned for the general stratification of area of production. The planting system employed (irrigated, by seedling or direct fallow) and land tenancy were also described (Table 1).

For the upland rice farms, the on-farm survey was concentrated in the central-western region of Brazil. Farm size distribution follows the prevalent medium and large farms for legume and grain production in the region. About 62 percent of the farms sampled were larger than 250 ha and 18 percent were up to 100 ha in size. Farmers were predominantly young (50 percent under 40 years old) and 40 percent of them had been living in the region for less than ten years. Regions visited in Minas Gerais and Mato Grosso can be considered areas of more recently developed agricultural frontiers (Texeira, Yokoyama and Seguy, 1989).

For the new rice varieties, their release to producers after 1986 resulted in limited adoption. Data from interviews with farmers indicate that 16 percent of the total area is planted with new varieties, while 81 percent of the area is planted with traditional varieties [denominated under the São Paulo Institute of Agronomy (IAC)]. The remaining area is planted with unknown or

TABLE 2 Frequency of adoption of technologies for rice and soybean by a sample of farmers in central-western Brazil, 1988*

Technologies	Adoption (%)					Gains in average yield (%)	
	MG	GO	MS	MT	Total	GO	Others
Previous crop residuals	87.5	68.3	76.0	90.6	77.7	47.1	-
Plant mechanized	89.5	100.0	83.3	75.0	86.4	16.7	-
Cover fertilizer in rice	10.5	5.1	25.0	21.9	8.0	50.8	21.5
Inoculant soybean	100.0	68.6	66.7	95.2	81.6	5.8	2.5
Blast disease control	5.3	10.5	25.0	18.7	11.5	-19.8	-5.0
Fertilizer in rice	100.0	81.8	50.0	76.2	87.3	67.5	13.3
Fertilizer in soybean	100.0	88.2	100.0	100.0	95.7	6.3	-
New rice varieties	38.5	14.6	25.0	59.6	25.5	20.5	10.8

*Of the total farmers interviewed, 314 planted rice (251 in GO, 32 in MT, 12 in MS and 19 in MG) and 141 were soybean planters (51 in GO, 42 in MT, 24 in MS and 26 in MG).

TABLE 3 Percentage use of rice varieties and average yields on a sample of farmers in central-western Brazil, 1987/88

Rice cultivar	GO (256 prod.)		MT (45 prod.)		MS (25 prod.)		MG (24 prod.)		Total (350 prod.)	
	Area (%)	Yield (*kg/ha*)	Area (%)	Yield (*kg/ha*)	Area (%)	Yield (*kg/ha*)	Area (%)	Yield (*kg/ha*)	Area (%)	Yield (*kg/ha*)
Araguaia	3.6	2 317.6	-	-	2.1	1 500.0	-	-	3.0	2 276.0
Cabaçu	1.4	1 635.7	10.3	1 644.0	2.7	480.0	1.0	1 500.0	2.3	1 542.0
Guarani	2.4	1 268.0	14.4	1 591.0	-	-	-	-	3.2	1 309.0
Rio Paranaíba	3.1	1 495.9	7.7	1 850.0	0.5	1 860.0	32.5	1 635.0	4.5	1 594.0
Cuiabana	3.0	1 674.0	8.7	1 121.0	0.5	1 860.0	-	-	3.3	1 538.0
IAC 25	26.7	1 501.0	17.7	1 284.0	2.3	1 464.0	14.2	1 605.0	23.6	1 440.0
IAC 47	44.0	1 293.5	22.3	1 683.0	13.5	630.0	17.0	753.0	38.8	1 287.0
Other IACs	11.7	876.6	18.9	710.0	78.4	1 247.0	20.4	1 334.0	17.4	908.0
Traditional	2.8	957.0	-	-	-	-	-	-	2.3	957.0
Irrigated rice	1.3	2 838.7	-	-	-	-	14.9	2914.0	1.6	908.0

local traditional varieties. Of all the farmers interviewed, 25.5 percent reported using new rice varieties. It is evident that, because of their better yield performance, this rate will increase as the availability of the seeds increases over time (Tables 2 and 3).

Yields of recent varieties represent an average gain of 17 percent over the IAC's average yields. For the sample of farmers in Goiás, yields from new varieties planted on 13.5 percent of the total area accounted for 20.5 percent of the gains in production. This means that for Goiás state, four years after their release, the investments made in the new varieties have resulted in benefits that compensate farmers with the equivalent value of tax (17 percent) charged over traded production.

Technological processes for the crops show signs of evolution mainly related to the use of new varieties, appropriate fertilization, blast disease control and soybean inoculant (Table 2). Soil preparation with deep-ploughing procedures is practised by 35.8 percent of farmers in Goiás, 15.9 percent in Mato Grosso do Sul and 24.6 percent in Mato Grosso. The more traditional harrowing procedures are used by 56 percent of the farmers (21.4 percent in Goiás, 61.4 percent in Mato Grosso do Sul and 49.3 percent in Mato Grosso). The remaining farmers use disc or dragging ploughs.

In central-western Brazil rice is cultivated after

TABLE 4 **Use of crop rotation in alternative production systems among farmers in a sample of central-western Brazil, 1987/88**

Rotation	Rice (%)	Soybeans (%)	Corn (%)
After cerrado	45.3	7.4	3.9
After pasture	4.6	4.6	2.0
After rice	28.1	35.2	11.8
After soybean	14.1	38.0	62.7
After maize	1.6	13.0	13.7
Others	6.3	1.8	5.9

deforestation or pasture in 49.9 percent of the cases and in rotation with soybean in 14.1 percent of cases. Successive rice cultivation is practised on 29 percent of the sampled farms. Soybean is planted in 7.4 percent of newly cleared areas and comprises 38 percent of monocrop systems, while 48.2 percent of farmers have attempted planting soybean in rotation with rice (35.2 percent) or maize (13 percent) (Table 4). Among Mato Grosso producers, 45 percent were concerned about the need for crop diversification to substitute for extensive soybean monocultivation.

An analysis of the rates of adoption of new technology and recommended practices in production systems indicates that 67 percent of the farmers employ some form of crop rotation. In addition to crop rotation, 7.4 percent have also combined the use of new rice and soybean varieties with recommended methods of soil preparation. Another 14.3 percent use crop rotation and a new variety but with conventional ploughing, while 25.2 percent use crop rotation and a new soybean (17.3 percent) or rice (7.9 percent) variety but traditional harrowing for soil preparation. The remaining 20.1 percent of farmers perform crop rotation but use traditional varieties and conventional ploughing (6.4 percent) or harrowing (13.7 percent).

TECHNOLOGY AND PRODUCTION COSTS

The two samples analysed here provide sets of farmer characteristics based on two approaches. The first approach is represented by the analysis of sample 1 where farm size, land tenure, production systems and planting procedures are taken as qualitative variables in an analysis of production functions. Quantitative information on the level of production factors used by farmers is also included.

For the second data set, technology adopted for the production of upland rice and social variables are discussed as determinant factors of production and costs. Reduced form determinants of technological adoption are explored. For the specific set of upland rice farmers in the central-western region, two types of human capital are related to technology adoption – education and experience in the region. Experience may provide general farming knowledge as well as specific knowledge about a particular farm, while education enables the farmer to process the information provided by different sources better and should increase both the allocative and technical efficiency of the farmer (Jamilson and Lau, 1982).

Farm size, land tenure and production systems

Let the dependent variables be total and average (by hectare) production and cost. Two sets of qualitative dummy variables are used for stratification and continuous variables for a Least Squares estimation procedure:

$$Yi = f(Di, Xi) \text{ and } Yi/ha = (Di, Xi/ha)$$

Where: Yi = total or average (Yi/ha) production or cost;
D1 = 1 if the farmer is a landowner and D1 = 0 if otherwise;
D2 = 1 if rice is produced under irrigated system and D2 = 0 if otherwise;
D3, D4 =
D3 = 1 and D4 = 0 if planting is done manually;
D3 = 0 and D4 = 1 if planting is mechanized;
D3 = 0 and D4 = 0 if planting is both manual and mechanized;
D5 = 1 for large farmers (total area >9 ha); and D1 = 1; and D5 = 0 for small if otherwise;
D6 = 1 if planting procedure is direct fallow and D6 = 0 if seedling.

Pearson and Spearman correlation analyses revealed low correlation between production and cost and the dummy variables (Di). Higher correlations were found with total production and costs than with the average values per hectare, implying that aggregation improves correlation among these variables. Landownership (D1) was not significant for correlation coefficients, supporting the general belief of regional rice agronomists that tenure is not an important decision variable. Contract farming is a very common practice both in small and large farms and in upland or irrigated rice production systems in Brazil. It is also worth noting the low

TABLE 5 **Correlation coefficients for sample 1**

Production/cost	Variable	Corr. Pearson	Signif.	Corr. Spearman	Signif.
Total production	D1	.083	.168	.063	.233
	D2	.268	.001	.311	.000
	D3	-.190	.013	-.195	.012
	D4	.161	.030	.124	.075
	D5	.537	.000	.639	.000
	D6	.178	.018	.171	.024
Production per ha	D1	-.130	.065	-.187	.015
	D2	.139	.053	.166	.027
	D3	-.126	.072	-.068	.215
	D4	.103	.115	.197	.011
	D5	-.135	.058	-.151	.040
	D6	.124	.075	.237	.003
Cost	D1	.063	.235	.099	.126
	D2	.147	.044	.333	.000
	D3	-.087	.158	-.184	.017
	D4	.279	.001	.110	.102
	D5	.256	.001	.630	.000
	D6	.261	.001	.173	.023
Cost per ha	D1	.006	.472	-.089	.153
	D2	.149	.041	.165	.028
	D3	-.093	.140	.006	.471
	D4	.209	.007	.137	.056
	D5	.031	.359	-.114	.097

Source: U.F.V. data from farmers in Minas Gerais state.

TABLE 6 **Coefficient estimators for production functions**

Variable	Model 1	Model 2	Model 3
A	413.9	0.32	-
A++2	-89.5	-	-
LP	6.4	0.01	-0.01
LH	12.8	-	-0.06
TL	2.7	0.33	0.24
AP	9.7	-	0.02
AP++2	0.3	-	-
MCP	252.0	-	0.01
OM	-22.3	-	-
TM	5.7	-	-
VOC	0.02	0.01	-
TFV	0.02	0.21	0.14
FER	0.09	-	-
SEM	7.5	-	-0.08
D2	-	0.14	-
D5	-	0.12	-
INS	-	0.01	0.01
HER	-	-0.01	-0.02
INV	-	-	0.11
D5+TL	-	-0.06	-
TM+A	0.21	-	-
DG+TL	-	-0.3	-
DG6+TM	-	0.33	-

Model 1: PROD = f (A, A++2, ...) Linear; where A++2 refers to quadratic A (area).
Model 2: ln PROD = f (lnA, lnLP, ...) coefficient estimates correspond to elasticities; where ln stands for logarithm.
Model 3: ln PROD/ha = f (lnLP/ha, lnLH/ha, ...) average product and factors per hectare.

correlation between stratification variables and total and average-per-hectare production and costs. Only for D5 in total production and cost did correlation coefficients show adequate levels of significance, implying that scale of production for irrigated systems in Minas Gerais, Maranhão and São Paulo is among the important determinants of production and cost levels (Table 5).

Production functions accounted for variations in the dependent variables as a result of interaction between explanatory variables also taken in Cobb Douglas form, assuming multiplicative effects and quadratic or cubic relations with production factors. The variables included in the analysis were:

PROD = total production (kg);
D2, D5, D6 as previously defined;
A = area under production (ha);
LLP = labour for land preparation (working days);
LCP = labour for cultural practices (working days);
LP = labour for planting (working days);
LH = labour for harvesting (working days);
TL = total labour (working days);
AP = animal power for soil preparation, in animal-days;
TA = total animal power, in day-animal;
MCP = machinery in cultural practices, in machine-hours;
TM = total machinery, in hour-machine;
OM = other machinery, excluding tractors and harvesters, in hour-machine;
VOC = value of other costs (transport, taxes, etc.) in cruzados;
TFV = total factor values (chemicals, seeds, etc.);
FER = chemical fertilizers (kg);
SEM = planted seeds (kg);
ORG = organic fertilizer (kg);
HER = herbicides (kg or litres);
INS = insecticides (kg or litres);
INV = fixed capital investment in cruzados.

The resulting estimated models are presented in Table 6.

Ordinary Least Squares (OLS) estimators for the coefficients involved multicolinear problems and were corrected by ridge regression analysis, and signs were as expected. Total machinery, labour and other production factors presented positive marginal products.

For the logarithmic model, the stratification variables D2, D5 and D6 coefficients are significantly different from zero, indicating that the irrigation system and production scale need to be differentiated. They also affect production elasticities for factors TL and TM. For D2 only the intercept changes, indicating larger production levels for irrigated and swampland systems. The planting system (direct fallow and seedling) affects

TABLE 7 **Relevant correlations of the variables tested for upland central-western farmers**[1]

Explanatory dependent	Total production (*y*)	Yields (*kg/ha*)	Cost/ha	Ln (*y*)
X3 Administration	0.00(0.99)	0.22(0.09)	0.21(0.10)	0.11(0.38)
X8 Area under rice	0.45(0.00)	-0.20(0.12)	0.17(0.00)	0.40(0.00)
X9 Total cultivated area	0.57(0.00)	-0.30(0.02)	0.24(0.06)	0.47(0.00)
X10 Total farm area	0.86(0.00)	-0.24(0.06)	0.10(0.43)	0.87(0.00)
X11 Credit	0.17(0.20)	0.04(0.74)	-0.09(0.49)	0.28(0.04)
X13 Number of machines	0.40(0.00)	-0.21(0.09)	0.20(0.12)	0.28(0.03)
X14 Crop rotation (y/n)[2]	-0.14(0.27)	0.10(0.42)	-0.39(0.00)	-0.08(0.52)
X15 Nitrogen	-0.04(0.73)	-0.13(0.32)	-0.05(0.71)	0.21(0.09)
X16 Phosphorus	-0.02(0.87)	-0.11(0.40)	0.00(0.99)	-0.01(0.90)
X17 Potassium	-0.04(0.76)	-0.18(0.16)	0.12(0.34)	-0.02(0.90)
X18 Cover fertilization (y/n)	0.24(0.06)	0.04(0.74)	0.02(0.85)	0.25(0.03)
X19 Herbicide (y/n)	-0.05(0.68)	0.08(0.56)	-0.12(0.35)	-0.07(0.57)
X20 Drought occurrence (y/n)	-0.22(0.09)	-0.37(0.00)	-0.05(0.67)	-0.22(0.09)
X21 Labour soil preparation	0.00(0.99)	-0.27(0.03)	0.50(0.00)	-0.25(0.05)
X23 Labour cult. practices	-0.01(0.93)	-0.11(0.41)	0.27(0.03)	-0.23(0.07)
X25 Total labour	-0.007(0.95)	-0.12(0.34)	0.35(0.00)	-0.25(0.05)
X26 Machine use soil preparation	0.21(0.11)	-0.25(0.04)	0.69(0.00)	-0.04(0.77)
X30 Total machine use	0.12(0.34)	-0.14(0.26)	0.62(0.00)	-0.003(0.98)
X34 Total fertilizer use	-0.008(0.90)	-0.21(0.11)	-0.00(0.99)	-
X09 + X13	0.52(0.00)	-0.29(0.02)	0.22(0.09)	-
X09 + X18	0.40(0.00)	-0.12(0.35)	0.06(0.65)	-
X10 + X13	0.78(0.00)	-0.27(0.03)	0.13(0.31)	-
X13 + X21	0.36(0.00)	-0.33(0.01)	0.38(0.00)	-
X13 + X25	0.35(0.00)	-0.22(0.09)	0.35(0.00)	-

[1]Significance level in parentheses.
[2]Yes (y = 1) or no (n = 0) technology adoption variables.

production elasticities for TL negatively, implying that total labour elasticity is greater for seedling than direct planting. For machinery, elasticity is higher for direct fallow than seedling.

Other variables with negative marginal product, such as HER (herbicide use), suggest that reduction in use would result in increased production or that herbicides are not being rationally used by farmers in the selected sample. Labour for planting (LP) and harvesting (LH), also with negative production elasticities, imply lower efficiency as larger amounts are used. Signs are negative for labour when directly sown and positive for machine use. Elasticity estimates are largest for labour in seedling for small farmers and for machinery in direct planting, implying that small-scale farmers can increase production by expanding labour use and rationalizing use of negative elasticity factors.

The main conclusions from this part of the study are:

- the stratification variable D1 (land tenancy) was not, in general, an important factor in explaining production variations among farmers.
- Size variables, both as qualitative dummies and continuous area under production, are important in separating small versus large producers, and production and planting systems are significant factors explaining production and cost levels.
- For large-scale farmers, production factors present constant returns to scale while, for small producers, these factors result in increasing returns to scale.
- Factors such as labour for soil preparation, labour for planting and cultural practices, organic fertilization and herbicides at lower use could decrease costs or increase yields.

TABLE 8 **Technology adoption and socio-economic variables regression equations for farmers in central-west Brazil, 1989**

Explanatory dependent	Soil analysis	Blast-disease control	Improved rice varieties	Crop rotation	Amount of fertilizer
X1 Total area (ha/1 000)	0.035	0.012	-0.016	0.14	11.527
X10 Experience (yrs/100)	0.056	-0.207	0.182	0.238	0.741
X12 Education (yrs/100)	1.012	-1.787	0.094	3.241	2.661
X21 Credit rice (Y=1, N=0) -0.008	- 0.008	-0.046	0.286	-0.189	17.322
EST 1 (MT)	0.254	-0.451	0.373	0.490	80.637
EST 2 (MS)	0.401	-0.287	0.788	0.467	51.160
EST 3 (MG)	-0.018	-0.252	0.736	0.298	37.886
Constant	-0.110	0.450	0.874	1.647	137.45

Note: Dummy for state related to Goiás farmers.

- Machinery use is positively related to the production system. The total machine use (TM) is directly related to direct fallow systems (positive elasticities) and it is smaller or equal to zero for the seedling system.
- The variables TL (total labour) and A (area) explain about 90 percent of total elasticities of production for the seedling system and 70 percent for the direct-planting system.
- Largest elasticities are for total labour in the seedling system and total machinery for the direct-planting system.

Determinant factors of production, technology and cost for upland rice

With respect to reduced-form determinants of technology adoption, for a zero and one dependent variable, implying non-adoption and adoption of technology, respectively, we find among central-western farmers that education and years of experience (time spent living in the region) are relevant and directly related (Barbosa *et al.*, 1989 and Texeira, Yokoyama and Seguy, 1989).

For a subsample where cost data and production factor use were available, qualitative variables, such as distance between farm and market areas, land tenure and administration, age of farmers and percentage of time dedicated to agriculture, were analysed along with total and planted area, machinery available and its use in rice production, as well as such technology variables as crop rotation (yes or no), fertilizer use on planting and cover, herbicides use and drought occurrence (yes or no) and labour and machinery used for different tasks. The relationships between these variables and production, yields and total costs were examined. Significant results are presented in Table 7, and the principal conclusions are summarized below.

- Administration and land tenure are directly related to yields.
- Total planted area is inversely related to yields. Other important factors such as machinery availability and machinery use are negatively related to yields, while other factors contribute to significantly lower yields, such as drought occurrence.
- Area planted, use of machinery and its availability and labour and machine use for soil preparation present positive marginal products (as indicated by the signs in the first column of Table 7).
- Education levels are directly correlated with machine availability and use and inversely related to age and time dedicated to agriculture.
- Credit use is directly related to total area, fertilizer and machine use and negatively correlated to labour use.
- Total planted area is positively correlated to the amount of nitrogen applied and use of cover fertilization.
- There is a positive relationship between the use of cover fertilization and the use of herbicides, and an inverse correlation between the use of cover fertilization and drought occurrence.
- Total machine use is directly correlated to distance from markets and labour use.

- Negative values for interactions between machinery availability, area and labour use (soil preparation, harvesting and total) implies a negative substitution effect or competition among these factors as related to yields.
- Fertilizer use was analysed in terms of quantity of different components (nitrogen, potassium and phosphorus) and also total quantity applied. Unexpected negative values for both production and yields were observed in the correlations. Only the logarithm of nitrogen use was in direct correlation with production. These results imply that inadequate amounts of potassium and phosphorus are being used, or quantities should be lessened, as indicated by negative marginal products.
- The cost of production was included on a per-hectare basis, showing an inverse correlation with yields, and was directly related to administration and land tenure.

Reduced-form determinants for main technologies adopted by farmers in the central-western region during 1988/89 (sample 2) reinforce the argument that education and experience are important factors. Both variables have shown direct relationships with response to new recommended cultivation practices, except for the use of chemical control for blast disease. This negative response may be explained by the increasing awareness of possible harm from fungicide use (Table 8).

CONCLUDING REMARKS AND IMPLICATIONS FOR RESEARCH

Socio-economic research aimed at supplementing technology generation and adoption in agriculture in Brazil has advanced from only quantifying the potential impact of technological change – proved to be enormous – into a more qualitative characterization of the socio-economic environment.

In this study we attempt to assess, from the farmer's point of view, the determinant factors in technology adoption and implications for production, costs and yields in important rice-producing regions. About 520 farms were involved in the analysis either in the context of production scale, systems, land tenure and administration or production technologies and factors affecting productivity and costs. Among the results of the analyses undertaken, the importance of production scale with implications of factor allocation and efficiency must be stressed.

The first stage of the analysis was composed of a quite diversified sample, which is representative of the diversity of rice systems and production procedures. The second stage involved a more homogeneous sample, where production systems and technology adoption were the rule: the behaviour of farmers toward factor use such as total labour for small farmers, seeds, machinery and cultivable land are very similar. These factors seem to be neutral to the variations characterizing the two samples and implied increasing marginal products. Total planted area seemed to be a limitation to yields for large farms in the second sample.

Other factors such as the use of herbicides and organic fertilizers were also found to relate inversely to both production and yields, implying that production decreases when higher levels are used. This was more evident in the first sample, while not significant as explanatory variables in the second.

While credit has been shown to have an important positive effect on both production yields and declining costs, it appears inversely proportional to labour use, which may indicate that this factor is inaccessible to more labour-intensive farmers.

Machinery use is a limiting factor to direct planting and labour elasticities are largest for small farm seedling planting for irrigated rice protection. Small farmers can increase production by expanding labour use and increase yields through the rationalization of factors with negative marginal products.

Fertilizer use must be reviewed. The investments in research to make *cerrado* land available for agriculture may have overvalued the need for chemical fertilization. Similarly, timing of herbicide use and application of blast disease control need to be better defined.

Agricultural research must not only take into account the socio-economic implications of factor allocation for production, yields and cost, but it must also emphasize factor use as related to these characterizations.

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Rice combine harvesters in fields drained 20 days before harvesting

Pre-emergence herbicide test

Upland rice after pre-emergence herbicide application