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THE IMPACT OF MECHANIZATION ON AGRICULTURAL PRODUCTION IN SELECTED VILLAGES OF NUEVA ECIJA

by

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THE IMPACT OF MECHANIZATION ON AGRICULTURAL PRODUCTION IN SELECTED VILLAGES OF NUEVA ECIJA*

Dermot Shields**

INTRODUCTION

Agricultural mechanization has been the focus of much debate and controversy for a long time now. The fundamental issue, as to whether mechanization has an effect, directly or indirectly, on yield is difficult to answer conclusively since either the data is not available or is site specific and hence not readily generalizable. Further, there are analytical difficulties in isolating the effects of mechanization from the effects of other complementary inputs.

The aim of this paper is to investigate the differences in yield, inputs and cropping intensity for alternative mechanization classes in both rainfed and irrigated areas.

The consequences of mechanization study aimed to collect data at four sites in South East Asia in order to provide the sort of quantitative data which is required for policy interventions.

In the Philippiines, the area chosen for the survey was Nueva Ecija Province in Central Luzon, where it was possible to find a sufficient number of tractors in both rainfed and irrigated areas.

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This survey, which was carried out in 1979/80, provides cross-section data from selected households in eight villages. Four villages were in Guimba district, a predominantly rainfed area, and the remaining four were irrigated and closer to Cabanatuan City. A stratified random sampling procedure was then used to further ensure that a sufficiently large number of mechanized farms were included in the survey. The Farm Management Data Collection and Analysis System (FMDCAS) was used, together with supplementary questionnaires providing detailed information on machine use, as well as historical information about the cause and consequences of any changes in land preparation techniques.

CLASSIFICATION SCHEME

Households were classified on the basis of both the land preparation technique employed and on the type of irrigation. Classification was on the basis of largest parcel. There were three irrigation classes - rainfed, pump irrigated and gravity irrigated.

In order to capture the shifts in mechanization classes between seasons, the mechanization groups were based on land preparation techniques in both the wet and dry seasons. Non-mechanized farms used draft animals for land preparation in both seasons, while fully-mechanized farms used tractors and/or power tillers in both seasons. The remaining farms who used a combination of animal and mechanical power were classified as partially mechanized.

Table 1 shows the number of sample households in each class. However, since the sampling design used was stratified, it is useful to consider a conceptual population based on the relationship between the sample size and the census population. This is shown in Table 2.

Roughly half of this estimated population are in the rainfed category and nearly three quarter of this group are non-mechanized. The rest are partially mechanized and employ animals for land preparation during at least one season.

Within the gravity irrigated group, only 2% of the households are non-mechanized, indicating a strong correlation between irrigation and mechanization. This confounds the analysis of the output effects of mechanization since irrigation is known to have a major effect on yield.

This study therefore focuses on the differences between non-mechanized and partially mechanized farms in the rainfed areas and between partially mechanized and fully mechanized farms in the gravity-irrigated class.

BACKGROUND

Nueva Ecija is a predominantly rice growing area and most of the farmers grew rice in both the wet and dry seasons. Nearly all farmers used modern varieties in both seasons and transplanting was everywhere preferred to broadcasting.

There was little difference in the age or educational backgrounds of the farmers although the farmers in the gravity irrigated areas were slightly older on average (Table 5).

Farm size, owned land plus net rented land, was larger in the gravity irrigated areas when compared to the rainfed area. Within both irrigation groups the more mechanized farms had larger areas.

However, the percentage of managed land which was owned was much less on the gravity irrigated farms and was particularly low for the fully mechanized group. This group had the lowest level of owned land, when compared to all the other groups.

CROPPING INTENSITY

Since virtually all the cultivated land is planted to rice, cropping intensity has been defined as the ratio of the sum of land planted in both seasons to farm size, where farm size is taken to be the largest area held in either the dry or wet seasons.

Clearly, availability of water in the dry season is the major constraint to increasing intensity of land use (Table 6). Cropping intensity in the gravity irrigated areas was close to 200% with virtually all farmers growing a second crop and using all their land. However, in the rainfed areas cropping intensity is much lower, 117% on non-mechanized farms and 124% on partially mechanized farms, although the difference between these groups is not significant. Less than one third of farmers in the rainfed areas grow a second crop and the mean area cultivated falls considerably from wet to dry seasons.

Although, the distribution of cropping intensity is both bimodal and extremely non-normal, a linear regression was carried out (Table 7). This shows clearly that while the mechanization dummies are insignificant, the irrigation dummies are strongly significant and, as expected positive. Area managed was included as an explanatory variable, and gave a significant (1%) negative parameter. Although, the absence of normality (or near normality) for the cropping intensity variable invalidates the statistical test, this result hints at the possibility that larger farms are somehow constrained from fully exploiting their land in the dry season. Further investigation is required in order to determine whether this is a power constraint which could be alleviated by the use of machinery.

When the same function was estimated separately for rainfed and irrigated farms, the overall significance fell drastically for both irrigation groups. This confirms that irrigation is the major determinant of cropping intensity and that within irrigation classes there is little variation.

Although positive, the coefficients for the mechanization dummies were small and insignificant for both the rainfed and irrigated equation. The area variable was again negative in both cases but only significant for the rainfed farms confirming that cropping intensity is much lower on the larger rainfed farms where it is expected that farmers are not under the same 'income' pressure to produce a second crop. In the irrigated areas, farm size has little effect on cropping intensity

since the provision of water nearly always makes double cropping attractive.

YIELD

Yields are significantly different between rainfed and irrigated groups (Tables 9 and 10), with dry season yields much higher than wet season yields.

In the wet season (Table 9), there were no significant differences between mechanization classes within each irrigation group.

In the dry season (Table 10), although yields in the gravity irrigated class are similar in the rainfed class non-mechanized farms have mean yields of over 1 tonne more than partially mechanized farms. It should be noted that few rainfed farms cultivate in the dry season and that those that do cultivate have very small plots (average less than 0.30 ha) and hence very intensive cultivation is possible. In these circumstances, there is unlikely to be any power constraint.

There are therefore no grounds to suggest that yields are significantly higher on mechanized farms. This is in line with other studies.

It is not merely enough to examine output, without also looking at input use since the effects of a change in technology may be either output increasing or input saving.

INPUTS AND PRODUCTIVITY

In the wet season, the profile of input use is correspondingly higher on irrigated than rainfed farms (Table 9). In particular

fertilizer use is much higher on the gravity irrigated farms (about 50% higher).

Within each irrigation class the differences are not significant. For the gravity irrigated farms, fertilizer use is the same for both partially and fully mechanized farms, while for the rainfed class, partially mechanized farms have higher mean inputs of both nitrogen and phosphorus than the non-mechanized farms.

Table 11 shows the average return per kg of nitrogen, in the wet season, which is similar for both irrigated and rainfed groups. Within the rainfed group, the reduced fertilizer productivity for the partially mechanized class is barely significant at 5% and reflects the insignificantly lower yields and the marginally higher fertilizer inputs for that class with respect to the non-mechanized class.

Total per hectare labor input is slightly higher on the rainfed farms (Table 9). However, this was the result of the higher level of mechanization on gravity farms and there was no difference in the mean requirements for the partially mechanized groups in both irrigation classes. As expected within each irrigation classes, the total labor requirement was lower on the more mechanized farms.

The proportion of the total labor which was hired was not significantly different between mechanization classes, although irrigated farms utilized considerably more labor per hectare in absolute terms.

This can be seen clearly in the crude average labor productivity ratios in Table 11, where there are no significant differences between

mechanization classes within each irrigation group. This is true for both total labor and hired labor productivity.

The power inputs for the wet season (Table 9) showed more variation both between and within irrigation groups. This reflects the fact that the partially mechanized group are more highly mechanized in the gravity irrigated stratum than the partially mechanized farms in the rainfed stratum.

Likewise, machine hours, comprising both land preparation and other activities including mechanical threshing, follows the reverse pattern. Most of the animal hours are used in land preparation.

The dry season picture is considerably different (Table 10). Yields are considerably higher than for the wet season corresponding to higher inputs of fertilizer, labor and power. In particular the highest per hectare inputs of fertilizer are for the non-mechanized rainfed category and this explains the significantly higher yields for this group within the rainfed class.

The dry season average productivity ratios (Table 12) show however that irrigated farms have much higher yields for each kg of nitrogen applied. However, within each irrigation group there was no difference between the mechanization classes in terms of the nitrogen productivity ratios.

The mean level of labor for non-mechanized rainfed farms used in the dry season was over 60% larger than in the wet season. This was partly the result of the higher dry season yield but was also largely due to the doubling of the per hectare labor required for dry season land preparation (which may have been a casual factor in the higher dry

season yields). The higher labor demand for dry season land preparation may be explained by technical difficulties that confront the few non-mechanized rainfed farmers who cultivate in the dry season. However, other cultural practices may also explain this increase. Much of this extra labor is hired but since only a small area of land is covered, the overall importance is minimal.

For the partially mechanized rainfed farms the labor required was 45% higher in the dry season, suggesting that, at least within our survey households, mechanization is not a sufficient factor enabling farmers to ensure a second crop. The provision of water is essential for this respect.

For the irrigated farmers, overall labor requirements differed only slightly between seasons, with the dry season requirements being lower. This reflects the relative ease of cultivation for irrigated farmers. Within the gravity irrigated class the difference in total labor requirement is more pronounced in the dry season. The percentage of hired labor however remains the same for both seasons.

The labor productivity ratios (Table 12) are almost three times higher on the irrigated farms. For the rainfed farms, the ratios for non and partially mechanized farms are not significantly different for both hired and total labor. However, within the irrigated group, fully mechanized farm productivity ratios for both total and hired labor is 50% greater than for partially mechanized.

A similar pattern can be seen in the mean levels of power input. The technical difficulties of dry season cultivation in rainfed areas

are only marginally, if at all, eased by partial mechanization. For the irrigated farms, land preparation times are roughly the same between seasons.

PRODUCTION FUNCTION ANALYSIS

The problems associated with the confounding of mechanization and irrigation cannot be isolated by tabular analysis. A production function relating yield to inputs for the wet season was therefore estimated in order to test where mechanization alone had any effect on yields when differences in other inputs were also taken into account. The standard Cobb-Douglas formulation was employed (Table 19) and estimated over all the sample households. This showed that fertilizer, pesticides and preharvest labor all had a positive and significant effect on yields. Dummies for irrigation classes were also positive and significant. However, dummies for mechanization classes gave small insignificant parameters suggesting that mechanization had little or no effect on yield.

When the functions were re-estimated for rainfed and gravity irrigated strata separately (Table 20), the mechanization dummies again remained small and insignificant.

Although this is a preliminary and limited attempt to consider the effect of mechanization on the relationship between yields and inputs, it suggests that after input differences are allowed for, mechanization

CONCLUSIONS

The major determinant of yield and cropping intensity for both seasons appears to be irrigation. Within each irrigation group there is little difference in fertilizer productivity between mechanization classes. The differences in labor productivity are largely due to the fact that the partially mechanized class are more 'highly' mechanized in the irrigated stratum than the partially mechanized farms on the rainfed areas. Few farms in the rainfed areas cultivate in the dry season. Those that do, require considerably higher material, labor and power inputs. There is no evidence that the partially mechanized farms within the rainfed areas are more productive. The non-mechanized farms within the rainfed area, Table 6, cultivate extremely small areas in the dry season, - about half the area cultivated by the partially mechanized group - thus enabling very intensive practices. We conclude from this preliminary analysis, that there is no evidence of a yield effect directly attributable to mechanization.

Table 1. Distribution of sample households among classification groups, wet season, 1979.

Irrigation class	Mechanization level			
	Non-mech.	Partial mech.	Full mech.	All
Rainfed	77	46	1	124
Pump irrigated	39	15	0	54
Gravity irrigated	7	79	54	140
All	123	140	55	318

Table 2. Distribution (%) of estimated population among classification groups, wet season, 1979.

Irrigation class	Mechanization level			
	Non-mech.	Partial mech.	Full mech.	All
Rainfed	31	14	0	46
Pump irrigated	8	4	0	12
Gravity irrigated	2	21	18	42
All	41	40	19	100

Source: Consequences of Small Rice Farm Mechanization.

Table 3. Distribution of sample households among classification group, dry season, 1979/80.

Irrigation class	Mechanization level			
	Non-mech.	Partial mech.	Full mech.	All
Rainfed	19	15	1	35
Pump irrigated	25	12	0	37
Gravity irrigated	7	78	54	137
All	51	105	55	211

Table 4. Distribution (%) of estimated population among classification groups, dry season 1979/80.

Irrigation class	Mechanization level			
	Non-mech.	Partial mech.	Full mech.	All
Rainfed	12	7	0	20
Pump irrigated	9	5	0	14
Gravity irrigated	3	34	30	66
All	24	46	30	100

Source: Consequences of Small Rice Farm Mechanization.

Table 5. Characteristics of farmer and farm holdings in selected villages, Guimba and Cabanatuan, Nueva Ecija, Philippines, wet season, 1979.

	Rainfed		Gravity irrigated	
	Non-mech.	Partial mech.	Partial mech.	Full mech.
Farmer's age (years)	43	44	46	47
Farmer's education (years)	4.6	5.0	4.7	4.2
Land managed (ha)	2.10	2.22	2.19	2.54
Percentage of managed land which is owned (%)	69	82	44	26
No. of draft animals per farm	1.07	0.79	0.89	0.16
No. of tractors per farm	0	0.02	0.47	0.70
Estimated population	276	128	190	163
Sample size	77	46	79	54

Source: Consequences of Small Rice Farm Mechanization.

Table 6. Average level of cropping intensity for rainfed and irrigated farms in selected villages in Guimba and Cabanatuan, Nueva Ecija, Philippines, crop year 1979/80.

	Rainfed		Gravity irrigated	
	Non-mech.	Partial mech.	Partial mech.	Full mech.
Cultivated area (ha)				
Wet season 1979	2.06	2.22	2.18	2.54
Dry season 1979/80	0.29	0.49	2.19	2.54
Cropping intensity	1.17	1.24	1.96	1.99
Percent of population planting dry season crop	25	33	99	100
Estimated population	276	128	190	163
Sample size	77	46	79	54

Source: Consequences of Small Rice Farm Mechanization.

Table 7. Weighted regression coefficients for cropping intensity function for all sample households in selected villages in Guimba and Cabanatuan, Nueva Ecija, Philippines, Cropping year 1979/80.

Explanatory variables	Weighted coefficients (All farms)
Intercept	1.20 (32.3)
Area managed	-0.024 (-1.92)
Dummy (fully mech.)	0.09 (1.41)
Dummy (partially mech.)	0.06 (1.30)
Dummy (gravity irrig.)	0.72 (14.71)
Dummy (pump irrig.)	0.39 (7.5)
R^2	0.62
F value	100.9
N	312

Figures in parenthesis are t-statistics to test the hypothesis that population coefficient is zero.

Source: Consequences of Small Rice Farm Mechanization.

Table 8. Weighted regression coefficients for cropping intensity for rainfed and irrigated farm households in selected villages in Guimba and Cabanatuan, Nueva Ecija, Philippines, cropping year 1979/80.

Explanatory variables	Weighted coefficients	
	Rainfed	Irrigated
Intercept	1.15 (19.7)	1.92 (16.7)
Area managed	-0.10 (-4.40)	-0.004 (-0.28)
Dummy (fully mech.)	0.01 (0.03)	0.06 (0.53)
Dummy (partially mech.)	0.09 (1.50)	0.01 (0.12)
R^2	0.16	0.02
F value	5.63	0.50
N	123	135

Figures in parenthesis are t-statistics to test the hypothesis that population coefficient is zero.

Source: Consequences of Small Rice Farm Mechanization.

Table 9. Average yield and inputs for households in selected villages in Guimba and Cabanatuan, Nueva Ecija, Philippines, wet season 1979.

	Rainfed		Gravity irrigated	
	Non-mechanization	Partial mechanization	Partial mechanization	Full mechanization
	per hectare			
Yield (kg)	1902	1826	3860	3803
Material inputs				
Seeds (kg)	100	74	123	108
Fertilizers				
N (kg)	25	29	52	52
P_2O_5 (kg)	9	15	21	16
K_2O (kg)	5	6	11	15
Labour inputs				
Total (mds)*	76	66	67	64
Hired - (mds)	47	44	58	55
- (%)	(62)	(67)	(87)	(86)
Power inputs				
Animal (hours)	119	65	26	-
Machine (hours)	5	15	23	42
- land prep. (hrs)	0	10	17	32
Estimated population	276	128	190	163
Sample size	77	46	79	54

*One manday is equivalent to 8 hours.

Source: Consequences of Small Rice Farm Mechanization.

Table 10. Average yield and inputs for households in selectd villages in Guimba and Cabanatuan, Nueva Ecija, Philippines, dry season 1979/80.

	Rainfed		Gravity irrigated	
	Non-mech.	Partial mech.	Partial mech.	Full mech.
	per hectare			
Yield (kg)	3426	2564	4469	4485
Material inputs				
Seeds (kg)	119	106	140	123
Fertilizer				
N	89	78	70	65
P_2O_5	31	39	28	20
K_2O	14	4	16	16
Labour inputs*				
Total (mds)	122	96	63	55
Hired (mds)	83	56	54	47
(%)	(68)	(58)	(86)	(86)
Power inputs				
Animal (hours)	214	114	27	0
Machine (hours)	3	11	27	39
- land prep (hrs)	0	9	20	32
Estimated population	66	41	188	163
Sample size	19	15	78	54

*One manday is equivalent to 8 hours.

Source: Consequences of Small Rice Farm Mechanization.

Table 11. Productivity ratios for rice production in rainfed and irrigated farms in selected villages, Guimba and Cabanatuan, Nueva Ecija Philippines, wet season 1979.

	Rainfed		Irrigated	
	Non-mech.	Partial mech.	Non-mech.	Partial mech.
Yield:				
per hectare (kg)	1902	1826	3860	3803
per kg nitrogen (kg)	76	63	74	73
per total labor (md)	25	28	58	59
per hired labor (md)	40	42	67	69
Estimated population	276	128	190	163
Sample size	77	46	79	54

Source: Consequences of Small Rice Farm Mechanization.

Table 12. Productivity ratios for rice production in rainfed and irrigated farms in selected villages, Guimba and Cabanatuan, Nueva Ecija, Philippines, dry season, 1979/80.

	Rainfed		Irrigated	
	Non-mech.	Partial mech.	Partial mech.	Full mech.
Yield:				
per hectare (kg)	3426	2564	4469	4485
per kg nitrogen (kg)	38	33	64	69
per total labor (md)	28	27	71	82
per hired labor (md)	41	46	83	95
Estimated population	66	41	188	163
Sample size	19	15	78	54

Source: Consequences of Small Rice Farm Mechanization.

Table 13. Weighted estimated coefficients of the Cobb-Douglas production function for all sample households in selected villages of Guimba and Cabanatuan, Nueva Ecija, Philippines, wet season, 1979.

Explanatory variables	Weighted coefficient
	All farms
Intercept	5.81 (23.52)
ln (area cultivation) ha	-0.02 (0.43)
ln (kg. nitrogen) kg/ha	0.19 (5.1)
ln (pesticide costs) ₱/ha	0.14 (4.6)
ln (preharvest labor) mds/ha	0.16 (2.6)
Dummy (fully mech.)	0.01 (0.15)
Dummy (partially mech.)	0.02 (0.28)
Dummy (gravity irrigated)	0.43 (5.88)
Dummy (pump irrigated)	0.13 (1.98)
R^2	0.56
F value	(42.73)
N	312

Dependent variable - ln (yield) in kg/ha.

Figures in parenthesis are t-statistics to test the hypothesis that population coefficient is zero.

Source: Consequences of Small Rice Farm Mechanization.

Table 14. Weighted estimated coefficients of the Cobb-Douglas production function for rainfed and gravity irrigated households in selected village in Guimba and Cabanatuan, Nueva Ecija, Philippines, wet season 1979.

Explanatory variables unit	Weighted coefficients	
	Rainfed	Gravity irrigated
Intercept	5.48 (11.1)	6.44 (15.8)
ln (kg Nitrogen) kg/ha	0.18 (4.9)	0.08 (2.8)
ln (pesticide costs) ₱/ha	0.12 (3.4)	0.08 (2.7)
ln (land preparation labor) mds/ha	0.18 (2.1)	0.17 (2.7)
Dummy (fully mech.)	0.55 (1.0)	0.13 (0.8)
Dummy (partially mech.)	-0.08 (0.9)	0.15 (1.0)
R^2	0.39	0.22
F-value	(12.44)	6.19
N	124	140

Dependent variable - ln (yield) in kg/ha.

Figures in parenthesis are t-statistics to test the hypothesis that population coefficient is zero.

Source: Consequence of Small Rice Farm Mechanization.