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FARM MECHANIZATION, EMPLOYMENT AND INCOME IN NEPAL: TRADITIONAL AND MECHANIZED FARMING IN BARA DISTRICT

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FARM MECHANIZATION, EMPLOYMENT, AND INCOME IN NEPAL: TRADITIONAL AND MECHANIZED FARMING IN BARA DISTRICT[1]

ABSTRACT

A survey of traditional and mechanized farms in Bara district, Nepal, was conducted to assess the impact of mechanization on cropping intensity, timeliness, yields, income, employment, and efficiency. Cropping intensity, yields, income, and employment were higher on mechanized than on traditional farms. However, the much greater use of cash inputs and higher education levels associated with mechanized farms made it difficult to attribute yields and income effects solely to machinery. Tractors could not be clearly linked with any on-farm labor displacement and pumpsets were found to raise farm employment. Tractor ownership allowed large farms to achieve higher cropping intensity through speedy and timely operations. Increased cropping intensity appeared to put a premium on timeliness for large farms, but did not seem important for small units. Tractorization permitted the farmers to nearly eliminate bullocks. The highest levels of efficiency were achieved by pumpset owning and tractor hiring farms rather than large tractor owning farms.

[1]By Som Prasad Pudasaini, former research scholar, Department of Agricultural Economics, The International Rice Research Institute. This paper is based on the author's MS thesis submitted to the University of the Philippines at Los Baños, 1976. Submitted to the IRRI Research Paper Series Committee August 1979.

FARM MECHANIZATION, EMPLOYMENT, AND INCOME IN NEPAL: TRADITIONAL AND MECHANIZED FARMING IN BARA DISTRICT

Farm mechanization[2] in the developed countries has occurred primarily as a response to high and rising wage rates. The recent spread of tractorization to countries with low wage rates such as India, Pakistan, and Nepal raises two sets of questions. First, because tractors must have been privately profitable at the prices and incentive structures under which they were bought, what is the source of benefits that account for the private profitability where wage rates are not high? Are yields raised, does cropping intensity rise, or is the primary benefit the replacement of animals? Second, does the tractor lead to direct labor displacement or to a slow-down in the growth of labor demand available from other innovations?

This paper attempts to answer those questions in the context of the Nepal Terai. A survey of different types of farms was conducted and the "before and after" as well as "with and without" approaches were used to evaluate these issues but the results were influenced by differences between bullock-operated and tractor and farms in respects other than tractors. In particular, tractor farms are usually larger, better capitalized, and also may have more qualified managers. Special attention has thus been placed on measuring these other differences. Finally production function analysis is used to "control" these other differences, at least in a statistical sense.

RESEARCH DESIGN

In 1975 there were slightly more than 2,000 tractors operating in Nepal. Fourteen percent (295) were operating in Bara District of the Terai. About 12% of the farmers falling in the largest farm size category owned tractors (Table 1).

Sample characteristics

Five different types of farmers, traditional with bullocks (TDF), pumpset owners (POF), tractor owners (TOF), tractor hirers (THF), and tractor and pumpset owners (TPOF) were identified and studied to trace differences in farm employment and income. A sample size of 20 or 21 was randomly drawn from each of the five specified types of farmers and 102 farmers from Bara District in the central Terai of Nepal were interviewed to gather necessary information on production, costs, labor use, etc., for the period November 1974 to December 1975.

The five specified types of farmers differed from each other in basic characteristics, such as cultivated area, expenses for improved inputs, investment in machinery and tools, and education of the farm operators (Table 2). Most traditional farmers were part owners of land in contrast to most machine users being full owners. The differences in expenses for improved inputs, value of machines and tools, and education between the traditional farmers and all other categories were large, indicating much poorer access to capital inputs of any type on these farms.

Impact of mechanization on farm operations and cropping intensity

Assessment of the quality of land preparation performed by the tractor was based on the farmer's judgment of degree of weed infestation immediately after transplanting, crop stand, and yield. Weed infestation was less on farms plowed by tractors as reported by most tractor users. Most tractor users also reported better rice and wheat stands and higher rice and wheat yields after use of the tractor for land preparation. Crop yields showed that both rice and wheat yields were higher on mechanized than on traditional farms (Table 3). But the simultaneous arrival of biological (modern varieties) and chemical (fertilizers, pesticides, etc.) innovations on mechanized farms makes it difficult to attribute higher yield and better crop stand solely to tractorization. Pumpset owners had lower yields for rice but marginally higher yields for wheat than the tractor as well as tractor and pumpset owners despite the fact that tractor owners used almost the same level of improved inputs and tractor and pumpset owners used substantially higher levels than pumpset owners. Thus, there was no clear evidence in support of the hypothesis that tractors improve yields.

Optimization of planting dates depends primarily on timely land preparation. Delay in land preparation means delay in planting, which in turn delays harvesting. The influence of tractorization on timeliness of farm operations was, therefore, based on farmers' reports of how their last rice and wheat planting dates compared with those of their neighbors before and after tractor use. More than 90 percent of the tractor owners and tractor and pumpset owners reported earlier completion of wheat planting and more than 62 percent of them reported earlier completion of rice transplanting than their neighbors.

[2] Although mechanization in the study refers to introduction of four-wheeled tractors or pumpsets or both, the major factor expressed in this paper is tractorization.

Table 1. Distribution of landholdings in Bara District, Nepal.

Farm Group	Average size of landholdings (ha)	Total cultivated area		Total landholdings	
		Thousand ha	%	Thousand ha	%
Large	9.02	22.376	33.2	2.481	8.7
Medium	3.56	19.482	28.9	5.473	19.2
Small	1.24	25.541	37.9	20.598	72.1
Total	2.36	67.400	100.0	28.552	100.0

Source: Agricultural Credit Survey, Nepal, 1972.

Table 2. Selected characteristics of traditional and mechanized farmers of Bara District, Nepal, 1975.

Characteristics	Traditional farmers (N = 20)	Pumpset owners (N = 20)	Tractor owners (N = 21)	Tractor hirers (N = 20)	Tractor and pumpset owners (N = 21)
Education (years)	3.8	5.6	7.0	6.7	7.9
Landholdings (ha)	5.9	8.8	32.1	9.4	25.0
Area cultivated (ha)	5.3	8.3	21.1	6.2	21.6
Expenses for improved inputs (Rs/ha per year)[a]	64	682	653	388	857
Value of machines and tools (Rs/farm)	254	5,521	47,805	938	58,157

[a] Rs 10.00 = US$1.00.

In contrast, almost no change was observed in the rice transplanting schedule of those hiring tractors. In the case of wheat, however, a relatively larger proportion (35%) of the tractor hirers reported planting earlier than their neighbors after using tractors; only 5 percent completed planting earlier before the introduction of the tractor.

Cropping intensity on all machine-using farms was higher than on traditional farms after mechanization. Differences in cropping intensity were prevalent among different types of machine using farms (Table 4). Their increase in cropping intensity indicated two important points. First, that mechanization possesses the potential for increasing cropping intensity. Second, a mechanization strategy combining irrigation and efficient land preparation facilities is likely to result in much higher cropping intensity than for either technology alone.

The similar cropping intensity of tractor owners and tractor hirers indicated that the tractor rental market could be as effective as tractor ownership in achieving higher cropping intensity.

Farm employment

Farm employment was measured in days per hectare per year of bullock and human labor used in rice, wheat, and sugarcane. The annual per hectare human labor absorbed by machine users was much higher than that absorbed by traditional farmers (Table 5). The maximum labor use of 190.4 days was on pumpset owning farms. Additional or alternative mechanization resulted in a decline in labor use. Pumpsets thus appeared to be more of an employment-generating form of mechanization than tractor farms, which employed more labor per hectare than traditional farms. The

Table 3. Crop yield of sample traditional and mechanized farmers, Bara District, Nepal, 1975.

Type of farmer	Yield (t/ha)[a]	
	Rice	Wheat
Traditional	1.72	1.98
	(.41)	(.63)
Pumpset owners	2.09	2.57
	(.45)	(.67)
Tractor owners	2.20	2.42
	(.34)	(.52)
Tractor hirers	2.09	2.09
	(.41)	(.67)
Tractor and pumpset owners	2.28	2.50
	(.37)	(.60)

[a]Standard deviation in parentheses.

Table 4. Cropping intensity [a] of sample farmers before and after mechanization, Bara District, Nepal, 1975.

Type of farms	Cropping intensity(%)[b]		
	Before	After	Increase
Traditional	145.0	145.0	
		(33.5)	
Pumpset owners	137.4	155.3	17.9
	(38.3)	(43.8)	
Tractor owners	121.2	165.0	43.8
	(42.2)	(19.2)	
Tractor hirers	148.8	166.9	18.1
	(22.6)	(14.1)	
Tractor and pumpset owners	155.2	174.1	58.9
	(29.3)	(36.4)	

[a] Cropping intensity:

$$\frac{\text{Total area under different crops during a given year}}{\text{Total cultivated area available}} \times 100$$

[b] Standard deviations in parentheses.

higher absorption of labor by machine users over the traditional farms resulted from the increased use of labor, mainly in weeding, harvesting, and threshing (Table 6). That may have been partly due to increased use of modern technology which demanded better weeding to attain a better harvest. The increased cropping intensity of machine users was also an important contributor to higher labor absorption in case of machine users.

Bullock labor employed by tractor owners, tractor and pumpset owners, and tractor hirers was also lower than that of traditional farmers (Table 7). Pumpset owners were not significantly different from traditional farmers in bullock use. This shows that the displacement of human labor in land preparation and the reduction in bullock needs on the farm was larger in total in the case of tractor owners, closely followed by tractor and pumpset owners; both displacements were nominal in the case of tractor hirers and pumpset owners were relatively neutral.

The large reduction in bullock use associated with tractor ownership was one of the primary benefits of tractorization while wage cost reduction was limited.

Farm income

The level of farm income is a measure of the profitability of a farm business and reflects the efficiency with which farm resources or services are utilized. Farm income can be measured as gross farm revenue (GFR), farm family income (FFI), returns to family labor and capital (RFLC), returns to family labor and management (RFLM), and returns to family owned capital (RFOC). Of these, FFI, which is return above paid out costs, and represents returns to owned land, family labor and management, and farm capital such as buildings, machines, tools and equipment, is perhaps most widely used. Machine users had higher income than traditional farmers as shown by the values of GFR, FFI, RFLC, RFLM, and RFOC in Table 8. Among machine users, almost all measures showed the highest income in the case of tractor and pumpset owners, followed by tractor owners, tractor hirers, and pumpset owners.

FARM EFFICIENCY AND FACTOR PRODUCTIVITY

Underlying the estimation of marginal productivity and efficiency of the farms under study is the production function concept that the quantity of output depends on the quantities of factor inputs or services employed. Assuming that the output (GFR) Y depends on the quantities of factor inputs, X_i, education of a farm operator, E, and types of farms, D_j, the production function can be expressed as

$$Y = f\ (X_i,\ E,\ D_j) \qquad (1)$$

Estimates of $\partial Y/\partial X$ and $\partial Y/\partial E$ provide the marginal value of products for factor inputs and education of

Table 5. Annual human labor employed by sample traditional and mechanized farmers, Bara District, Nepal, 1975.

Type of farms	Annual labor use (days/ha)				Hired labor as percentage of total	Increase over traditional farms
	Total	Family	Exchange	Hired		
Traditional	149.0	37.0	7.0	104.4	70	-
Pumpset owners	190.4	11.6	*a*	178.8	94	41.4
Tractor owners	176.4	3.1	*a*	173.0	98	27.4
Tractor hirers	187.0	16.8	0.2	170.0	91	38.0
Tractor and pumpset owners	182.0	3.6	0.1	178.3	93	33.0

[a] Less than .01.

Table 6. Human labor for farm operation on sample traditional and mechanized farmers, Bara District, Nepal, 1975.

Farm operation	Annual labor used (days/yr)				
	Traditional farmers	Pumpset owners	Tractor owners	Tractor hirers	Tractor and pumpset owners
Land preparation	33.0	33.9	4.7	29.3	7.3
Dike repair and irrigation	8.0	9.6	9.8	9.0	13.6
Transplanting or planting	49.7	50.4	49.3	53.8	52.0
Fertilizing and spraying	1.3	1.9	2.8	3.3	3.3
Weeding	22.0	40.4	50.8	39.7	40.3
Harvesting and threshing	35.0	54.2	59.0	51.9	65.5
Total	149.0	190.4	176.4	187.0	182.0

Table 7. Bullock labor absorption by sample traditional and mechanized farmers, Bara District, Nepal, 1975.

Type of farm	Annual bullock labor (days/ha)			
	Total	Family	Exchange	Hired
Traditional	63.3	49.3	14.0	*a*
Pumpset owners	57.4	46.4	9.9	1.1
Tractor owners	3.4	2.9	0.5	
Tractor hirers	53.5	40.8	12.4	0.2
Tractor & pumpset owners	4.8	4.5	0.3	

[a] Less than 0.1.

a farm operator. For my purpose, the following specification in natural logarithms was estimated to investigate whether selected conventional and non-conventional inputs significantly raised farm revenue.

$$Y = X_1^{\alpha_1} \; X_2^{\alpha_2} \; X_3^{\alpha_3} \; X_4^{\alpha_4} \; e^{\beta} \qquad (2)$$

where

$$\beta = \gamma_1 X_5 + \gamma_2 X_6 + \gamma_3 X_7 + \sum_{j=2}^{5} \partial_j D_j \, ,$$

and

X_1 = total crop area per farm (ha),

X_2 = total human labor used per farm (days),

X_3 = cash expenses on fertilizer, pesticides, irrigation, and land revenue per farm (Rs)*,

X_4 = total bullock labor used per farm (days),

X_5 = schooling of farm operator (yr),

X_6 = total tractor use per farm (h),

X_7 = total pumpset use per farm (h), and

Y = total gross farm receipts (Rs)*.

Table 8. Farm income of sample traditional and mechanized farmers, Bara District, Nepal, 1975.

Measures of income[a]	Farm income (Rs per ha per year)[b]				
	Traditional farms	Pumpset owners	Tractor owners	Tractor owners	Tractor and pumpset owners
GFR	2167	3533	3687	3110	4527
FFI	1484	2031	2222	2277	2635
RFLC	7[illegible]0	1001	1481	1[illegible]62	1666
RFLM	594	648	1115	705	1099
RFOC	535	58	1447	923	1621

[a]*GFR* (gross farm revenue): Sum of the values of all farm crop output, amount received from the sales of livestock; value of products received by leasing or renting land (if any), and income earned from renting out of tractor and/or pumpsets by a farm family. *FFI* (farm family income): GFR minus paid out costs represented total cash and kind costs actually incurred during the farm revenue generating process. Cash component of paid out costs included expenses on fertilizer, insecticides, land revenue, irrigation fee, fuel and lubricants, repair and maintenance of farm machinery, cash labor cost. The kind component included produce paid to landlord, seed, kind payment to labor. *RFLC* (return to family labor and capital): FFI minus imputed rental costs of owned land. The imputed rental cost on the owned land was assumed to be 10 percent of the value of the land. *RFLM* (return to family labor and management): RFLC minus imputed interest cost on family owned capital. The interest cost charged on family owned capital was 15 percent. *RFOC* (return to family owned capital): RFLC minus imputed costs on family labor. In imputing cost on family labor on-going wage rate was used. [b]Rs 10.00 = US$1.00.

The dummy variables are

D_2 = 1 if pumpset owners, 0 otherwise;

D_3 = 1 if tractor owners, 0 otherwise;

D_4 = 1 if tractor hirers, 0 otherwise; and

D_5 = 1 if tractor and pumpset owners, 0 otherwise.

The marginal value product (MVP) of a given factor input is the first derivative[3] of the estimated specification with respect to that factor input. Thus, the MVP of X_i, with all other inputs at their geometric means, was computed as:

$$\frac{\delta y}{\delta X_i} = \alpha_i \cdot \frac{\bar{y}}{\bar{X}_i}, \quad i = 1, 2, 3, 4$$

and

$$\frac{\delta y}{\delta X_i} = \alpha_i \cdot \bar{y}, \quad i = 5, 6, 7$$

[3]Because the dependent variable (y) is in monetary value here, the first derivative directly gives MVP, otherwise it would be only the marginal physical product for the input in question. *Rs 10.00 = US$1.00 as of June 1979.

where

$\bar{y}$ = gross farm receipts at its geometric mean

$\bar{X}_i$ = $_i$th factor input at its geometric mean

α_i = partial regression coefficient of $_i$th input.

In addition, farm type dummies were employed in the function to see whether the specified types of machine users were significantly different from traditional farmers in terms of efficiency. The results, reported in Table 9, showed that all conventional resources, viz. land, human labor and bullock labor, contributed significantly to increase farm revenue of traditional farmers as well as machine users. Land had the largest coefficient, followed by human labor, indicating that land and human labor were the most important productive resources in the district, contributing a larger share to farm revenue.

As expected, the nonconventional inputs, viz. cash expenses in chemical fertilizers, pesticides, irrigation, etc., and education of farm operators also had a positive and significant impact on farm revenue.

The contribution of both tractors and pumpsets to farm revenue was positive but insignificant in Equation 2, whereas the contribution of tractor

Table 9. Partial regression coefficients obtained by fitting the specified function to pooled data of sample traditional and mechanized farmers, Bara District, Nepal, 1975.

Independent variables	Partial regression coefficients of equations	
	1	2
Crop land: X_1	0.3710**	0.3823***
	(0.0956)	(0.0942)
Human labor: X_2	0.2837***	0.2708***
	(0.0965)	(0.0951)
Cash: X_3	0.0827**	0.0815**
	(0.0397)	(0.0391)
Bullock labor: X_4	0.0556**	0.0554**
	(0.0299)	(0.0294)
Education: X_5	0.0137**	0.0126*
	(0.0080)	(0.0078)
Tractor labor: X_6	0.0003*	0.0002
	(0.0002)	(0.0002)
Pumpset use: X_7	0.0004	0.0003
	(0.0004)	(0.0004)
Dummy variables		
Pumpset owners: D_2	0.1988	0.2540*
	(0.1562)	(0.1538)
Tractor owners: D_3	0.0525	0.2308
	(0.2210)	(0.2177)
Tractor hirers: D_4	0.4032***	0.4195***
	(0.1312)	(0.1292)
Tractor and pumpset owners: D_5	-0.2078	0.0048
	(0.2443)	(0.2406)
R^2	0.9029	0.9097
Constant	6.0607	6.1286

*Significant at 10 percent level, ** significant at 5 percent level, *** significant at 1 percent level. Figures within parentheses indicate standard errors of the coefficients. NOTE: Regressions 1 and 2 differ in that the dependent variable (Y) of 2 includes earnings from machine renting out whereas the other includes earnings only from within a farm.

labors to farm revenue was positive and significant in Equation 1. Because the contribution of a machine can be realized over a period of time, the estimate based on cross-sectional data for one year might not have caught the effect of machines on revenue fully. The ambiguity of the results may, therefore, indicate a deficiency in the data, and not permit drawing of any strong conclusions about the contribution of machines to farm revenue.

The positively significant coefficients of farm type dummies for tractor hirers and pumpset owners (Equation 2) showed that both were more efficient than traditional farmers. On the other hand, the insignificant coefficients of farm type dummies for tractor owners and tractor and pumpset owners, regardless of their size, indicate that those farmers were not significantly different from traditional farmers with regard to their efficiency. Overall, the small tractor use coefficients, together with the nonsignificant dummy variables for tractor ownership on the one hand, indicate that differences in farm earnings are related more closely to the use of other labor and capital inputs and education than to tractor ownership per se. The large coefficient associated with land (crop area), however, indicates the possibility that tractors indirectly contribute to increased farm earnings through increased cropping intensity and probably through better land preparation.

Marginal analysis showed that the marginal value products of land, human labor, cash expenses, and bullock labor were more than their unit prices. In addition, the marginal value products of education of a farm operator was also substantial (Table 10). Although the marginal value of products for the pumpset was more than the custom rate and for the tractor less than its custom rate, the reliability of the estimate is dubious because the coefficients were insignificant.

DIFFERENCES AND BENEFITS

The production function analysis shows that most of the observed differences in gross farm revenue between mechanized and traditional farms are primarily a reflection of the much higher use of cash inputs and higher education levels. This, however, does not rule out the possibility of tractors indirectly contributing to higher farm earnings. There is evidence that the highest efficiency levels are achieved by small pumpset owning and tractor hiring farms rather than the large tractor owning farms.

Nevertheless, the source of private benefits from tractor ownership was clear. In the case of Bara District, tractor ownership allows large farms to achieve and surpass intensity levels otherwise associated with smaller bullock farms. It has also allowed them to almost fully eliminate bullocks. Conversely, there is no clear evidence of yield increases caused by tractors alone, despite the fact that tractor farmers report fewer weed problems and a higher degree of timeliness. This implied that timeliness was not a very important premium for the second crop on small farms in the area which was irrigated, or that nontractor farmers may properly take care of added weeds by later weed control measures or both. However, increased cropping intensity appeared to put a premium on timeliness for large farms in the area.

Table 10. Marginal value products of factor inputs computed from the estimated specification.

Inputs	Unit	Marginal value products (Rs)[a] Computed from equations 1	2	Rental rates
Crop land[b]	ha	806.85	892.00	894.00
Human labor	days	11.12	10.53	6.00
Cash expenses	Rs	1.10	1.08	1.00
Bullock labor	days	17.46	17.40	13.00
Tractor labor	hours	11.53	7.55	40.00
Pumpset use	hours	15.10	11.33	9.20
Education	years	517.18	475.68	

[a]Rs 10.00 = US$1.00. [b]The marginal value products presented are for crop area whereas the rental rates are for the physical area. Adjusted for cropping intensity, rental rate per hectare of crop area turns out to be Rs 555.00.

On-farm labor displacement did not seem to be large and was not a primary source of private benefits. This does not imply that tractors do not displace labor from a broader societal point of view. The large amount of capital invested in tractors did not create as much employment as the pumpsets on all types of farms. But it must be noted that tractors may increase employment on large farms allowing them to raise cropping intensity while the same may not be true on small farms, which constitute a large bulk of total holdings in Nepal. The small farms appear to be able to attain high intensity even without tractors.

If the capital invested in tractors had been invested in additional irrigation facilities, however, labor requirements would have increased. It is also likely that most nonagricultural investments would also have led to more employment creation.

Considering the foregone opportunities for employment creation, as well as potential on-farm displacement, investment in irrigation facilities such as pumpset mechanization rates priority in the context of low-wage (labor abundant), capital-scarce economies such as Nepal.

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