ABSTRACT

Power Tiller Use on Rice Farms in West Java, Indonesia: An Analysis of Their Employment Effects and Private Profitability

Sanim Bunasor and John Lingard

Respectively IRRI Partial Research Scholar and University of Newcastle-upon-Tyne, England

This study documents the use of hand tractors in West Java, analyzes their private profitability, and measures some of their effects on employment. For a subsample of 61 tractor owners (43 gasoline, 18 diesel) it was found that 28 gasoline and 9 diesel tractors were operating at less than breakeven capacity. At current new purchase prices tractor ownership is not profitable. Covariance analysis was used to examine mechanization effects on employment through comparative analysis of 220 mechanized and 214 non-mechanized farms. Non-mechanized farms used more labor per hectare, particularly family labor and female labor. Key variables affecting labor use were season, mechanization, farm size, fertilizer use and soil type.

ABSTRAK

Penggunaan Traktor Tangan pada Usahatani Padi di Jawa Barat, Indonesia: Sebuah Analisis tentang Ketenagakerjaan dan Keuntungan Pemilik

Sanim Bunasor dan John Lingard

Kajian ini mempelajari penggunaan traktor tangan di Jawa Barat, menganalisis keuntungan pemilik traktor, dan mengukur akibatnya terhadap tenaga kerja. Dari contoh sejumlah 61 pemilik traktor (43 bensin dan 18 disel) didapati 37 pemilik (28 bensin dan 9 disel) yang beroperasi di bawah titik impas. Pada saat pengumpulan data, harga baru pembelian traktor tidak menguntungkan bagi pemilik. Efek mekanisasi terhadap ketenagakerjaan diuji dengan analisis kovarian melalui analisis perbandingan 220 usahatani mekanis dan 214 non-mekanis. Usahatani non-mekanis menggunakan lebih banyak tenaga kerja per hektar, terutama tenaga dalam keluarga dan tenaga wanita. Peubah kunci yang mempengaruhi penggunaan tenaga kerja adalah musim, mekanisasi, ukuran usahatani, penggunaan pupuk dan macam tanah.

Power Tiller Use on Farms in West Java, Indonesia: An Analysis of Their Employment Effect and Private Profitability

Sanim Bunasor[2] and John Lingard[3]

. INTRODUCTION

The major efforts of the Indonesian government to increase agricultural production have been through both intensification and extensification programs. Using improved technology and the mass guidance (BIMAS and INMAS) program, output per unit of land has been increased. To increase the number of crops per unit of land per year (cropping intensity) the government has financed the construction and rehabilitation of irrigation infrastructure. During the Second Five Year Plan (1972-78) 627 000 ha of irrigated land were rehabilitated, and new construction irrigated an additional 273 000 ha (Nyberg and Prabowo, 1979). At the same time the pace of agricultural mechanization, especially power tiller utilization, has significantly increased. In West Java the population of tractors (especially hand tractors) has increased by a factor of 2.7, from 431 in 1974 to 1154 in 1978 (Saefuddin, 1980). Unlike pump-set mechanization, the tractor represents a heavily capital-intensive form of mechanization with tremendous but unproven labor-displacing potential.

[1]Consequences of Small Rice Farm Mechanization Project (IRRI/ADC), Working Paper 64.

[2]IRRI Partial Research Scholar.

[3]University of Newcastle-upon-Tyne, England.

In Indonesia, as in other less-developed countries, agricultural mechanization, and particularly tractorization, has been the subject of widespread controversy. The issue has been widely and continually debated. Five key questions are posed:

(a) Does mechanization increase farm output? If so, how?
(b) To what degree is labor displaced by these machines, and what are the alternative employment opportunities for displaced labor?
(c) To what extent are the benefits of mechanization concentrated in the "less poor" sectors of society?
(d) With the rising prices of fossil fuel energy, is it still economic to mechanize?
(e) What policies should the government follow to obtain the socially desirable benefits of mechanization, whilst simultaneously minimizing undesirable direct and indirect effects?

The wide divergence of opinion among researchers on the desirability of agricultural mechanization has been discussed by Gemmill and Eicher (1975) amongst others. Binswanger's seminal work reviews Indian evidence.

Our research area of Subang and Indramayu obtains water from the Jatiluhur irrigation system. In recent years, the water management system here has been improved with tertiary and quaternary irrigation networks being built in each tertiary block. With such an irrigation network delivery of water is much faster (4 days) than the traditional delivery from sector to sector of rice fields which often takes up to 30 days. This has also resulted in improved efficiency of water use. The period of water availability in each irrigation block is limiting tightly scheduled and can cause problems at planting time by, however, the time available for land preparation. Land preparation labor must be rapidly mobilized to follow the water distribution schedule in each block, and as a consequence the demand for labor is concentrated in a short period, often making it difficult to obtain the necessary labor. The problem is also aggravated by a decrease in the draft animal/bullock population and reduced immigration of seasonal labor from outside the district (Bernsten and Rochim, 1980). This study examines some of the questions arising out of the introduction of tractors in West Java. In particular it considers whether the ownership of hand tractors is economically profitable from a private viewpoint. Also it looks at the impact of tractor mechanization on employment.

METHODOLOGY

Two different methods of analysis are used in the study: covariance analysis and private profitability analysis.

Covariance Analysis

Covariance analysis is used to determine the impact of mechanization on employment or human labor use and to identify the key variables affecting labor use at the farm level. The labor used in specific farm operations (i.e. for land preparation, pulling seedlings and planting, weeding and crop care, harvesting and drying) differs between tractorized and untractorized paddy rice farms and might be associated with variables other than tractorization. Such variables include season, soil type, size of farm, age and education of the farmers, and fertilizer and pesticide use. Analysis of means between mechanized and non-mechanized farms does not separate the effects of these variables from those of tractorization. Covariance analysis, which separates the additive and multiplicative effect of these variables is, therefore, applied to the data in an attempt to account for differences in these other farm characteristics. All sample farms are irrigated and planted to modern varieties. The covariance analysis is based on the following relationships:

1) Unconstrained equation:

$$L_i = b_{0i} + B_{1i}M + b_{2i}S + b_{3i}W + b_{4i}H + b_{5i}A + b_{6i}E + b_{7i}P + b_{8i}N + b_{9i}F + b_{10i}M.S + b_{11i}M.W + U_i \quad (1)$$

2) Constrained equation:

$$L_i = b_{0i} + b_{1i}M + b_{2i}S + b_{3i}W + b_{4i}H + b_{5i}A + b_{6i}E \; b_{7i}P + b_{8i}N + b_{9i}F + V_i \quad (2)$$

where:

L_i = refers to the level of human labor used in specific farm operations (i.e. land preparation, planting, weeding and nursery labor, etc.) in man-hours, i = 1, ..., 7.

M = mechanization dummy; this takes a value of unity if the farm is mechanized (tractor-owning and tractor-hiring farms) and a value of zero otherwise (manual/hoeing farms).

S = soil-condition dummy based on soil texture. It takes a value of unity if the soil is a clay or clay loam (heavy cultivated soil), and a value of zero otherwise (easily cultivated soil).

W = season dummy; takes a value of unity for the wet season 1979/80 and zero for the dry season, 1980.

H = size of landholding measured as the total lowland holding of the farmer in hectares.

A = age of the farmer in years. Younger farmers are expected to have a greater physical endurance for farming and may also be readier adopters of new technology.

E = education measured in the number of years the farmer has attended formal school. Educated farmers are expected to have better technical and managerial information.

P = farm experience in the number of years the farmer has managed his own farm.

N = potential family labor available given by the number of family members 10 years old and above. The higher the potential family labor available, the less the likelihood that the farmer will use tractors and the higher will be labor use per hectare.

F = value of fertilizer used expressed in rupiah (Rp).

b_{0i} = intercept for i^{th} dependent variable, $i = 1, ..., 7$.

b_{ki} = k^{th} parameter for i^{th} dependent variable, $i = 1, ..., 7$; $k = 1, ..., 11$.

U_i and V_i = disturbances or statistical error terms for i^{th} dependent variable.

Covariance analysis also permits investigation of the multiplicative effects between independent variables, e.g., interactions between mechanization dummy (M) and soil condition dummy (S), mechanization dummy (M) and season dummy (W). To test for the statistical significance of the interactive effect, the F-statistic based on the residuals of estimating the unconstrained equation (i.e., with variables MS and MW) and constrained equation (i.e., without variables MS and MW) is used. The null hypothesis is that H_o: $b_{ki} = 0$ (the regression slope of interaction variables M and S is equal to zero), against the alternative hypothesis H_a: if H_o is not true, or that $b_{ki} \neq 0$. The F-statistic is computed as follows:

$$F'_{r}\,N\text{-}K = \frac{\left(\sum \hat{V}_i^2 - \sum \hat{U}_i^2\right)/r}{\sum \hat{U}_i^2/N\text{-}K}, \tag{3}$$

where:

$\hat{V}_i^2$ = residual sum of squares of the constrained equation
$\hat{U}_i^2$ = residual sum of squares of the unconstrained equation
r = number of restrictions
N = number of observations
K = number of regressors or independent variables
r, N-K = degrees of freedom (df)

If $F'_{r, N-K}$ calculated is greater than the F-table value, the null hypothesis (H_o), is rejected and the alternative hypotehsis H_a is accepted. If $F'_{r, N-K}$ is less than the F - table value, the null hypotehsis is accepted and the alternative hypothesis (H_a) is rejected.

Two alternatives buying prices of the tractor are used for each analysis. Buying price I is the actual price derived from the survey data, or the average buying price when the tractors were bought. Buying price II is the current (1981) purchase price of a new tractor ready for use.

Tractor benefit and cost analysis. This analysis is divided into two groups: gasoline and diesel tractors. The analyses, which are strictly financial/private analyses, are shown below for benefit-cost ratios (B/C), net present values (NPV) and internal rates of return (IRRI) (Gittinger, 1972).

$$B/C = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+r)^t}} \tag{4}$$

$$NPV = B - C = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+r)^t} \tag{5}$$

$$IRR = B - C = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+r)^t} = 0 \tag{6}$$

where:

B_t = benefit occurring in year t
B = $B_1 + B_2 + B_3$

B_1 = benefit from own farm land cultivated per year; this is measured as the total area of the tractor-owner's farm cultivated by tractors, multiplied by the average custom rate per hectare for the respective tractor group (gasoline or diesel) in rupiahs. In other words, we are assuming that the farmer would have to hire a tractor in the absence of owning one himself.

B_2 = benefit of off-farm land cultivated per year; computed as the area of off-farm land cultivated, times the custom rate per hectare received by the tractor owner. This benefit is the total return from hiring the tractor, measured in rupiahs.

B_3 = salvage value of the tractor in rupiahs. This benefit is realizable only in the last year of the economic life of the hand tractor.

C_t = cost incurred in year t
C = NC + VC where VC = U + O + R + L
NC = initial cost defined as capital outlay in buying a tractor

VC = variable cost per year expressed in rupiahs -- the sum total of expenditures per year on diesel or gasoline fuel used (U), oil/lubricants used (O), repair and maintenance costs (R), and the labor costs of the operator (L).

t = index of the t^{th} year
n = number of years involved (n = 1, 2, ..., 6)
r = discount rate

The assumptions used in the analysis are:

1. Flows of benefits and variable costs are the same for each year of the economic life of the tractor.
2. The expected economic life of a hand tractor is 6 years. This estimate was based on two considerations: first, the distribution of ages of the sample tractors in this survey varied from 0 to 9 years. Second, from the technical point of view, a hand tractor cannot reliably be used after six years.
3. The salvage value of the tractor is 10% of capital investment.
4. The discount factor on capital investment is 12% per year. This is based on the consideration that the interest rate for government KIK (credit for small investment) facilities

which include a tractor is 10.5% per year, or 0.8% per month. In addition the borrower is charged an undefined administrative cost, estimated at 0.5 to 1.0% of the total credit advanced.

Tractor breakeven point analysis. The breakeven point is the number of hectares of land cultivated or the custom rate to be charged which is just sufficient to cover the total annual costs of the tractor (fixed and variable costs). This is computed on an annual per-hectare basis. The analysis is carried out for both gasoline and diesel tractor groups. The formula used to calculate the breakeven point is presented below:

$$T \times G = FC + VC, \qquad (7)$$

where:

- G = area served in hectares, defined as the total area of cultivated land just sufficient to cover the operating of the tractor.
- T = custom rate in rupiahs per hectare, computed as the average custom rate of the respective tractor gorup.
- FC = fixed cost in rupiahs per year, defined as the sum total of depreciation (D) and interest on capital investment (I).
- VC = variable cost, also expressed in rupiahs year as previously defined.

STUDY AREA, DATA COLLECTION AND SITE DESCRIPTION

The Study Area and Selection of the Farmers

The surveys were conducted in the districts of Subang and Indramayu, in the province of West Java (Fig. 1). In each district, three subdistricts with the greatest number of hand tractors were radomly selected. Four villages with four or more farmers owning tractors were selected in each district. Before choosing the sample of farmers, a block census was carried out in eight villages covering 1600 households. Census respondents were grouped according to the power used for primary tillage in the wet season of 1978/79. The six stratified groups were: 1) tractor owner farmers; 2) tractor hiring farmers; 3) animal-hoeing farmers; 4) manual/hoeing farmers; 5) tractor-animal farmers, and 6) field laborers. By using proportionate random sampling from each census block, sample households were chosen.

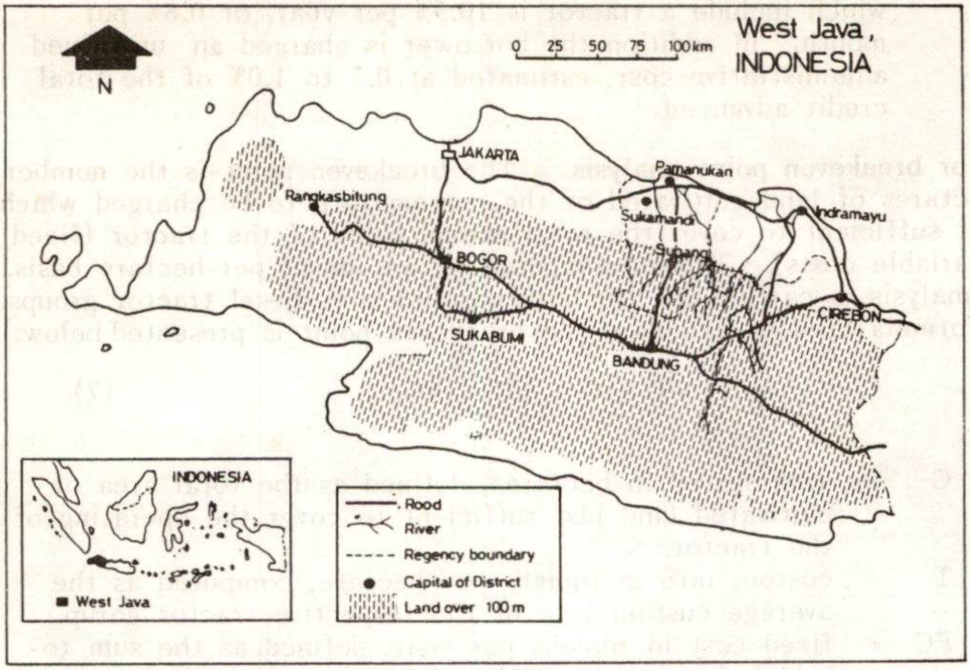

Figure 1. Location of sample area, West Java, Indonesia

This study uses data for the wet season 1979-80 and dry season 1980, with three groups of farmers (hand-tractor owner farms, hand-tractor hired farms, and manual/hoeing farms). The six subdistricts and eight villages selected and the number of the respective groups samples for the two seasons are presented in Table 1.

Source of Data and Its Limitations

The data used for this study were collected as part of the study entitled "The Consequences of Small Rice Farm Mechanization Project in Asia", conducted by the International Rice Research Institute (IRRI). Farm level primary data were collected through a series of cross-sectional surveys and a complementary daily record keeping system, for two crop years. Two areas in Indonesia were chosen for this study: West Java and South Sulawesi provinces. The present comparative study uses data pertaining only to West Java.

All the information, both farm-level primary data and complementary daily records, were collected based on the farmers' recall.

Table 1. Subdistrict and village sample and number of sample farmers in each group and each season. West Java, 1979-80.

Subdistrict and village sample of the study area

District	Subdistrict	Village
Subang	Pusakanegara Pamanukan Binong	Bojong Tengah Pamanukan Hilir Mariuk Tambak Dahan
Indramayu	Bangodua Gabus Wetan Anjatan	Sukadana Gabus Kulon Anjatan Sukra

Number of sample farmers in each group and each season

Group (Power source for primary tillage)	Wet season 1979-80	Dry season 1980	Total
Hand-tractor owner farmers	68	64	132
Hand-tractor hiring farmers	49	39	88
Manual/hoeing farmers	56	158	214
Total	173	261	434

Farmers have not established farm record systems and have difficulty in accurately recalling information. In addition because of possible taxation considerations there may be a tendency for farmers to over-estimate costs and underestimate returns.

The two districts were selected because farmers in the area were early adopters of tractors and used about 32% of total tractor horsepower consumption of the 20 districts of West Java. The districts are also major rice-producing areas, and are well irrigated. In 1978, the number of hand tractors reached 137 units or about 934 hp in Subang. In Indramayu hand tractors numbered 260 units, totalling 1889 hp. The most common brands used by farmers in the area were Kubota, Honda, Patra and Yanmar.

Social Features

The household heads of tractor-owning farms were older and had more schooling and farm experience than those of tractor-hiring farms and manual/hoeing farms. Family size and potential family labor (family members 10 years old and above) of the three types of farms did not vary greatly during the wet and dry seasons. Manual/hoeing farms had the highest real family labor (defined as the number of family members who work on their own farms) compared to the real family labor of other types of farms (tractor-owner farms and tractor-hired farms). During the wet season, real family labor of manual/hoeing farms, tractor-owner farms and tractor-hired farms were 1.65, 1.10 and 1.07 persons respectively. Real family labor was 1.51 persons for manual/hoeing farms, 1.16 persons for tractor-owner farms and only 1.02 persons for tractor-hiring farms during the dry season.

For tractor-owner farms, permanent labor, (labor hired on a contractual basis for a certain period of time) had a more important role in farm operations than on the two other types of farm. This is because the tractor driver may be the only permanent male labor on tractor-owner farms. Sometimes he will take the place of the household head in supervising field workers (hired labor) in farm operations. Permanent female labor serves as household help, nursing the children and preparing meals for family members and field workers. Farmers who owned cattle usually used their children to feed or tend them. Permanent laborers were mostly paid seasonally or annually in kind (paddy rice), aside from provisions (i.e. food, clothing and shelter). The existence of permanent labor on farms is clearly related to the level of prosperity of the farmer. Permanent labor was 0.79 persons for tractor-owner farms, 0.08 for tractor-hired farms, and 0.09 for manual/hoeing farms during the wet season. In the dry season these figures were 0.84, 0.15 and 0.14 persons, respectively.

Economic Features

Farm size and tenure. Landholding, defined as the total of land owned and net rented in and out, was related to the type of farm. In general the higher the level of mechanization, the larger the landholding. The same trend applies to operated land. This might be based on the fact that more income can be derived from larger farms (primarily from rice sales) to finance the purchase of tractors. Landholding and operated land differed significantly among the three types of farms.

Based on land tenancy of all operated parcels of sample farms, a farmer can be classified as either an owner-operator, part owner-operator, lessee-operator, or a share-cropping operator. More than two-thirds of the farmers on tractor-owner farms and tractor-hiring farms were owner-operators. The remaining third were part-owner, lessee, share-croppers and others. For manual/hoeing farms, about 60% of the total land holders consisted of owner-operators. The second largest landholder category after owner-operators was lessee-operator for both tractor-owner farms and tractor-hired farms, and share-cropper operator for manual/hoeing farms.

Improved input use and yield. Improved inputs include high yielding variety (HYV) seeds, chemical fertilizer, and pesticides such as herbicides, insecticides, and rodenticides. The most common rice varieties used by farmers in the study were C4-63, IR26 and IR28. The types of fertilizer used were single fertilizer, urea (40 to 45% N), and triple superphosphate (TSP). Sevin, Furadan, Thiodan, Gamma BHC and Basudin were pesticides commonly used on the farms.

More fertilizer, but less seed and pesticide, were used during the wet than the dry season of farm. During both seasons, tractor-hiring farms had the highest fertilizer use. Fertilizer consumption during the wet season was 341 kg per ha (251 kg urea and 90 kg TSP). During the dry season, total fertilizer used by tractor-hiring farms was 313 kg (233 kg urea and 80 kg TSP). Mechanized farms had higher yields per hectare than non-mechanized farms during the dry season. This cannot, however, be solely attributed to mechanization, since almost 24% of the non-mechanized farms harvested crops from only 50% of the area planted, due to extensive damage by rats and stemborers. The difference in yield between mechanized and non-mechanized farms was insignificant during the wet season. Apparently, the highest yield attained by tractor-hired farms was not due to the level of mechanization, but primarily to massive fertilizer use during both seasons. Mechanized (tractor-owner and tractor-hired) farms have slightly higher yields per hectare than non-mechanized (manual/hoeing) farms.

Patterns of labor use. Mechanization has changed the pattern of labor use in terms of both the source and the type of labor. During the wet season, non-mechanized farms used a total of 1691 hours per hectare, while tractor-owner farms and tractor-hiring farms used only 1034 and 1205 hr/ha respectively. The corresponding figures are 1186 hr, 996 hr and 1609 hr/ha for manual/hoeing farms, tractor-owner farms and tractor-hiring farms respectively during the dry season. These figures of total human labor used support the hypothesis that mechanization replaces human labor, especially at the land preparation stage. In terms of source of labor, on mechanized farms family labor constitutes only 5 to 11% of the total human labor used. The remainder is hired. On non-mechanized farms family labor makes up 23 to 26% of total labor use. Tractor owners and tractor-hiring farms used almost the same proportions of male and female labor. For manual/hoeing farms, however, male labor use per hectare was higher than female labor, accounting for about 60% of labor use.

RESULTS

Tractor Ownership Survey

Gasoline tractor owners (46) stated that they found machines cheaper in land preparation. Diesel tractor owners (18) stated their main reason in using a machine was that it enabled them to plant on time.

The average age of gasoline tractors was 2.06 years, and of diesel tractors 1.75 years. Fifty percent of both sample groups had a machine size of 7 horsepower. In terms of the area served, both types of tractor were used less on the owner's farm than off-farm. The area served per year averaged 23.9 ha for diesel tractors and 20.7 ha for gasoline tractors.

Private Profitability Analysis

Two analyses were conducted to determine the profitability of tractor ownership: benefit-cost analysis and break-even analysis. Benefit-cost analysis calculates the benefit-cost ratio (B/C), the net present value (NPV) and internal rate of return (IRR). Break-even analysis refers to the computation which equates costs and returns based on a simulated average cost curve. Two alternative buying prices of tractors were used for each analysis. Buying price I is the price derived from the survey data, or the average buying price of a sample tractor. The average prices were Rp 783 600 for a gasoline tractor, and Rp 1 360 179 for a diesel tractor. Buying price II is the current buying price of a new tractor ready for use: Rp 1 500 000 for a gasoline tractor and Rp 3 000 000 for a diesel tractor.

Results of the benefit-cost analysis are summarized in Table 2. At buying price I both types of tractor are still profitable to operate as denoted by their positive net present values (NPV), benefit-cost ratios (B/C) greater than unity and internal rates of return (IRR) higher than the opportunity cost of the capital (12%). Conversely, ownership of both types of tractor at buying price II is not profitable. Based on the actual area served, the profitability of tractor ownership is very sensitive to the buying price, but is only slightly affected by the discount factor.

The results of the profitability analysis using buying price II should be treated with appropriate caution. In particular, two specific points should be borne in mind. First, there is suspicion of bias in the computation procedure. Net present values (NPV), benefit-cost ratios (B/C) and internal rates of return (IRR) obtained using the survey data may be underestimated. The benefit from a new tractor should be higher than that of the old one because of the potentially

Table 2. Benefit-cost ratios (B/C), net present values (NPV) and internal rates of return (IRR) for operation of sample tractor. West Java, 1979-80.

	Gasoline tractor (n = 43)		Diesel tractor (n = 18)	
	Undiscounted	Discounted at 12%	Undiscounted	Discounted at 12%
Benefit/cost ratio (B/C)				
Buying price I[a]	1.19	1.02	1.29	1.04
Buying price II[b]	0.93	0.74	0.84	0.62
Net present value, NPV (Rp)				
Buying price I[a]	421 548[c]	28 352	782 413[c]	83 955
Buying price II[b]	-223 212[c]	-651 727	-693 426[c]	-1 472 727
Internal rate of return, IRR (%)				
Buying price I[a]	13.25		14.11	
Buying price II[b]	1[d]		1[d]	

[a]Buying price I is the average buying price of a sample tractor. The buying price is Rp 783 600 for a gasoline and Rp 1 360 179 for a diesel tractor.

[b]Buying price II is the current buying price of a new tractor ready for use. This is Rp 1 500 000 for a gasoline tractor and Rp 3 000 000 for a diesel tractor.

[c]In strict usage, this figure represents net benefit (NB) instead of net present value (NPV)

[d]This means that the IRR is less than the opportunity cost of the capital of 12%.

larger area served by the new tractor. On the other hand, average variable costs of a new tractor could be lower than those of an old one because of the lower cost of repair and maintenance and more efficient use of fuel and oil/lubricants of new machines. Second, although from the private economic viewpoint the ownership of a tractor seems unjustified, it may still be socially worthwhile, compared to farmers spending their earnings from rice sales for unproductive consumption purposes, e.g. on a motorcycle, television set or tape recorder, or to entertain guests during the fiesta. Furthermore, several farmers with larger farms considered ownership of a tractor as a source of pride and prestige and derived consumption benefits from their ownership in the form of trasnport, etc. Such factors are not incorporated in the analysis.

There does, however, appear to be an oversupply of tractors at prevailing custom-hire rates, tractor prices, interest rates and fuel costs. Adjustment in this market could take many forms, depending upon the competitive forces and surpluses accruing in these input markets. Cost items might fall in price in response to falling demand, but it seems most likely that the apparent disequilibrium in the tractor hiring industry will to a large extent be removed by contractionary market forces. Some tractor owners will not replace their assets, having had difficulty repaying their previous loans. With a smaller number of tractors, the area served by each tractor might rise; custom-hire rates may go up, and a competitive market equilibrium would occur where all tractor-owners earn normal profits and all costs are just covered. Such as long term adjustment mechanism will, however, be a somewhat inefficient and painful one, and government intervention may be necessary to iron out some of the fluctuations. Maranan (1981) observed similar behavior in the Philippines power tiller industry.

Breakeven point (cost curve) analysis. Results of a cost curve analysis are presented in Figures 2 and 3. These cost curves were derived from fixed and variable costs for operating both types of tractors. To obtain the figures used in plotting the curves, each tractor's total fixed cost (based on buying prices I and II) was divided by the area served, then added to the average variable cost (AVC). The resulting figures are expressed as an average total cost (ATC) per hectare.

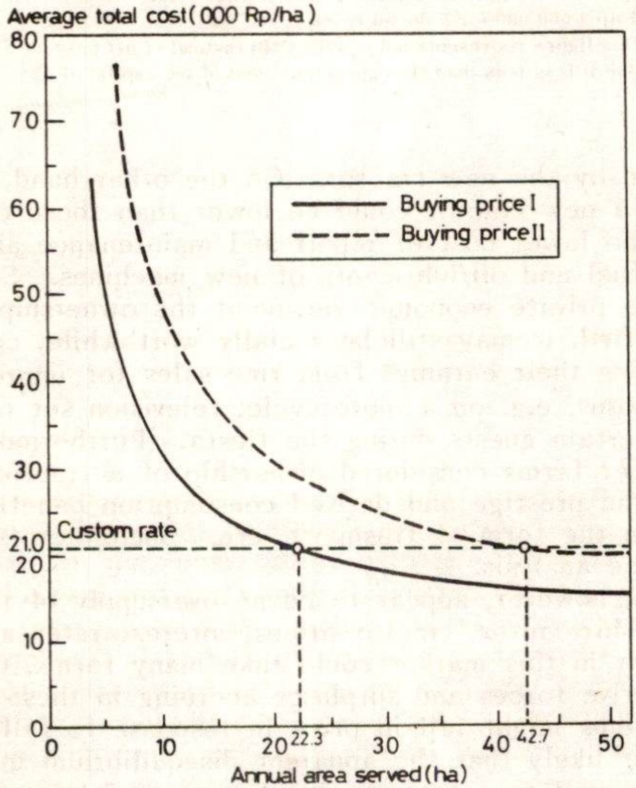

Figure 2. Relationship between cost and area served for a gasoline tractor. West Java, 1979-80

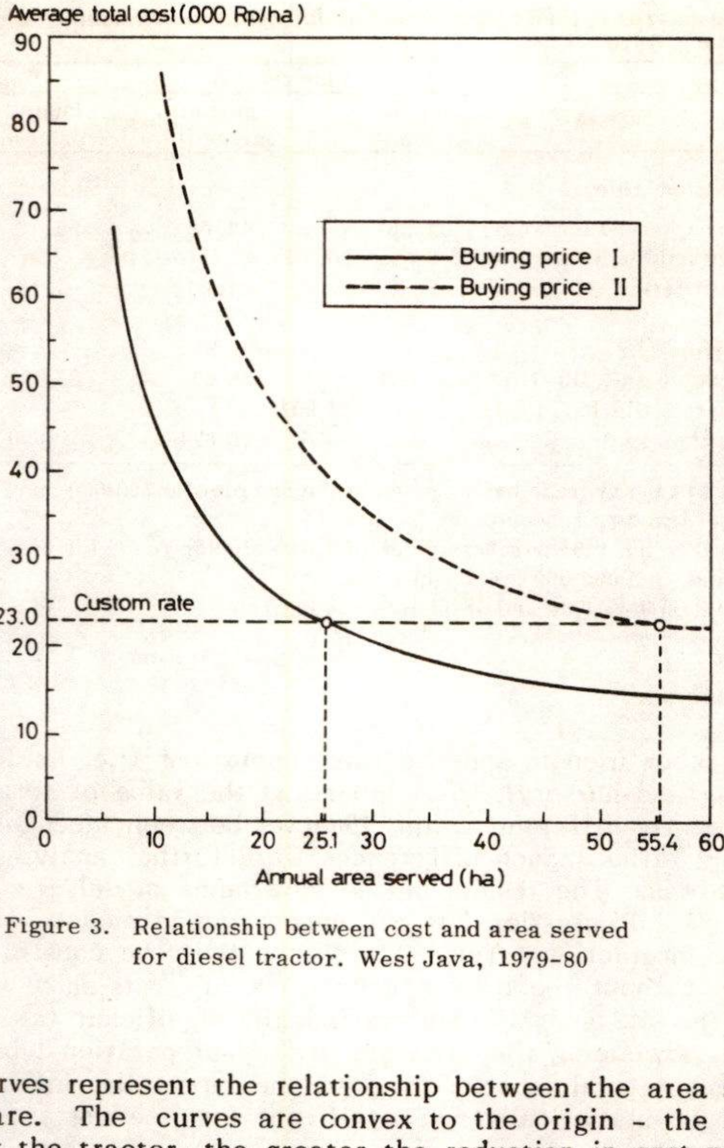

Figure 3. Relationship between cost and area served for diesel tractor. West Java, 1979-80

Cost curves represent the relationship between the area served and ATC per hectare. The curves are convex to the origin - the larger the area served by the tractor, the greater the reduction in cost per hectare.

Based on the actual/existing custom rate, the breakeven area served by gasoline tractors is 22.3 ha and 42.7 ha per year, using buying prices I and II respectively (Table 3). Similarly, the break-even area for a diesel tractor is 25.1 ha and 55.4 ha per year for buying prices I and II respectively. On the other hand, if the actual area served is maintained, it would be necessary for gasoline tractor owners to charge Rp 21 700/ha to cover all costs based on buying price I, and Rp 30 600 based on buying price II. Similarly, for diesel tractors breakeven custom rates of Rp 23 700 and Rp 41 400 would be necessary to cover all costs at buying prices I and II respectively.

Table 3. Breakeven area served and custom rate for operation of sample tractors. West Java, 1979-80.

	Gasoline tractor			Diesel tractor		
	Buying price I[a]		Buying price II[b]	Buying price I[a]		Buying price II[b]
Based on actual custom rate						
Break-even area served (ha/year)	22.28		42.66	25.12		55.41
Actual area served (ha/year)		20.70			23.94	
Difference (ha/year)[c]	-1.58		-21.96	-1.18		-31.47
Based on actual area served						
Break-even custom rate (Rp/ha)	21 669		30 628	23 697		41 369
Actual custom rate (Rp/ha)		21 004			23 007	
Difference (Rp/ha)[c]	-695		-9 624	-690		-18 362

[a] Buying price I is the average buying price of the sample: Rp 783 600 and Rp 1 360 179 for gasoline and diesel tractors respectively

[b] Buying price II is the 1981 purchase price of a new tractor ready for use: Rp 1 500 000 for gasoline tractor and Rp 3 000 000 for diesel tractor.

[c] Between actual custom rate and breakeven custom rate.

Covariance Analysis

Human labor used in specific farm operations (i.e. land preparation, weeding and nursery), total labor and the value of total labor are all significantly different at the 1% level between mechanized and non-mechanized farms. Such differences were further analyzed using covariance analysis. The results of the covariance model are presented in Tables 4 to 6. Regression I is the unconstrained model which incorporates the interaction terms. Regression II is the constrained/non-additive model without the interactions terms. F-tests show that the interaction terms MS and MW are statistically significant (at 5% level) for regressions explaining the variation in land preparation labor, total labor and value of total labor. However, the interactive influences were found to be statistically non-significant for weeding and nursery labor (unreported).

The value of the coefficient of determination (R^2) obtained from the analyses is smaller than 50%. This indicates that less than 50% of the variation in labor use can be attributed to the selected explanatory variables. Judging from the corrected coefficients of determination (R^2), regression I (additive model) is better than regession II. However, for discussion purposes both regressions are used. Furthermore, the results of the analysis show that there is multi-colinearity between season (W) and the interaction term of mechanization and season (MW) ($r = 0.75$), and between age (A) and farm experience (P) ($r = 0.85$).

Table 4. Results of covariance analysis on human labor used in land preparation (hr/ha). West Java, 1979-80.

Independent variables	Dependent variable Regression I	Regression II
Intercept	125.709***	135.837***
	(49.879)[a]	(47.666)
(M) Mechanization	-156.016***	-212.148***
	(30.378)	(20.083)
(S) Soil condition	- 8.041	15.268
	(24.845)	(17.402)
(W) Season	218.662***	94.340***
	(25.379)	(17.376)
(H) Size of landholding	- 1.707	- 1.850
	(2.941)	(3.048)
(A) Age of farmer	- 0.783	- 0.405
	(1.290)	(1.341)
(E) Farmer's education	- 3.299	- 3.757
	(2.424)	(2.494)
(P) Farm experience	0.784	0.306
	(1.459)	(1.525)
(N) Potential labor	1.265***	1.201***
	(0.281)	(0.294)
(F) Value of fertilizer used	6.753***	6.806***
	(1.267)	(1.325)
(MS) Interaction term, mechanization-soil condition	34.701	NA
	(33.147)	
(MW) Interaction term, mechanization-season	-213.993***	NA
	(33.139)	
(R^2) Coefficient of determination	0.429	0.372
($\bar{R}^2$) Correlated coefficient of determination	0.414	0.358
(n) Number of observations	429	429

NA = not applicable

[a]Figures in parentheses are standard errors of the estimated coefficients

*Significant at 10% (*), 5% (**), and 1% (***) levels

$F_{r;\ N-K}$ (Computed F ratio with 2 and 420 degrees of freedom) = 21.26, greater than F table (significant at 5% level) value of 3.02.

Table 5. Results of covariance analysis on total human labor (hr/ha). West Java, 1979-80.

Independent variables	Dependent variable	
	Regression I	Regression II
Intercept	817.705***	762.191***
	(157.184)[a]	(146.726)
(M) Mechanization	-166.052*	-207.434***
	(95.651)	(61.759)
(S) Soil condition	- 90.512	28.921
	(78.320)	(53.526)
(W) Season	478.457***	213.607***
	(80.004)	(53.477)
(H) Size of landholding	- 21.714**	- 22.354**
	(9.172)	(9.376)
(A) Age of farmer	- 1.216	0.122
	(4.066)	(4.132)
(E) Farmer's education	- 13.078*	- 12.293*
	(7.631)	(7.67)
(P) Farm experience	2.373	1.152
	(4.600)	(4.698)
(N) Potential labor	4.558***	4.394***
	(0.885)	(0.905)
(F) Value of fertilizer used	22.693***	23.081***
	(3.994)	(4.081)
(MS) Interaction term, mechanization-soil condition	198.122**	NA
	(104.403)	
(MW) Interaction term, mechanization-season	-451.665***	NA
	(104.359)	
(R^2) Coefficient of determination	0.268	0.230
(R^2) Corrected coefficient of determination	0.249	0.214
(n) number of observations	430	430

NA = not applicable

[a]Figures in parentheses are standard errors of the estimated coefficients.

*Significant at 10% (*), 5% (**), and 10% (***) levels

$F_{r,\ N-K}$ (computed F ratio with 2 and 421 degrees of freedom) = 6.80, greater than F table (significant at 5% level) value of 3.02.

Table 6. Results of covariance analysis on value of total human labor (000 Rp/ha). West Java, 1979-80.

Independent variables		Dependent variable	
		Regression I	Regression II
Intercept		98.162***	93.258***
		(16.477)[a]	(15.237)
(M)	Mechanization	-8.554	-11.610*
		(10.027)	(6.413)
(S)	Soil condition	-22.728***	-12.593**
		(8.210)	(5.558)
(W)	Season	37.004***	15.210***
		(8.387)	(5.553)
(H)	Size of landholding	-2.032**	-2.987**
		(0.961)	(0.974)
(A)	Age of farmer	-0.575	-0.463
		(0.426)	(0.429)
(E)	Farmer's education	-0.939	-0.867
		(0.800)	(0.797)
(P)	Farm experience	0.680	0.578
		(0.482)	(0.488)
(N)	Potential labor	0.448***	0.435***
		(0.093)	(0.094)
(F)	Value of fertilizer used	2.615***	2.649***
		(0.419)	(0.424)
(MS)	Interaction term, mechanization-soil condition	16.854	NA
		(10.944)	
(MW)	Interaction term, mechanization-season	-37.154***	NA
(R^2)	Coefficient of determination	0.225	0.200
(R^2)	Corrected coefficient of determination	0.205	0.183
(n)	Number of observations	430	430

NA = not applicable

[a]Figures in parentheses are standard errors of the estimated coefficients.

*Significant at 10% (*), 5% (**), 1% (***) levels

$F_{r,\ N-K}$ (computed F ratio with 2 and 421 degrees of freedom) = 10.92, greater than F table (significant at 5% level) value of 3.02.

The covariance analysis revealed that mechanization has a significant negative effect on land preparation labor and total labor use per hectare. In other words, mechanization decreases labor used in land preparation and total labor use. Labor use per hectare in land preparation and total labor use by mechanized farms in regression I were respectively 156.02 and 166.05 hours lower than those of nonmechanized farms. In regression II, the corresponding figures are

212.15 and 207.43 hours. Although its effect was non-significant, mechanization had a negative effect on weeding and nursery labor and on the value of total labor. Furthermore, the findings show that in addition to the mechanization dummy, the other key variables affecting land preparation labor are season and the interaction term between season and mechanization, potential labor and value of fertilizer used. The major variables that affect total labor use are season and its interaction with mechanization, size of landholding, farmer's education, potential labor, value of fertilizer used and the interaction between mechanization and soil condition.

POLICY IMPLICATIONS

In the study area, labor shortages, primarily in land preparation, appear to be a binding constraint for the larger rice-producing farms. Since the period of water availability is tightly scheduled, the time available for land preparation labor is concentrated in a short period and it is sometimes difficult to get necessary labor.

Two approaches to this problem can be used. The first is to increase the mobility of existing labor through an improved flow of labor market information in order to better equalize demand and supply over space and time. Wage rises for peak periods could perform this function. In designing an appropriate policy regarding mobilization of existing labor, however, in-depth research must be carried out concerning the demand-supply pattern of agricultural labor, season by season at least at the kecamatan (sub-district) level and preferably at the kabupaten (district) level.

As a second approach, it may be necessary to increase the land preparation power capacity of the study area through the introduction of more draft animals and mechanical power. This seems difficult. At present the condition is not favorable to draft animals, primarily because of a large decrease in available grazing areas. Often the only available grazing is on the edges of forests which are some distance from the farm owner's residence. This situation causes difficulties in both animal care and control. Animals are often stolen, and wages for permanent labor for feeding or tending the animals are high. Another problem is the threat of the irrigation authority and village officials to impose fines on farmers who let their animals wallow in the irrigation canals and roam on village roads, especially during the wet season.

Therefore, the introduction of selective mechanical power/tractorization could be appropriate in increasing land preparation power capacity. The government should provide guidance in the adoption of farm machinery in such a way that tractorization would intensify and expand output in the agricultural sector. Recent data on the tractor population shows a continuously increasing trend without preferential credit facilities. This is supported by the fact that of 68 sample tractor owners, only 7 bought tractors through formal credit facilities (government banks) and nonformal sources (moneylender, their family, etc.). The real question, therefore, is perhaps not whether farms are to be mechanized or not, but how should mechanization be carried out? The findings suggest that tractor ownership should not be restrcited to larger farmers since many of them already have a sufficiently large area to employ a hand tractor.

The point to be borne in the policymaker's mind is how to set up some short term interim guidelines to minimize--if not eliminate--the undesirable labor-displacing side-effects of mechanization. Policy measures can be implemented as follows: first, the tractorization program should consider shortage of labor by season (busy and idle time), location (densely or non-densely populated area in relation to availability of labor), and size of farm (larger farms more often have shortages of labor than smaller farms). This is popularly called a "selective mechanization program". Second, the adoption of tractorization should be steered along an "intensification" pathway. Thus, mechanizing farmers should increase their cropping intensity (i.e., double or triple cropping) on their existing cultivated area (McInerney and Donaldson, 1975). If mechanizing farmers are in some way constrained from expanding farm size beyond a minimum efficient level, then they will be more inclined to seek these intensity increases (either on their own farms, or by hiring out tractor services to neighboring non-mechanized farms) as the only means to make their capital investment economically justified. Otherwise, mechanization follows the wrong route, called the "extensification pathway". This means mechanizing farmers expand their annual cropped area by taking over the land already cultivated by another farmer.

To prevent or at least minimize displacement of human labor, machinery should be introduced together with an "improvement package" including improved seed, fertilizers, pesticides, irrigation and better management. This "package deal" should increase human labor use and even lead to the creation of employment opportunities. In other words, mechanization is just one part of a technology choice complex, and the availability of a full array of complementary inputs must be ensured.

With regard to the private profitability of tractor ownership at buying price I, both types of tractors are still profitable to operate. The results of profitability analysis, using buying price II, which shows that tractor ownership is not profitable, should be interpreted carefully. First, there is a suspicion of bias in the computation procedure. Secondly, from the sociocultural viewpoint, instead of spending their money from rice sales on consumption, it might be better for farmers to spend it on a productive good such as a tractor. Although from the private economic viewpoint a tractor appears unjustified, it may still be a socially worthwhile long run alternative. The constraints or deterrents to unnecessary consumption expenditure might be, for example, some form of progressive tax on durable goods ownership beyond a certain need, or a high fee to permit farmers to hold fiestas more than a certain number of times within a year. However, the availability of consumer goods may be necessary to induce output responses from farmers.

To make tractor ownership economically justified, two policy measures are suggested. On the ownership side, if mechanizing farmers are in some way constrained from expanding farm size beyond a minimum level or cannot reach break-even point for the area served, joint ownership and operation of one hand tractor by two or three farmers is advisable. This cooperation can be carried out primarily through kinship. On the other hand, the operational problems related to mechanization should be given immediate and proper attention by coordinating government agencies (agriculture, credit, industries and manpower agencies) and private agencies (i.e. tractor dealers) in establishing and directing workshop facilities. Presently, tractor owners must go to Karawang (the nearest district capital to the study area), Bandung (the provincial capital) and Jakarta (the national capital) to buy spare parts. Workshop facilities with adequate space, technical personnel and stocks and spare parts should be established strategically in Subang, Indramayu and Pamanukan. A policy framework to prevent or minimize undesirable effects of mechanization on casual and displacement labor, especially landless labor, should also be considered and the effects on employment at both the regional and national levels should be evaluated.

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