PN-AAQ-930
ISN 36449

THE CONSEQUENCES OF SMALL RICE FARM MECHANIZATION PROJECT

Working Paper No. 72

THE ECONOMIC IMPACT OF MECHANICAL LAND PREPARATION UNDER CONDITIONS OF WEATHER UNCERTAINTY

By

B. Reyes
The International Rice Research Institute

1983

The Consequences of Small Rice Farm Mechanization Project is supported by the United States Agency for International Development under Contract tac-1466 and Grant No. 931-1026.01 and is being implemented by the International Rice Research Institute and the Agricultural Development Council, Inc.

THE ECONOMIC IMPACT OF MECHANICAL LAND PREPARATION UNDER CONDITIONS OF WEATHER UNCERTAINTY*

Blanquita Reyes**

ABSTRACT

A discrete stochastic linear programming model was used to determine if mechanical land preparation can increase net income and cropping intensity under conditions of weather uncertainty. Four weather combinations, (1) good wet season good dry season; (2) good wet season bad dry season; (3) bad wet season good dry season; and (4) bad wet season bad dry season, were evaluated in the model. Two representative farms, one irrigated and the other rainfed were developed using survey data from the IRRI Consequences of Farm Mechanization Project. Bounding activities, which are restrictions on the level of activities, were included to create six farm types. Net incomes and cropping intensities were computed from the optimal solutions for each of the six farm types.

---

*A summary of the author's M.Sc. Thesis "The Economic Impact of Mechanical Land Preparation on Rice Farmers in Nueva Ecija Under Conditions of Weather Uncertainty". College of Development Economics and Management, UPLB, Los Baños, 1982.

**Former Research Fellow, Economics Section, IRRI Agricultural Engineering Department, Los Baños, Laguna.

Results showed that mechanical land preparation not increase net income and cropping intensity of small, irrigated farms or the net income of small, rainfed farms. Mechanical land preparation did increase cropping intensity on small, rainfed farms only under good-good and good-bad weather combinations.

INTRODUCTION

Mechanical power and equipment along with high yielding varieties, fertilizers and other chemicals, and irrigation systems are needed to increase agricultural output in less developed countries like the Philippines (Cantada 1979). The government provides long term loans for farm machinery acquisition to encourage farmers to mechanize. The major credit institutions providing loans for farm machinery acquisition are the Central Bank through the Rural Banking systems (CB:IBRD), the Development Bank of the Philippines (DBP), the Land Bank of the Philippines (LBP) and the Agricultural Credit Administration (ACA). Credit programs are however, biased towards irrigated farms and large rainfed farms. CB:IBRD loans for four-wheel tractors were made available in the early 1970s to farmers with minimum holdings of 40 hectares of unirrigated or 25 hectares of irrigated land. For two-wheel tractors, the farm area should be at least 8 and 5 hectares for rainfed and irrigated farms, respectively. The LBP provides loans for the purchase of power tillers on two-hectare farms which are fully irrigated. The ACA extends loans to three-hectare farms which are fully irrigated at an interest rate of 15%/year.

Of the farm machinery and equipment available, farmers seem to prefer four- and two-wheel tractors. These machines, used primarily for plowing and harrowing, are labor saving, till the land quickly, loosen the soil more easily, and seldom destroy the dikes that are patiently built before each crop (Alviar 1974).

Weather plays a decisive role in food production since it can affect the success or failure of food production programs (Serquina 1977). Decisions by Filipino farmers are often influenced by weather conditions. Beneke and Winterboer (1973) point out that the number of hours or days which land worked varies with weather. The longer heavy rains or drought prevail, the longer land preparation and the planting season, is delayed. Late sowing of the first crop delays planting of the succeeding crop. Farmers, therefore, need to hurry their operations to avoid incur major delays. Use of tractors makes this possible.

Farm plans are not based on the assumption that unsuitable weather will prevail every year. Nor do farmers plan assuming favorable weather each season. Random weather conditions affect the use and amount of inputs applied. With land preparation delayed due to adverse weather, planting and harvesting dates are delayed. Yield is less when there are typhoons or too much rain. Thus, land preparation, planting, and harvesting dates, yield, as well as labor and machinery and other inputs used for production are affected by prevailing weather conditions. This study, however, is concerned only with the effect of various weather conditions on land preparation.

With the risk of bad wet season weather, will the farmer be able to recover his investment in buying or hiring-in a two-wheel tractor? Acknowledging that weather uncertainties have an impact on a farmer's machinery use/investment decision, this study evaluates the potential benefits of mechanical land preparation under conditions of weather uncertainty.

The possibility of increasing cropping intensity in the Philippines using mechanization was mentioned by Alviar (1974) and Moss (1980). However, studies assessing the impact of mechanization on cropping intensity show varied results. Studies in the Philippines (e.g., King, 1974 and Duff, 1978) and Pakistan (e.g., Ahmad 1979) conclude that tractor mechanization increases cropping intensities only if adequate irrigation facilities are available. However, Pudasaini (1976) and Sharma's (1978) studies, conducted in Nepal and India, respectively, concluded that cropping intensity increased through use of mechanical land preparation assuming irrigation quality was constant.

Alviar (1974), Pudasaini (1976), Sharma (1978) and Ahmad (1979) all found that net income could be increased through mechanization. However, Singh and Yadao (1979) found that power tiller farms produced higher net incomes than animal-cultivated farms while four-wheel tractor farms earned less than both farms.

Specifically, this study aims to assess whether mechanical land preparation can increase the cropping intensity and net income of small rice farmers under conditions of weather uncertainty.

METHODOLOGY

The mechanization study in the Philippines was conducted in Cabanatuan City and Guimba in the province of Nueva Ecija. Selection was based on the type and extent of irrigation available and the degree of mechanization in land preparation. Data for the 1979 wet season and 1980 wet and dry seasons collected as a part of the Farm Mechanization Consequences project using a series of cross-sectional surveys and complementary daily recordkeeping activities (Moran and Casillan 1981), formed the basis for the study.

Selection of Typical Farms

Farm households were divided into irrigated and rainfed classes. A three-way table (Table 1) was constructed and the number of households in each class was summed. The class having the largest number of households was the modal class. Farms not belonging to the modal class were eliminated. One farm from each classification was randomly chosen from those remaining.

Description of the Model

The study used discrete linear stochastic programming to test the various hypotheses. Merrill (1965), Cocks (1968), Rae (1971a and 1971b) and Anderson, et al (1977) each used this programming technique.

The first step in discrete stochastic linear programming (DSLP) is to obtain the distribution probability of each state of nature. This involves isolation of decision dates and the division of planting periods into a number of stages, definition of the possible random events (states of nature) within each stage, specification of the subjective probabilities of each state that will occur, and statement of the appropriate information structures (Rae 1971b).

Crop year was divided into wet and dry seasons. The wet season for the irrigated farms was from June to November, while the dry season was from December to May. Due to water constraints, the length of each season for the rainfed farm types was shorter than for irrigated farms June to October for the wet season and October to December for the dry season.

The second step was division of the distribution of values that each random variable could take. The outcomes of the weather variables of the two seasons were divided into two segments, -- good and bad. No strict metereological definition was given to the two weather conditions. All possible combinations of weather variables (rainfall, temperature, etc.) that might be measured by a weather index

were replaced by a relatively small number of broadly defined states. Determination of the two weather conditions was based on the delay in land preparation resulting from typhoons or drought. Bad weather was defined as a delay in the land preparation due to typhoons or drought. Good weather was defined as the absence of typhoons or drought during the land preparation period. The probability of a bad season for irrigated farm types was based solely on the occurence of typhoons since droughts have no effects on these farms. The probability of typhoons occuring in the early part of June and December was computed using a thirty-year record of tropical cyclones and rainfall data gathered from the IRRI Multiple Cropping Department. The probability of a bad weather on rainfed farms was computed as:

$$P_B = \frac{N_o}{30 \text{ years}} \qquad P_A = 1 - P_B$$

where:

P_B is the probability of bad weather

N_o is the number of years land preparation was delayed due to typhoons or droughts

P_A is the probability of good weather

Input-output coefficients were derived from budgets of activity operations, resource requirements and cash flows constructed for each possible state of nature.

The objective function of the model maximized net farm income. Expressed in mathematical equation, the objective function is:

$$\text{Max } Z = \sum_{w=1}^{2} P_{1,w} \left(\sum_{w=1}^{2} \sum_{i=1}^{n} \sum_{t=1}^{n} C_{1,w,i,t} X_{1,2,i,t} \right) +$$

$$\sum_{d=1}^{4} P_{2,d} \left(\sum_{d=1}^{4} \sum_{i=1}^{n} \sum_{t=1}^{n} C_{2,d,i,t} X_{2,d,i,t} \right)$$

where:

Z is the total net income and the indices:

w refers to the weather condition in the wet season such that

1 = good

2 = bad

i refers to the activity

t refers to time

d refers to the weather condition in the dry season such that

1 = good weather following good weather

2 = good weather following bad weather

3 = bad weather following good weather

4 = bad weather following bad weather

$C_{i,w,i,t}$ is a vector that contains the ith activity payoffs and costs for the wet season given w weather at time t

$C_{2,d,i,t}$ is a vector that contains the ith activity payoffs and costs relevant for the dry season given d weather at time t

$X_{1,w,i,t}$ is a vector of the ith activity levels in the wet season given w weather at time t

$X_{2,d,i,t}$ is a vector of the ith activity levels in the dry season given d weather at time t

$P_{1,w}$ and $P_{1,d}$ are the probabilities of different weather conditions in the wet and dry seasons, respectively.

subject to the following constraints:

$$
\begin{array}{llll}
A_{1,g}X_{1,g} & & & \leq b_{1,g} \\
 & A_{2,gg}X_{2,gg} & & \leq b_{2,gg} \\
 & A_{2,gb}X_{2,gb} & & \leq b_{2,gb} \\
A_{1,b}X_{1b} & & & \leq b_{1,b} \\
 & A_{2,bg}X_{2,bg} & & \leq b_{2,bg} \\
 & A_{2,bb}X_{2,bb} & & \leq b_{2,bb} \\
-IX_{1,g}^{*} & IX_{2,gg}^{*} & IX_{2,gb}^{*} & \leq 0 \\
-IX_{1,b}^{*} & IX_{2,bg}^{*} & IX_{2,bb}^{*} & \leq 0
\end{array}
$$

and $X_{1,w,i,t}$ and $X_{2,d,i,t}$ ≥ 0

where:

$A_{1,g}$ is the matrix of wet season input-output coefficients given good weather

$A_{1,b}$ is the matrix of wet season input-output coefficients given bad weather

$A_{2,gg}$ and $A_{2,gb}$ are matrices of dry season input-output coefficients given good weather in the wet season and good and bad weather, respectively, in the dry season

$A_{2,bg}$ and $A_{2,bb}$ are matrices of dry season input-output coefficients given bad weather in the wet season and good and bad weather, respectively, in the dry season.

$X_{1,g}$ and $X_{1,b}$ are vectors of activity levels to be initiated in the wet season given good and bad weather, respectively.

$X_{2,gg}$ and $X_{2,bg}$ are vectors of second-stage activity levels to be initiated given a good dry season following good and bad weather, respectively, in the wet season.

$X_{2,gb}$ and $X_{2,bb}$ are vectors of second-stage activity levels to be initiated given a bad dry season following good and bad weather, respectively, in the wet season.

$X_{1,g}^*$ and $X_{1,b}^*$ are vectors that include only those first-stage activities that are continued into the second stage, given good and bad wet seasons, respectively.

$X_{2,gg}^*$ and $X_{2,gb}^*$ are vectors that include only those second-stage activities that are continued into the second stage, given good and bad weather, respectively, in the dry season

$X_{2,bg}$ and $X_{2,bb}$ are vectors that include only those second stage activities that were initiated in the bad wet season, given good and bad weather, respectively, in the dry season.

$b_{1,g}$ and $b_{1,b}$ are vectors of resource supplies in the wet season, given good and bad weather.

$b_{2,gg}$ and $b_{2,gb}$ are vectors of resource supplies in the dry season, given good weather in the wet season and good and bad weather.

$b_{2,bg}$ and $b_{2,bb}$ are vectors of resource supplies in the dry season, given bad weather in the wet season and good and bad weather, respectively, in the dry season.

Z are the net returns

I is the identity matrix

Figure 1 shows a schematic representation of the model. The requirement of each restricted resource by a unit given activity was expressed by a coefficient, r, in the relevant vector row. Positive coefficients measure utilization or consumption per unit level of activity, while negative coefficients indicate an addition to the restraint per unit level of activity.

Objective function. The objective function (C_j) consists of six general terms. The first two deduct the costs of short-term and long-term loans. The third deducts the fixed cost of either a carabao or a two-wheel tractor. The fourth adds revenue from crop production, while the fifth deducts costs paid for hiring-in labor, carabao, two- and four-wheel tractors. The last term adds income from hiring-out a two-wheel tractor.

Constraints. Constraints were divided into three groups. First were those not affected by weather conditions (e.g. land and long-term loans). Second were those which become binding under good weather and the last, those which are active during bad weather. The constraints in the two situation were the same although the supply level varied according to weather conditions. Resource constraints include land, family labor, hired animal power, hired two- and

four-wheel tractor power and cash. Hired labor, total labor and cash were specified for a monthly period and long-term loans for a one-year period. The rest were defined fortnightly.

Activities. Activities were divided into current decision, good weather activities, and bad weather activities. Current decision activities were those made before the farmer knew if the coming season was good or bad. Included were level of land supply, short- and long-term loans and buying of either a carabao or a two-wheel tractor.

Good and bad weather activities included crop production alternatives, hiring-in of labor, animal power, a two-wheel and four-wheel tractor and hiring-out of animal power and a two-wheel tractor. Crop production alternatives included choices of crops, varieties, planting method and planting time.

Model Specification for a Typical Irrigated or Rainfed Farm.

The features of the two representative farms are shown in Table 2.

Irrigated farm. The land constraint for the irrigated farm was 2.5 hectares. Although there were five adult children who could help, only two worked regularly. With a labor input of 20 mandays per month each, the total available labor was 60 mandays per month including the farmer. Maximum hired labor was 70 mandays per month. Own animal and two-wheel tractor power were equal

to zero since it was assumed that at the start the farmer had neither a carabao or a two-wheel tractor. The maximum animal days that could be hired-in was 20 every two weeks. The maximum two-wheel tractor power that could be hired-in was twelve power tiller days per two weeks. The maximum four-wheel tractor power that could be hired-in was 12 tractor days during each two weeks period. These constraints were based on interviews with a farmer in the area. Cash supply at the start of the first cropping season was ₱750.

The farmer was required to pay the principal on short term loans as well as interest (interest rates were 6%/six months). The interest rate for long-term loans was 15%/year. A 40% down payment was required to purchase a two-wheel tractor with engine, costing ₱11,000.[1]

Only rice, the main crop planted was considered during the wet season. Different combinations of varieties, power used for land preparation, planting methods and planting times were allowed. Rice varieties included IR36, IR42 and PETA. Planting methods were transplanting and broadcasting, while planting times were early, mid, late and very late.

Rice, corn, mungbean and tomatoes were considered as alternative crops during the dry season. Rice varieties, planting methods and planting times were the same as those in the wet season. Alternative

---

[1]Based on interviews with personnel from General Agricultural Machineries, Incorporated (GAMI) in August, 1981.

varieties of corn, mungbean and tomatoes were not considered although different combinations of power for land preparation and planting times were permitted.

Farmers paid the National Irrigation Administration (NIA) 2.5 and 3.5 cavans[1] per hectare in the wet and dry season, respectively, so long as water passed through his field.

Rainfed Farm. The maximum land area for the rainfed farms was 1.5 ha. Only two of five adult children worked regularly on the farm thus total labor available per month was 60 mandays including the farmer. Cash supply was ₱500 while supply of hired labor, own animal and two-wheel tractor power, hired animal power and hired two- and four-wheel tractor power were equal to those of the irrigated farm.

The alternative combinations of rice varieties, power for land preparation, planting methods and planting times for the wet season were the same as those of the irrigated farms. In the dry season, however only early and late broadcasting of mungbean were allowed due to restricted water supplies.

Creation of Six Farm Types

The discrete stochastic linear program was run using the Mathematical Package Extended (MPSX) 370 package. Bounding activities,

---

[1]One cavan is equal to 50 kilograms of rough rice.

which are restrictions on the level of any activity, were imposed to create three types of irrigated and rainfed farms. These bounds were:

1. Buying carabao was set equal to one, buying of a two-wheel tractor was zero and hiring-in of two- and four-wheel tractors was zero.
2. Buying of carabao was set equal to zero, buying a two-wheel tractor was one and hiring-in of a carabao was zero.
3. Buying carabao was set equal to zero, buying a two-wheel tractor was equal to zero and hiring-in of a carabao was zero.

The first bound defines a carabao owner farm; the second, a two-wheel tractor/owner farm and the third, a mechanical power hiring-in farm. These last two farms are mechanized. Hence, six classifications were created: (1) irrigated, carabao owner; (2) irrigated, two-wheel tractor owner; (3) irrigated, hiring-in mechanical power; (4) rainfed, carabao owner; (5) rainfed, two-wheel tractor owner; and (6) rainfed, hiring-in mechanical power.

The cropping intensities and net incomes of each farm type, computed from the optimal solution, were compared to determine if mechanical land preparation increased net income and cropping intensity.

RESULTS AND DISCUSSION

Irrigated Farm Types

Comparison of net income. The irrigated, carabao owner had the highest expected net income for all weather situation except the bad-bad combination (Table 3) since it incurred the lowest costs (Table 4). Most Filipino farmers spend little for medicine and usually let their carabaos graze on stubble, thus, little is spent for the food, care, and maintenance of the carabao. The two-wheel tractor owner had high fixed and variable costs due to high investment cost and expense of fuel and oil. The mechanical power hiring-in farm, spent for fuel and oil, and also paid a high custom rate, especially in a bad season.[1]

The two-wheel tractor owner incurred the highest cost for all weather combinations but his expected net income was not the lowest because he derived additional income from hiring-out of his power tiller. Due to the additional income derived from hiring-out the power tiller, the two-wheel tractor owner had the highest expected net income given a bad-bad weather combination. With custom rates higher in a bad season, income derived from custom services were higher under bad-bad combination.

---

[1] For details of why rates of hiring-in or hiring-out a two-wheel tractor is higher in a bad season, see Appendix.

Comparison of cropping patterns. Tables 5, 6 and 7 show the optimal cropping patterns for the carabao owner, two-wheel tractor owner and mechanical power hiring-in farm. Except for a bad dry season following a bad wet season, the two-wheel tractor owner and the mechanical power hiring-in farm had the same cropping patterns. The mechanized farm types favor the earliest possible transplanting/ planting time unlike carabao owner farms. The mechanized farm types had enough power to finish land preparation immediately and transplant quickly. An option not possible for the carabao owner farm.

A large part of each irrigated farm type was planted to IR42 in the wet seson regardless of weather condition because IR42 had the highest yield. Tomato production was included under all states of nature in the dry season because tomatoes are a cash crop and produced high profits. However, compared to rice, corn and mungbean tomatoes require considerable labor at harvest time.

Comparison of cropping intensity

From the optimal cropping patterns, the potential cropping intensity was computed as:

$$CI = \frac{A_w + A_d}{A_t} \times 100$$

where:

CI is cropping intensity

A_w is area planted in the wet season

A_d is area planted in the dry season

A_t is total farm area

Land preparation is much faster using a two- or four-wheel tractor. However, the cropping intensities for the three irrigated farm types remained the same (Table 8). This implies mechanical land preparation could not increase cropping intensity of a small, irrigated farm and it is the presence of proper irrigation systems which makes two cropping seasons possible.

Rainfed Farm Types

Comparison of net income. The carabao owner had the highest net income under all weather combinations (Table 9) because his expenditures were lower than other rainfed farm types (Table 10). The two-wheel tractor owner farm had the lowest expected net income under good-good and good-bad combinations due to the high costs it incurred. The farm hiring in mechanical had the lowest net income during the bad-good and bad-bad combinations because the total area planted during those weather situations was lower compared with other rainfed farm types. A smaller cropped area also explained why the total costs of hiring-in mechanical power decreased for these weather combinations.

The area planted was smaller due to higher custom rates during bad seasons while the potential yield of the farm was low, being a rainfed farm.

The irrigated, two-wheel tractor owner always exhibits higher net income than the irrigated, mechanical power hiring-in farm. This, however, was not true for the rainfed farm types because the additional costs for the income derived from hiring-out the power tiller by the irrigated, two-wheel tractor owner was greater than those of the rainfed, two-wheel tractor owner.

Comparison of cropping patterns. Tables 11, 12 and 13 show the cropping patterns of the carabao owner, two-wheel tractor owner and mechanical power hiring-in farms for each weather condition. Although IR42 has a higher potential yield than IR36, each farm type planted the latter, primarily in the wet season because it matures within four months thus permitting broadcast seeding of mungbean.

It takes five months for IR42 to mature. Thus, only 1.42 ha were available to the carabao owner farm for mungbean in October during both good and bad dry seasons following a good wet season. For the mechanical power hiring-in farm in the good and bad dry season following a bad wet season 0.95 ha could be used for mungbean farming.

Comparison of cropping intensity. Two-wheel tractor ownership proved to be beneficial since the two-wheel tractor owner had a 200% cropping intensity under all weather combinations (Table 14).

However, the mechanical power hiring-in farm had the lowest cropping intensity under the bad-good and bad-bad weather combinations because being rainfed, the farm had a low potential yield while the custom rate for hiring-in the power tiller during a bad season was high. The carabao owner had a lower cropping intensity than mechanized farm types in the good-good and good-bad weather combinations. Mechanical land preparation was to be favored under those weather combinations if the farmer wished to increase cropping intensity without considering the effect on net income.

Parameterization of Custom Rates

The custom rate for the two-wheel tractor was ₱85 and ₱110 per day given good and bad seasons, respectively. To determine the effects of lower contract rates, these rates were parameterized to P_{T1} and P_{T2}. P_{T1} was equal to ₱60 and ₱85 given good and bad seasons, respectively and P_{T2} was equal to ₱35 and ₱60 per day for good and bad seasons, respectively.

The optimal cropping pattern for the irrigated, two-wheel tractor owner farm did not change when custom rates were changed to P_{T1} and P_{T2} therefore cropping intensity remained the same. However, net income decreased. The same was true for the rainfed, two-wheel tractor owner farm. This further emphasized that ownership of a two-wheel tractor was of marginal benefit to small farms, irrigated or rainfed.

CONCLUSION

Mechanical land preparation did not increase net income because the fixed and variable costs of owning and using a power tiller was greater than for a carabao. Use of the power tiller did not increase cropping intensity on irrigated farms. The three irrigated farm types had the same cropping intensity under weather combinations. Mechanical land preparation increased cropping intensity for rainfed farms only in the good-good and good-bad weather combinations.

The results indicated that there is no need to promote mechanical land preparation in small, rainfed farms such as the representative farm. This is consistent with current credit programs. It was also not economically beneficial for small, irrigated farms to shift to mechanical land preparation even though credit for farm machinery acquisition was provided at low interest rates. This suggests there is no need for credit programs for small, irrigated farms.

The conclusions, however, are based only on the economic viability of using two- or four-wheel tractors for land preparation. Other factors, e.g., social and institutional, which affect farmers' decisions were not considered and may substantially mitigate these normative findings.

APPENDIX

The custom rate of hiring-out the two-wheel tractor during a good season was assumed to be lower than that in a bad season since no data were available. This assumption was based on the supply and demand for the two-wheel tractor during land preparation given bad weather. S_G and D_G are the supply and demand curves, respectively, while P_G is the custom rate given a good season (Appendix Figure 1).

Since land preparation is delayed during bad weather, farmers have to work more quickly to maintain planting schedules. Thus, the demand for the power tiller will increase. But with custom rates constant at P_G, the increase in demand causes the demand curve to shift from D_G to D_B. However, two-wheel tractor owners also rush their land preparation thus the amount of two-wheel tractor time available for hiring-out decreases. This shifts the supply curve from S_G to S_B. These shifts in the demand and supply curves will increase the equilibrium contract rate from P_G to P_B.

LITERATURE CITED

Ahmad, B. 1979. Bullock farming vs. tractor farming. Agricultural Mechanization for Asia 10 (3):51-54.

Alviar, N. G. 1974. An economic comparison of tractor-operated and water buffalo cultivated farms in Laguna, Philippines. In Herman Southworth and Milton Barnett (eds). Experience in Farm Mechanization in South East Asia. Agricultural Development Council, Inc., New York.

Anderson, J. R., J. L. Dillon and J. B. Hardaker. 1977. Agricultural Decision Analysis. Iowa State University Press, Ames, Iowa, 344 p.

Beneke, R. R. and R. Winterboer. 1973. Linear Programming Applications to Agriculture. Iowa State University Press, Ames, Iowa, 244 p.

Cantada, L. J. 1979. Status of Agricultural Mechanization in the Philippines. Paper presented during the Agricultural Engineering Research Planning Workshop held at PCARR Headquarters, Los Banos, Laguna.

Cocks, K. D. 1968. Discrete stochastic programming. Management Science 15 (1):72-79.

Duff, J. B. 1978. The mechanization and use of modern rice varieties. Economic Consequences of the New Rice Technology. IRRI, Los Banos, Laguna.

King, F. 1974. Evaluation of the CB:IBRD Agricultural Credit Program in the Philippines. In J. B. Duff. 1978. The mechanization and use of modern rice varieties. The Economic Consequences of New Rice Technology, IRRI, Los Banos, Laguna.

Merrill, W. C. 1965. Alternative programming models involving uncertainty. Journal of Farm Economics 47 (3):595-610.

Moran, P. B. and E. C. Casillan. 1981. Consequences of Farm Mechanization Project Site Description: Philippines. Working Paper No. 34, The Consequences of Small Rice Farm Mechanization Project.

Moss, C. J. 1980. The challenge of Asia farming to the engineer. Agricultural Mechanization for Asia 11 (1):11-16.

Pudasaini, S. P. 1976. Resource Productivity, Income and Employment in Traditional and Mechanized Farming in Bara District, Nepal. Graduate School, University of the Philippines at Los Banos (unpublished graduate thesis).

Rae, A. N. 1971a. Stochastic programming, utility and sequential decision problems in farm management. American Journal of Agricultural Economics 53 (3):448-460.

_____. 1971B. An Empirical application and evaluation of discrete stochastic programming in farm management. American Journal of Agricultural Economics 53 (4):625-638.

Serquina, M. C. S. 1977. Statistical Analysis of Philippine Rainfall Data. Graduate School, University of the Philippines at Los Banos (unpublished graduate thesis).

Sharma, A. C. 1978. Impact of tractorization on production pattern, cropping intensity and farm income in India. Agricultural Mechanization for Asia 9 (2):49-52.

Singh, G. and G. S. Yadao. 1979. Field study of agricultural mechanization in Central Mindanao, Philippines. Agricultural Mechanization for Asia 10 (1):13-15.

Table 1. Three-way table used for determining modal class.

	Total production (tons/farm)															
	<1.5 Yield/hectare (tons)				1.5 - <3.0 Yield/hectare (tons)				3.0 - <4.5 Yield/hectare (tons)				4.5 and above Yield/hectare (tons)			
	<1.0	1.0-<2.0	2.0-<3.0	3.0 and above	<1.0	1.0-<2.0	2.0-<3.0	3.0 and above	<1.0	1.0-<2.0	2.0-<3.0	3.0 and above	<1.0	1.0-<2.0	2.0-<3.0	3.0 and above
<1.5																
1.5-<3.0																
3.0-<4.5																
4.5 and above																

Table 2. Features of representative irrigated and rainfed farms Nueva Ecija, 1982.

Item	Farm type	
	Irrigated	Rainfed
Land area (hectare)	2.50	1.50
Tenure status	lessee	amortizing owner
No. of male children 10 yrs. old and above	4	3
No. of female children 10 yrs. old and above	1	2
No. of children below 10 years	0	3
Cash supply (₱)	750	500
Source of water	National Irrigation Administration	Rainfall
Irrigation fee:		
Wet season (cavans/hectare)	2.5	
Dry season (cavans/hectare)	3.5	

Table 3. Expected net income by irrigated farm type and weather combination.

Weather combination[a]	Irrigated farm type		
	Carabao owner	Two-wheel tractor owner	Hiring-in mechanical owner
	pesos per farm		
Good - good	12,710	11,800	9,238
Good - bad	10,918	10,583	7,621
Bad - good	11,698	11,241	8,226
Bad - bad	9,906	10,023	6,749

[a]The weather combinations are:

Good - good - good wet season, good dry season
Good - bad - good wet season, bad dry season
Bad - good - bad wet season, good dry season
Bad - bad - bad wet season, bad dry season

Table 4. Cost incurred by weather combination and irrigated farm type.

Weather combination	Irrigated farm type		
	Carabao owner	Two-wheel tractor owner	Hiring-in mechanical power
	pesos per farm		
Good - good	8,568	11,536	10,612
Good - bad	8,748	11,290	10,708
Bad - good	9,104	11,314	10,980
Bad - bad	8,972	11,238	10,592

Table 5. Optimal cropping pattern for irrigated, carabao owner farm.

Cropping Pattern		Area (ha)	Time period
Wet season			
Good weather			Early June-Mid Nov.
Mid transplanted	IR36	0.26	
Early transplanted	IR42	0.26	
Mid transplanted	IR42	1.98	
Bad weather			Mid June-Late Nov.
Very late transplanted	IR36	0.95	
Mid transplanted	IR42	1.55	
Dry season			
Good weather following good weather			Early Dec. - Late Mar.
Early planted tomatoes		2.50	
Good weather following bad weather			Early Dec. - Late Mar.
Early planted tomatoes		2.50	
Bad weather following good weather			Mid Dec. - Mid Apr.
Mid planted tomatoes		1.75	
Late planted tomatoes		0.75	
Bad weather following bad weather			Mid Dec. - Mid Apr.
Mid planted tomatoes		1.75	
Late planted tomatoes		0.75	

Table 6. Cropping pattern for the irrigated, two-wheel tractor owner farm.

Cropping patter	Area (ha)	Time period
Wet season		
Good weather		Early June - Mid Nov.
Early transplanted IR36	0.10	
Early transplanted IR42	2.40	
Bad weather		Mid June - Late Nov.
Mid transplanted IR42	2.50	
Dry season		
Good weather following good weather		Early Dec. - Late Mar.
Early planted tomatoes	2.50	
Good weather following bad weather		Early Dec. - Late Mar.
Early planted tomatoes	2.50	
Bad weather following good weather		Mid Dec. - Mid Apr.
Mid planted tomatoes	2.50	
Bad weather following bad weather		Mid Dec. - Mid Apr.
Mid planted tomatoes	2.50	

Table 7. Cropping pattern for irrigated, hired-in mechanical powered farm.

Cropping pattern	Area (ha)	Time period
Wet season		
Good weather		Early June - Mid Nov.
Early transplanted IR42	2.40	
Early transplanted IR36	0.10	
Bad weather		Mid June - Late Nov.
Mid transplanted IR42	2.50	
Dry season		
Good weather following good weather		Early Dec. - Late Mar.
Early planted tomatoes	2.50	
Good weather following bad weather		Early Dec. - Late Mar.
Early planted tomatoes	2.50	
Bad weather following good weather		Mid Dec. - Late Mar.
Mid planted tomatoes	2.50	
Bad weather following bad weather		Mid Dec. - Late May
Mid planted tomatoes	2.05	
Mid transplanted IR42	0.45	

Table 8. Cropping intensity by irrigated farm type and weather combination.

Weather combination	Irrigated farm type		
	Carabao owner	Two-wheel tractor owner	Hiring mechanical power
	percent		
Good - good	200	200	200
Good - bad	200	200	200
Bad - good	200	200	200
Bad - bad	200	200	20

Table 9. Expected net income by rainfed farm type and weather combination.

Weather combination	Rainfed farm type		
	Carabao owner	Two-wheel tractor owner	Hiring-in mechanical power
pesos per farm			
Good - good	2,121	1,601	1,898
Good - bad	1,484	1,063	1,222
Bad - good	1,170	681	546
Bad - bad	1,168	817	546

Table 10. Costs incurred by weather combination and rainfed farm type.

Weather combination	Rainfed farm type		
	Carabao owner	Two-wheel tractor owner	Hiring-in mechanical power
	pesos per farm		
Good - good	3,433	6,994	4,324
Good - bad	3,433	6,994	4,324
Bad - good	3,512	6,994	4,264
Bad - bad	3,512	6,994	4,264

Table 11. Cropping pattern for rainfed, carabao owner farms.

Cropping pattern		Area (ha)	Time period
Wet season			
Good weather			Early June - Late Oct.
Early transplanted	IR36	1.42	
Mid transplanted	IR42	0.08	
Bad weather			Mid June - Late Oct.
Mid transplanted	IR36	1.50	
Dry season			
Good weather following good weather			Mid Oct. - Mid Dec.
Early broadcast mungbean		1.42	
Good weather following bad weather			Late Oct. - Late Dec.
Late broadcast mungbean		1.50	
Bad weather following good weather			Late Oct. - Late Dec.
Late broadcast mungbean		1.42	
Bad weather following bad weather			Late Oct. - Late Dec.
Late broadcast mungbean		1.50	

Table 12. Cropping pattern for rainfed, two-wheel tractor owner farm.

Cropping pattern	Area (ha)	Time period
Wet season		
Good weather		Early June - Mid Oct.
Early transplanted IR36	1.50	
Bad weather		Mid June - Late Oct.
Mid transplanted IR36	1.50	
Dry season		
Good weather following good weather		Mid Oct. - Mid Dec.
Early broadcast mungbean	1.50	
Good weather following bad weather		Late Oct. - Late Dec.
Late broadcast mungbean	1.50	
Bad weather following good weather		Late Oct. - Late Dec.
Late broadcast mungbean	1.50	
Bad weather following bad weather		Late Oct. - Late Dec.
Late broadcast mungbean	1.50	

Table 13. Cropping pattern for the rainfed, hired-in mechanical power farm.

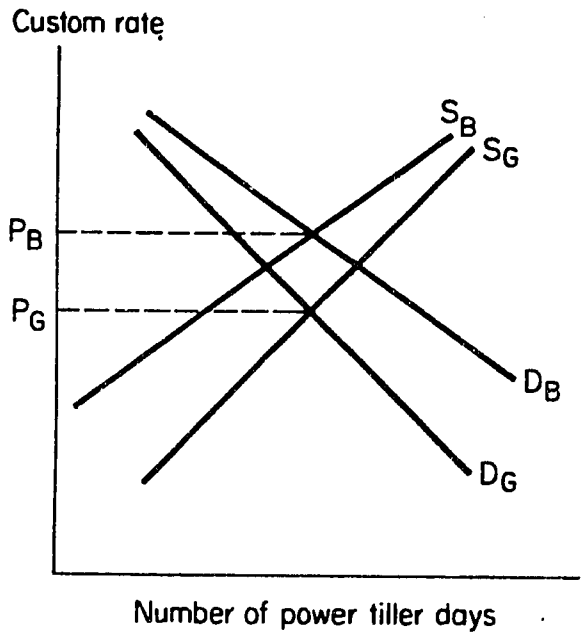
Cropping pattern	Area (ha)	Time period
Wet season		
Good weather		Early June - Mid Oct.
Early transplanted IR36	1.50	
Bad weather		Mid June - Late Nov.
Mid transplanted IR36	0.82	
Mid transplanted IR42	0.55	
Dry season		
Good weather following good weather		Mid Oct. - Mid Dec.
Early broadcast mungbean	1.50	
Good weather following bad weather		Late Oct. - Late Dec.
Late broadcast mungbean	0.95	
Bad weather following good weather		Late Oct. - Late Dec.
Late broadcast mungbean	1.50	
Bad weather following bad weather		Late Oct. - Late Dec.
Late broadcast mungbean	0.95	

Table 14. Cropping intensity by rainfed farm type and weather combination.

Weather combination	Rainfed farm type		
	Carabao owner	Two-wheel tractor owner	Hiring-in mechanical power
		percent	
Good - good	195	200	200
Good - bad	195	200	200
Bad - good	200	200	155
Bad - bad	200	200	155

Restraint	Current Decisions					Good Weather						Bad Weather						RHS Sign	Unit
	Land Supply	ST Loan	LT Loan	Buying Anim.	Buying 2 WT	Crop Alt.	Hiring-in Labor	Hiring-in Anim.	Hiring-in 2 WT	Hiring-in 4 WT	Hiring-out 2 WT	Crop Alt.	Hiring-in Labor	Hiring-in Anim.	Hiring-in 2 WT	Hiring-in 4 WT	Hiring-out 2 WT		
	(ha)	(₱)	(₱)			(ha)	(md)	(ad)	(ptd)	(td)	(ptd)	(ha)	(md)	(ad)	(ptd)	(td)	(ptd)		
Max. land (fortnightly)	1																	≤	hectares
Long-term Loan (per season)			-1	+r	+r													≤	0
Good Weather																			
Land supply (fortnightly)	-1					1												≤	0
Family labor (monthly)							-1				+2							≤	mandays
Hired labor (monthly)							1	1	2	2								≤	mandays
Own animal power (fortnightly)				-r				-1										≤	animal days
Hired animal power (fortnightly)								+1										≤	animal days
Own 2 WT power (fortnightly)					-r				-1	-2	+1							≤	power tiller day
Hired 2 WT power (fortnightly)									+1									≤	power tiller day
Hired 4 WT power (fortnightly)										+1								≤	tractor day
Cash Supply (monthly)		-1/+r				+r/-r	+r	+r	+r	+r	-r							≤	pesos
Bad Weather																			
Land supply (fortnightly)	-1											1						≤	0
Family labor (monthly)													-1				+2	≤	mandays
Hired labor (monthly)													+1	1	+2	+2		≤	mandays
Own 2 WT power (fortnightly)					-r							+r			-1	-2	1	≤	power tiller day
Hired 2 WT power (fortnightly)															1			≤	power tiller day
Own animal power (fortnightly)				-r								+r		-1				≤	animal day
Hired animal power (fortnightly)														1				≤	animal day
Hired 4 WT power (fortnightly)																1		≤	tractor day
Cash supply (monthly)												+r/-r	+r	+r	+r	+r	-r	≤	pesos
C_j		-c	-c	-c	-c	+c	-c	-c	-c	-c	+c	+c	-c	-c	-c	-c	+c		

Figure 1. Schematic presentation of the stochastic linear program model.



Appendix Figure 1. Supply and demand curves given good and bad weather.