FARM ORGANIZATION AND THE FEASIBILITY OF AGRICULTURAL MECHANIZATION IN THE RICE REGION OF TAICHUNG AREA, TAIWAN

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

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ABSTRACT

FARM ORGANIZATION AND THE FEASIBILITY
OF AGRICULTURAL MECHANIZATION IN THE RICE REGION OF
TAICHUNG AREA, TAIWAN

By

Ming-Wu Wu

Problem - Farming in Taiwan is highly intensified, and it often gives rise to severe peak labor requirements, chiefly in March, July and November. Labor supplies in these months are most likely to be limiting factors in the choice of certain crop patterns. The number of draft animals is decreasing, due to the shortage of feed to maintain a draft animal. At least 60% of the farmers in Taiwan have neither draft animals nor power tillers but are compelled either to work without them or to hire them from their neighbors. The dependence on one's neighbor for farm power is likely to create serious problems in that the selected crops frequently cannot be planted on time. The time available between crops is critical in that the following crop needs to be planted just as soon as possible, so adequate power is essential.

Purpose - The purposes of the study were to measure

the economic efficiency and resource productivity of current farm organization. They were, firstly, to measure the marginal value productivity of resources used, and, secondly, to study the feasibility of farm mechanization (use of power tillers). More specifically, the study may indicate, (1) the return to be expected when different quantities and combinations of resources are used under the current cropping patterns, and (2) the way farm resources should be allocated to produce optimum profit or a higher profit.

Method - The Cobb-Douglas form of production function was derived from a cross section sample containing 40 farms in the Rice Region of Taichung Area relating to the production year of 1967.

Analysis of data involved measurements of reliability of the production function, and the regression coefficients of the production function. The marginal value productivity of the inputs were estimated and compared to the corresponding marginal factor costs.

Cost and working capacity of a power tiller, economic advantages of mechanization, possible farm reorganization for higher profits and optimum conditions were discussed.

Findings - The marginal value productivities of each input were higher than the corresponding factor cost. Among the five input categories, the marginal value productivity of machine use was about 56 times higher than its marginal ector co

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factor cost, and 4.11, 1.41, 1.35 and 1.31 times higher on bullock labor, human labor, working capital and cropland, respectively.

In other words, the per dollar additional input used in machine may earn NT $56 gross return, which was by far the highest of all input categories. This means, of any change to be made in input combination for higher profits, increased use of machine (power tillers) should be regarded as the first consideration.

It may be possible to increase the machine use by 40 times. In this case, the total cost is increased by NT $1,696, while cropland, human labor, bullock labor and working capital remain at the usual level, and will result in an increase in the estimated gross farm income from NT $76,908 (the current organization) to NT $86,289, or NT $9,381 total increase, or NT $7,685 net increase. The ratio of each marginal value productivity of input to the respective marginal factor cost, except for the input of bullock labor, which has been constrained by the feed supply, are almost equal to a constant value 1.5. So, increasing the machine use by 40 times may be highly considered.

Conclusion - There is little chance for expansion of farmland in Taiwan, consequently, higher output per hectare will be needed to meet with the continual increase in population. With power tillers speeding up the land prepara-

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tion work, the farmers can time their crop planting and harvesting to their best advantage, and in most cases, realize added crop production that was previously unattainable, due to delay in planting, caused by the shortage of animal or human labor for land preparation. Thus, farm incomes may be increased through a higher multiple cropping index, made possible by having more adequate power. In other words, increased use of power tillers not only may replace the bullock labor but also may provide more power for more highly intensified farming operation.

Use of power tillers will be one step forward toward the long range goal of more intensive utilization of farmland to produce more food.

An average farm in Taiwan (about 1 hectare) is not big enough to keep the power tiller working up to the minimum economic annual working hours (490 hours). Therefore, it is not sound economics to persuade every farmer to purchase a power tiller. Rather it is feasible that one power tiller be purchased cooperatively by several nearby farmers. Five to 10 farmers having a total farm area of 7 to 8 hectares could make efficient use of a power tiller.

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By

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CHAPTER I

INTRODUCTION

General Situation of the Study Area

The rice region of Taichung area is located in the central part of Taiwan, which is considered the best farming area. The average annual temperature is about 72° F. The temperature in the coldest month, January, averages 58° F compared with 90° F in the warmest month, July. The average yearly percipitation is around 75 inches. Summer rainfall makes up 70 per cent or more of the whole year's rainfall. The index of humidity is about 85 per cent.[1] Winter is a dry season with lots of sunshine, hence the climate is favorable for crop growth tweles months of the year. These climatic characteristics of the area make possible intensive cultivation of the farm land.

Rice is usually the crop of first choice of farmers in their use of paddy land. It is planted primarily for the purpose of home consumption, payment in kind of rent, taxation and in exchange for fertilizers. This region is often called the granary of Taiwan and produces rice of high quality and yield. In addition to rice, this area produces important

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[1]Lee, Shison C.,"An Economic Analysis of Land Use in Taichung Hsien and City," Provincial Chung Hsing University, 1960.

quantities of vegetables, beans and tobacco.

Farming in this area is characterized by small sized family farms because land is a scarce factor. The average size of farms is 0.99 hectares.[2] With an average family of 7.02 persons per farm to be supported, intensive cultivation is required when the farm is less than one hectare.

The functions of production and living are combined into one unit, the farm family. The main purpose of farming, in general, is to provide employment opportunity for the farm family throughout the year in order to earn a living for the family. Therefore, the motivational forces behind the farm production unit are consumption-inspired as well as profit-inspired. Maximization of satisfaction of the family is generally considered as the goal for farming, and the goal of satisfaction will not deviate very much from the goal of profit or return maximization.

Since land is more limited than the supply of capital and labor on a majority of farms in the area, the goal of farmers' planning for choice and combination of cropping systems on a farm is generally directed to obtaining the highest return per unit of land. This may explain why farm land in the area is intensively cultivated.

Family labor constituted 88.11% of total human labor

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[2]One hectare = 2.4711 acres.

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used in farm production, according to a 1967 study, while the remaining 11.89% was hired labor.[3] The supply of family labor is usually constant throughout the year in the majority of farm families. The hiring of labor involves cash outlay. So farmers, after considering the competitive and supplementary relationships among crops, tend to choose a cropping system or a combination of cropping systems which will provide an opportunity for the full use of their family labor throughout the year and will require the least hired labor to fill the gap between total labor requirement and the available family labor supply at any given period during the year.

Agriculture in the area is relatively unmechanized, with human labor being of special importance on the majority of farms. All kinds of farm work are carried out by the hands of farmers with the assistance of simple implements and animal labor.

Besides human labor, animal labor is the major source of power for cultivating the land. The draft animals in Taiwan are first the water buffalo and, second in importance, the yellow cow. The water buffalo is a strong animal, slow in movement, likes to wade in water, and is satisfied with coarse fodder. The yellow cow is less powerful but more quick moving.

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[3] Report of Farm Record-keeping Families in Taiwan: 1967, Department of Agriculture and Forestry, Taiwan Provincial Government, 1968, p. 196.

The Intensity of Cropping

The multiple cropping index, which is measured by the ratio of gross cropped area in a year to total cultivated area, is on the average 304% in the region. It is the highest on the smallest size group farms and decreases with the increase in farm size (Table 1). The cropping index is higher on the smaller farms because the farmers with small farms have to use their limited land more intensively to support their families.

TABLE 1

MULTIPLE CROPPING INDEX OF THE 40 SAMPLE FARMS, RICE REGION OF TAICHUNG AREA

Farm Size (ha)	Number of Farms	Multiple Cropping Index
Less than 0.5	5	464
0.5 - 0.99	12	341.6
1.0 - 1.49	8	260
1.5 - 1.99	6	243.3
2.0 and over	9	246.6
Average/Total	40	304

In the area irrigation water is available, usually two crips of rice are grown per year, which are supplemented with winter crops such as sweet potatoes, vegetables, wheat, etc. They select different crops which will make full use of their limited land.

The farm operation is also highly diversified. The diversification of farming is to save cash outlay as much as possible, by providing for the sufficient primary needs of the family and to have as much opportunity as possible to make use of family labor all the year. Accordingly, in determining what crops should be selected and how to organize a well-balanced farming program, farmers usually take into consideration the requirements of the different enterprises so there will be a minimum conflict for available resources. Attention also has to be given to the utilization of by-products. In this sense, most farmers generally keep three or four hogs, and some poultry either for home consumption or sale. Also a diversified farming program may reduce the risk faced by the farmers. (In this study, hog and poultry enterprises are excluded because the data are not available and the difficulties in estimating the amount of labor being used.)

The cropping patterns, as shown in Figure 1, are fairly complicated ones. To introduce second crops, it is not only the input-output relation that is important but also the timing -- proper time to plant and harvest paddy rice, the first crop should be harvested as early as possible

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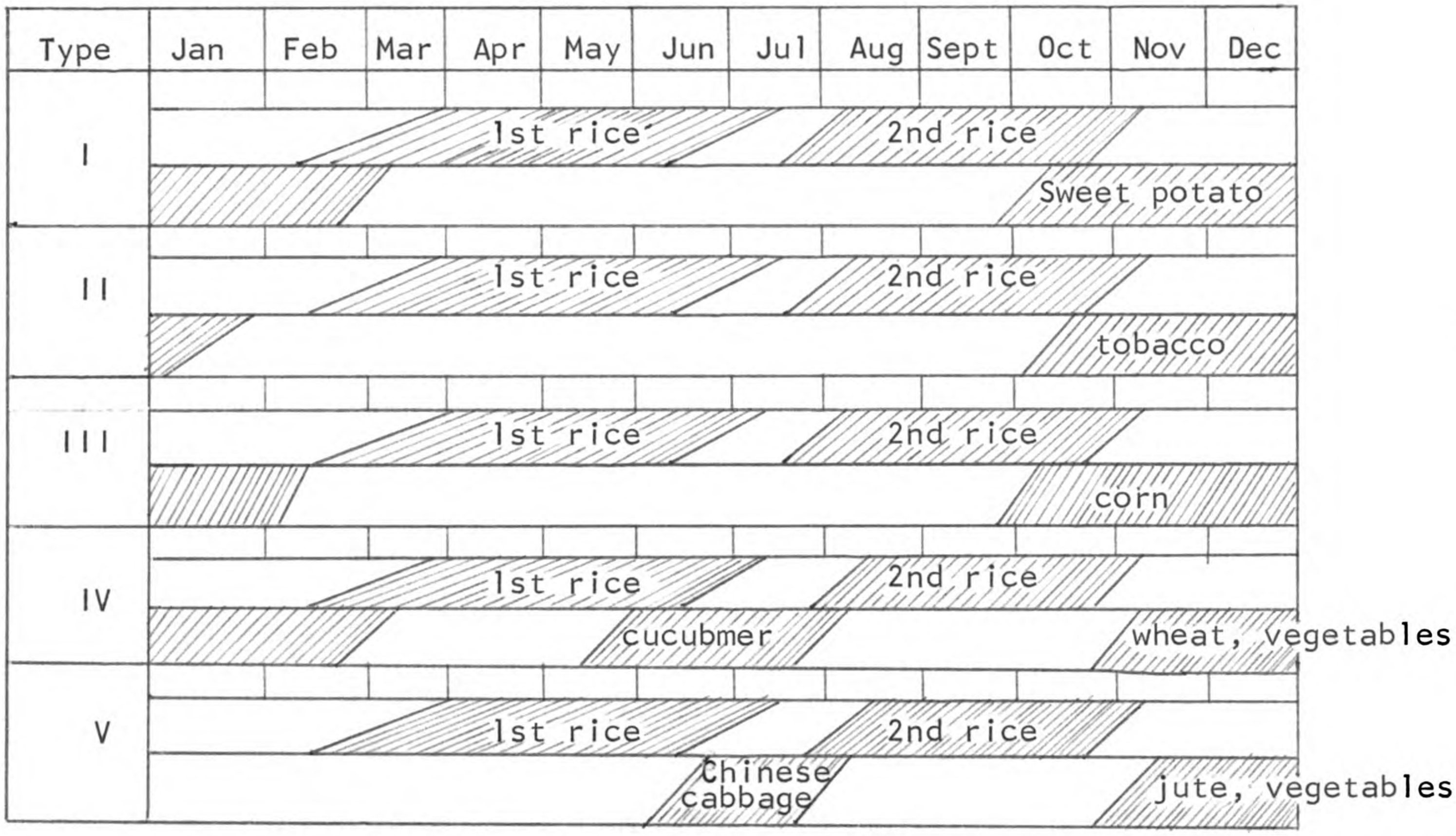
and a new crop planted as soon as the old one is harvested, or if intercropping is feasible, even before it is harvested. The time required for threshing and husking also matters. It must be shortened.

Let us take the Type I cropping pattern, for an example (Figure 1). The first rice crop can be transplanted at the earliest in the middle of February and may be harvested in the middle of June; or transplanted at the latest date, at the end of March and may be harvested in the middle of July. The second rice crop can be interpreted in the same manner. But the winter crop, sweet potatoes in this case, is planted in early October, before the second rice crop is harvested, and harvested in early March of the next year. Thus, intercropping of second rice crop and sweet potatoes occur for about two weeks during the middle of October. Certainly, it needs special skills for this kind of farm operation.

If, in case, sweet potatoes are considered to be not profitable, or the labor required for such crop is not available, farmers may choose other crops which requires less labor, or shorter period of growing or one that might yield higher profits.

FIGURE I

MAJOR CROPPING PATTERNS OF THE RICE REGION OF TAICHUNG AREA, TAIWAN



Source: Derived from "Major Crops Grown in Taichung Area," Extension Bulletin, Taichung District Agricultural Improvement Station, 1967.

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Current Problems

Decline in Average Farm Size and Increased Demand for Food

The rapid growth of population and limited arable land available cast a gloomy shadow over the future prospects of Taiwan's agriculture. Expansion of cultivable land is now almost at a standstill (Table 2, Column 2), while population is growing continuously at an annual rate of 2.3 per cent,[4] thereby exerting an increasingly heavy pressure on available food supply. Agriculture, therefore, is faced with the serious problem of how to get the limited land area under cultivation to produce more in order to cope with the food requirement of a fast growing population.

In other words, the limitation on possible expansion of cultivated land area and the continuous growth of population have presented two serious problems. One involves the steady decline in the average size of farms (Table 2, Column 6), due to the increase of agricure population and farm families, while the other is related to an increasing demand for food supplies. Both the decline in average farm size and the increase demand for food indicate a strong need for more intensive use of available farm land unless it is imported. But most foods produced in Taiwan are much cheaper than that of imported ones.

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[4]Taiwan Statistical Data Book:1968, Council for International Economic Cooperation and Development, Executive Yuan, Rep. of China, 1968

TABLE 2

TABLE 2

TOTAL POPULATION, CULTIVATED LAND AND NUMBER OF FARM FAMILIES, TAIWAN

Year	Total Population (1,000 persons)	Agricultural Population (1,000 persons)	Total Cultinated Area (ha)	Number of Farm Families	Area per Farm Family (ha)
1960	10,792	5,373	869,223	785,592	1.11
1961	11,149	5,467	871,759	800,835	1.09
1962	11,512	5,531	871,858	809,971	1.08
1963	11,884	5,611	872,208	824,560	1.06
1964	12,257	5,649	882,239	834,827	1.06
1965	12,628	5,739	889,563	847,242	1.05
1966	12,993	5,806	896,347	854,203	1.05
1967	13,297	5,949	902,406	863,731	1.04
1968	13,650	5,999	899,926	977,114	0.92

Source: Taiwan Statistical Data Book: 1968, Council for International Economic Cooperation and Development, Executive Yuan, Rep. of China, 1968

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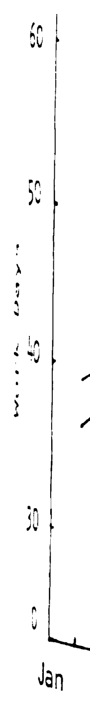

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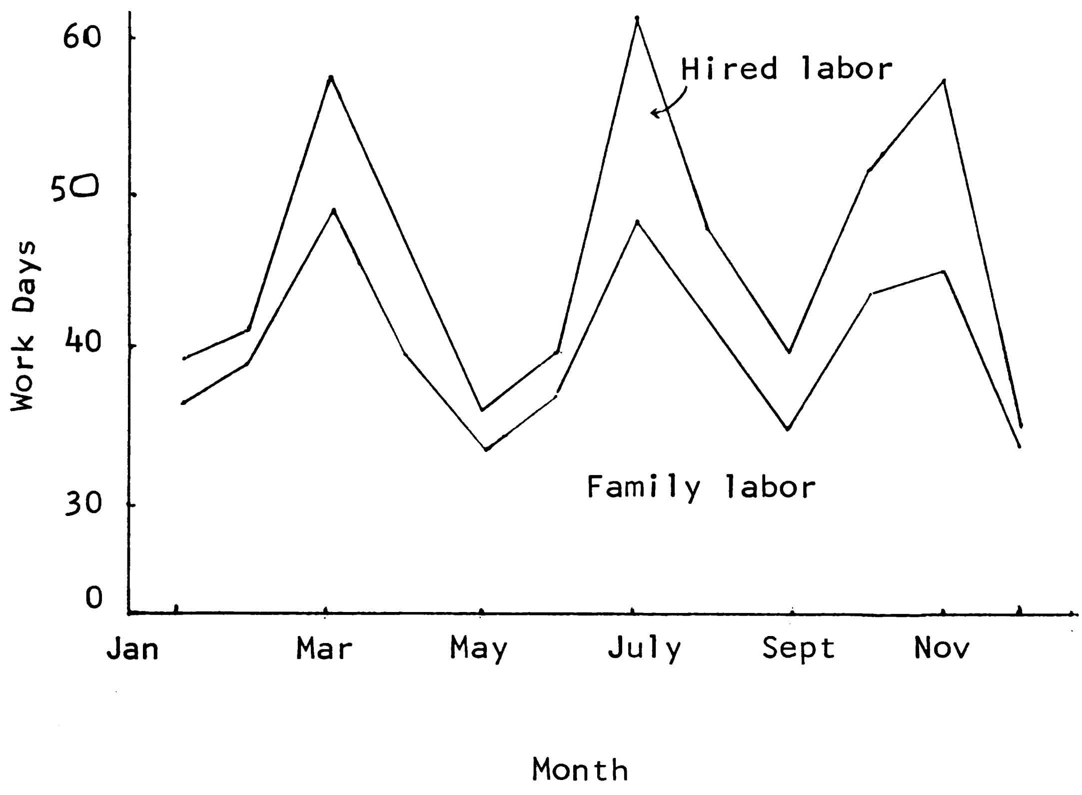
Peak Labor Season in Crop Production

Since farming is so highly intensified that it often gives rise to severe peak labor requirements, chiefly in the spring, Summer and Fall, no matter how crop patterns may be selected, family labor may be distributed evenly throughout the year (Figure 2).

FIGURE 2

LABOR DISTRIBUTION DURING A YEAR: 40 SAMPLE FARMS, THE RICE REGION OF TAICHUNG AREA



In general, it is believed that in terms of total labor supply, labor is not a limiting factor on crop choice in the majority of farm situation. However, when labor supply is divided into months, labor may become a limiting factor in the choice of a crop with a heavy demand in a given month. Under the farm situations in the area, labor supplies during the busy seasons of farming, i.e. March, July, and November, are most likely to be limiting factors in the choice of certain crop patterns.

Shortages of Farm Power - Insufficient Draft Animals

Animal power is usually deficient in both number and quality. They consume food in competition with humans. They cannot supply the power needed to rapidly till a soil when timing of this operation is critical.[5]

The number of farm families in Taiwan in 1968 was 977,114 (Table 2, Column 5), and the total number of draft animals was 337,000 (Table 3, Column 2). Assuning the total number of draft animals are in working condition (actually many of them are not in a good working condition), then an average of only 0.33 head (one third) of a draft animal was available for each family. The total number of power tillers was about 20,000.[6]

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[5]Clyma, Wayne, "Engineering, Economic, and Educational Factors to Consider in Changing From Animal to Tractor Power in Developing Countries," Papers in the 1968 ASAE Annual Meeting, No. 68-507, 1968.

[6]Estimated based on Taiwan Agricultural Yearbook, Provincial Department of Agriculture and Forestry, Taiwan, 1967, p. 329.

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The point which is that at least 60% of the farmers in Taiwan have neither draft animals nor power tillers but are compelled either to work without them or to hire them from their neighbors. The dependence on one's heighbor for farm power is likely to create serious problems. As a result, each of the selected crops often cannot be planted timely and hence it is hard to carry out intensive farming effectively.

The time available between crops for intensive cultivation is often very short. The time interval between the harvesting of one crop and the planting of a new one must be reduced as much as possible. This is completely different from the traditional custom in that in the past farmers have passively accepted the natural, annual cycle of seasons, letting the fields lie fallow in winter, or plow the field after the crop is harvested and expose the soil to the air for a couple of weeks before the new crop is planted. Because the tight farming schedule as it is today, some operations require more power than a bullock can supply.

Furthermore, we may note the growing problem of shortage of draft animals by comparing the area per head of draft animals of a year with the previous years.

The average area per head of draft animal is increasing and the situation is becoming less and less favorable.

The area per draft animal was 2.15 hectares in 1962, increasing to 2.65 hectares in 1967, or an increase 0.5 hectares during the five year period. The increasing rate was 0.1 hectare per head per year (Table 3).

Animals must have rest. They cannot work incessantly, even for relatively short periods of time, as can a tractor.

TABLE 3

AVERAGE AREA PER HEAD OF DRAFT ANIMALS: 1962 - 1967, TAIWAN

Year	Draft Animals (head)	Cultivated Area (ha)	Area per Head of Draft Animal (ha)
1962	405,026	871,858	2.15
1963	389,448	872,208	2.24
1964	379,073	882,239	2.32
1965	370,316	889,563	2.24
1966	360,294	896,347	2.48
1967	331,878	902,406	2.65

Source: Derived from Taiwan Statistic Data Book: 1968, Council for International Economic Cooperation and Development, Executive Yuan, Rep. of China, 1968.

In the above table, only cultivated land was taken into consideration, not multiple cropping, which is in fact larger, and was growing rapidly, due chiefly to the improvement of irrigation systems and land consolidation, so that the situation is actually worse than the figures suggest.

Timeliness factor is one of the major considerations in modern farming operations. Higher yield and intensive cropping patterns can be attained only when a crop is planted in a given time period. Soil is prepared only when it is an ideal condition and moisture content. Farmers should get the job done on time before the soil becomes too dry or the season too late for seeding.

There is another problem involved in draft animals that should not be overlooked. That is the scarcity of feed supply. Generally speaking, for keeping draft animals, feeds and labor are required. And that, such costs have little or no bearing upon the frequency of use of draft animals. Feeds for draft animals in Taiwan consist of the following:

(1) By-products of rice and other crops, such as rice straw, bean, etc.

(2) Forage crops grown in farmland, such as barley, etc.

(3) Feeds collected by family labor, such as wild green grass, etc.

(4) Commercial feeds.

Roughage should constitute 80% of the total quantity of the feeds. Wild grasses, rice straw, sugarcane tops, sweet potatoes, etc. are the major ones. Today, sweet potatoes and their leaves are used by farmers mostly as hog feed. Rice straw is used for making compost for growing mushrooms, and therefore can not be used entirely as cattle feed. In the very well developed rural area, there is very little land that can be spared to produce roughage for draft animals. It is much harder to maintain a draft animal than in earlier times.

There may be various alternatives to overcome such difficulties, but one of the most important means that has been carried out effictively in Japan and other developed countries is to provide farmers with the various equipment or machinery required for successful carrying out of such intensive farming operations.

Objectives of the Study

Based on the above described problems, this study will be dealing with the economic efficiency of resource use in farm production in a specific area. It is intended to measure the economic efficiency and resource productivity of current farm organization and operation. The central objectives of this study are firstly to measure the marginal value productivity of resources used, especially labor and power in crop production and to predict the effect of different quantities of resources used on the value of the products produced; and secondly to study the feasibility of farm mechanization in the area. From the standpoint of the individual farmer the study may indicate (1) the return or income to be expected when different quantities and combinations of resources are used under the current cropping pattern, and (2) the answer to the question as to how farm resc

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resources should be allocated to produce optimum profit or a higher profit within the limitation of the methods of production being used.

About the Area and Data Selected

The rice region of Taichung area was chosen as a case study for several reasons: (1) this region is located in the central part of the island and the land, as well as physical, climatic and other features are representative of Taiwan and are homogeneous which is suitable for intensive cultivation, (2) this region constitutes a representative rice farming region and is an important agricultural region of Taiwan, known as the rice bowl of Taiwan;[7] (3) the crop pattern and its production are also homogeneous with very little variation from year to year; and (4) the farmers have a strong desire to improve their farm organization.

The data were collected by survey by the author with the help of the extension agents of the local farmers associations in 1967. The primary purpose of the survey was for a study on the crop rotation systems in the area.

The sampling procedure adopted was a random sampling from a given group. A random sample of 40 farms was taken from the 1,100 farms who were involved in the Farm Extension

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[7]Lee, Shison C., op. cit.

Discussion Groups of the Farmers' Association.[8] The sample size was approximately 3.63% of the whole groups in the region.

The distribution of farms by size of the sample farms in the region may be seen in Table 1. The average farm size was 0.99 hectares, while the average of all farms in Taiwan was 1.02 hectares.

In view of various criteria these data seemed fairly likely to meet the requirements for further study in this analysis. Therefore, this study was based mainly on the sample farms relating to a single production year of 1967.

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[8]Volunteer organization of adult farmers for the purposes of improving agricultural techniques and social life. These farmers may be considered to be above average level in regard to their agricultural techniques.

CHAPTER II

THE THEORETICAL FRAMEWORK

The Conceptual Problem

Land is the most scarce production factor in Taiwan, and we shall assume that the input of land is fixed. Other inputs are treated as variable inputs. Let us take labor as an example here. The important question is how to improve the productivity of the labor force without reducing the total product. There are many theoretical alternatives in coping with this problem. The important ones are, (1) to improve the production potential of the land, (2) to improve the equipment or machinery being used by the laborer, and (3) to improve the techniques of the laborer.

Raising the productivity of the land may take a variety of forms such as land consolidation, improvement of irrigation system, seed variety improvement, and application of farm machinery or any other measure that would shift the production function upward. The effect of this improvement is illustrated in Figures 3 and 4 where land is fixed and the labor is variable. Assume labor will be adjusted to the point where, for the optimum combination, marginal value prod

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productivity equals marginal factor cost.

In Figure 3, improved land consolidation practices or the use of farm machinery in Taiwan may shift the land production function upward from TP_1 to TP_2. The marginal productivity curves corresponding to the two production functions are shown in Figure 4. The marginal productivity also shifts from MR_1 to MR_2. Marginal factor cost of labor is equal to the wage rate and assumed to be constant. With the improvement in land quality or the use of farm machinery, the intersection of marginal factor cost and marginal productivity has shifted to the right from Point A to Point B. The aggregate effect is to increase total output by adjusting the quantity of labor that can be profitably combined with the land. In other words, land can now absorb more labor without reducing the labor productivity.

If, in other cases, the quantity of labor being used in the production is too great as a result, the marginal productivity is smaller than wage rate, the production as far as the labor input is concerned, may be over employed. Under this circumstance, the withdrawal of a certain amount of labor will not cause reduction in total product, but on the contrary, it will allow the total product return to the higher level along the same production curve. To what extent the surplus labor should be withdrawn will depend on the reduction of the total product. Assuming other factors remain unchanged, the amount of labor should be added if the

marginal value productivity of labor is greater than the wage rate, and vice versa.

The problem involved is to decide the proportional make up of the package of resources that will be required to make the jump from Point A on TP_1 to Point B on TP_2.

Figure 3 TOTAL PRODUCT OF LABOR, HOLDING OTHERS CONSTANT

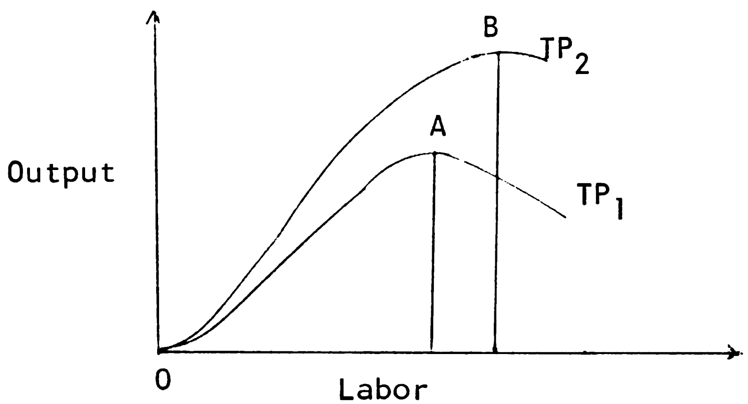
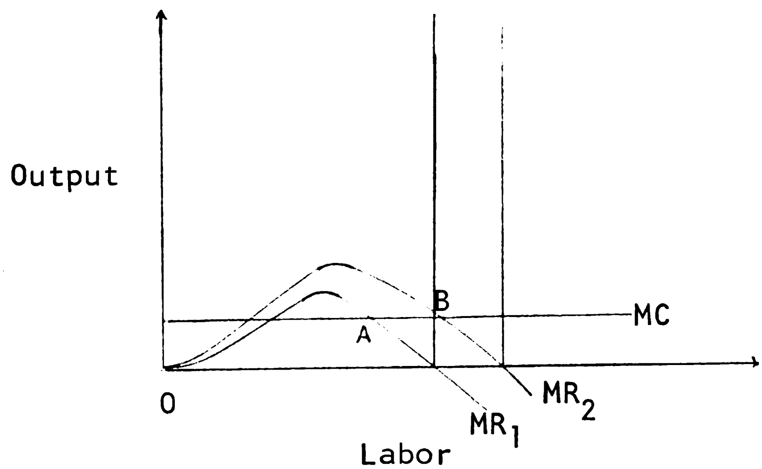


Figure 4 MARGINAL VALUE PRODUCT OF LABOR, HOLDING OTHERS CONSTANT



It is not enough to simply suggest that farmers should use certain amounts of resources. It may also be necessary to improve other situations, such as, land tenure situation to create the proper incentive, or to improve the marketing system which may provide further encoruagement. The kind of measures that will be discussed in this study are mainly related to the machine or power use.

Machine use[9] not only can increase the productivity of land and human labor, but also can substitute for labor, capital, etc. If the output of a crop is given, the crop can be produced by different combination of labor and machine use assuming other factors remain unchanged. The optimum combination of labor and machine use for instance, is the point where the iso-product curve is tangent to the price line of the two inputs.

The Model to be Used

A general approach to the problem is to derive production functions from which to measure the regression coefficients of production and the marginal productivity of the input factors. The Cobb-Douglas form of production function is chosen for this analysis because of its possibility of goodness of fit to the data, and also because of the usefulness of interpretation of

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[9]Machine use in this study is meant particularly the use of power tillers.

the obtained regression coefficients.

The coefficients of the production function are estimated from a cross section sample containing 40 farms. The Cobb-Douglas type production function is applied to the logarithms of the variables. The data are concerned with the short-run of a single production year. The variables being studied can not be considered as a function of time. The gross farm receipts (Y) is used as the dependent variable of the various input factors, or the independent variable, (X_i).

By the nature of the Cobb-Douglas functions, if output is to be nonzero, at least some quantity of each input must be used. This does not hold true in real world situation, for instance, we might get some product without applying any fertilizer. Because of the multiplicative basis of aggregation approaches of the production function, if any one or more independent variables is zero, the total product or dependent variable will be zero. The difficulty arises in the conversion of the data to a logarithmic form, the logarithm of zero equals minus infinity. But the Cobb-Douglas functions have greatest use in the diagnostic anaysis, reflecting marginal resource productivities at mean levels of inputs.

The general production function may be written as:

$$Y = f(X_1, X_2, \ldots\ldots X_n)$$

Which expressed the output as a function of the various input factors. In Cobb-Douglas type, the mathematical notation is:

$$Y = a\, X_1^{b_1}\, X_2^{b_2} \;.\;.\;.\;.\;.\;.\;.\; X_n^{b_n}$$

Where a and b's are the parameters of the function. b's are the regression coefficients with respect to each of the inputs, they are the elacticities of production for the production function or regression equations in the form presented above. The elasticity of production simply shows the average percentage change in the product for each increase of one per cent in input of respective resources and can be expressed in the formula below:

$$E_p = \frac{dY}{Y} / \frac{dX}{X} = \frac{dY}{dX} \cdot \frac{X}{Y}$$

In the Cobb-Douglas production function, the sum of the regression coefficient of the independent variables Σb_i, is an indication of the returns to scale. $\Sigma\, b_i = 1$ implies constant returns to scale, i.e., a one per cent increase in all inputs results in a one per cent increase in total output and constant productivity prevails as all resources are increased in constant proportions. By the same token $\Sigma\, b_i < 1$ indicates decreasing returns to scale and $\Sigma b_i > 1$, increasing returns to scale. However, such estimates of returns to scale may be biased unless all input factors are included in the production function.

There will be no bias in the estimates of returns to scale if the excluded variables vary on the average in same proportion with proportional variations in all the included variables. But the returns to scale will be underestimated if the proportional changes in the included inputs are associated with less than proportional changes in the excluded variable in the sample and vice versa.[10]

The Cobb-Douglas production function, for computational convenience is usually estimated by use of a logarithmic transformation, such as

$$\text{Log } Y = a + b_1 \log X_1 + \ldots\ldots + b_n \log X_n + U$$

Where the _b_'s become the regression coefficients of the inputs. U is the residuals.

The reasons why the logarithm form is used in addition to the computational convenience are:

(1) The relationships between the variables are believed to be multiplicative rather than additive.

(2) The relations among variables are believed to be more stable in percentage than in absolute thems, and

(3) The unexplained residuals are believed to be more uniform over the range of the independent variables when expressed in percentage rather than in absolute terms.

From the production function derived, we can easily determine

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[10]Griliches, Z., "Specification Bias in Estimates of Production Function," _Journal of Farm Economics_, Vol. 39, p.12.

if production is located in stages I, II, or III. The rational stage of production, stage II, for a particular input is characterized by a, the function s constant having a positive sign, and by b, the power of the particular input being a positive fraction. However, no maximum can be reached by this kind of production function.

Marginal Productivity

The marginal productivities of each input in the process of production can be defined as the change in the total physical product caused by a small change of the particular input, while the other inputs are held unchanged at a mean level. The marginal productivity estimates may be computed by taking the first partial derivatives with respect to each of the input factors included in the production function.

Let all the variables be set at their respective geometric mean levels, then the production function is:

$$\text{Log } \overline{Y} = a + b_1 \log \overline{X}_1 + b_2 \log \overline{X}_2 + \ . \ . + b_n \log \overline{X}_n$$

The marginal productivity of X_i, holding all variables at their respective geometric mean level, is estimated with:

$$\overline{Y} = (\text{antilog } a)\ \overline{X}_i^{\,b_i}$$

$$\frac{d\overline{Y}}{d\overline{X}_i} = \frac{d(\text{antilog } a)\ \overline{X}_i^{\,b_i}}{d\overline{X}_i}$$

$$= b_i \ (\text{antilog } a) \ \overline{X}_i^{\,b_i - 1}$$

$$= \frac{b_i \ (\text{antilog } a) \ \overline{X}_i^{\,b_i}}{\overline{X}_i}$$

$$= \frac{b_i \ \overline{Y}}{\overline{X}_i}$$

This derivative gives the slope, at a particular point of the production curve.

The efficiency of resource use, then, can be measured by comparing the marginal productivities of factors with their prevailing market prices or opportunity costs. If the marginal productivities are higher than opportunity costs of the factors, this indicates the scope for raising output profitably through the increased use of the resource input concerned, whereas those less than market costs indicate the unprofitable nature of resource use.

But there is some limitations of using the marginal productivity as a tool for the guidance of farmers. First of all, it is not easy for a farmer to readily vary such inputs as land and durable machinery which are more or less fixed for him. This may leave relatively little freedom for the farmer to optimize profit by equating marginal product with marginal cost. Secondly, since the marginal productivities are derived from regression coefficients, which may be biased due to exclusion of certain variables from the function, the estimated marginal products would also be biased in the same direction as the regression coefficients.

Specification and Measurement of Variables

A farm is not merely a piece of land. People cannot operate the land as a farm unless they have buildings, livestock, machinery, and other things to go with it. Land is the thing into which inputs are put. Labor is the input of man's efforts. Capital is wealth used in the production of new wealth and in one form or another is necessary in order for the farm to be a productive unit. In the basic sense all these inputs are essential to constitute a farm unit.

There are many kinds of inputs in agricultural production. Some are visible and measurable, while others are invisible and it is difficult to measure their quantity as well as their influence on production.

The unmeasurable or excluded variables are usually regarded as constant. However, the measurement problem exists so long as the excluded variable is uncorrelated with any of the other inputs being included, and its omission will not bias the estimates of the coefficients. Still the assumption of zero correlation between the excluded inputs and any of the other inputs is not likely to hold in the real world. The result will be a tendency to overestimate one or more of the coefficients of the included variables.[11]

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[11] Heady, Earl O., and John L. Dillon, Agricultural Production Functions, Ames, Iowa, 1966, p. 214.

In classifying or aggregating the variables, two rules should be used in order to minimize the bias. First, resources with perfect complements in the production process should be aggregated as a single input, such as fuels and maintenance costs being used more or less in fixed proportions.

To include each of the complementary categories would lead to multicollinearity because of the perfect correlation between levels of the complementary input.[12] Secondly, perfect substitutes should also be aggregated into a single input category.

Ideally, the input and output variables to be used in deriving the production functions should be measured in physical units of a homogeneous nature. But there is no common physical unit for measuring the heterogeneous capital goods and services. They must be aggregated to some extent and measured in value terms for computational purposes.

Some resources can be distinguished as productive and non-productive. Only productive resources which contribute directly to production were included, and such as assits not directly related to farming were excluded. Problems arise in regard to the fact that farm production and family living are not mutually exclusive nor separable from each other. The farm house, for instance, is both a means of

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[12]Johnston, J., Econometric Methods, McGraw-Hill Book Co., New York. 1960, pp. 201-7.

farm production and family living. Some farmers may have much better housing than others. These factors were excluded in this study.

However, one can make certain plausible assumptions regarding the behavior of these inputs vis-a-vis other included inputs and then interpret the results in the light of such assumptins.[13]

The variables included in this study are: (1) gross farm receipts, which is the dependent variable; and (2) land, (3) human labor, (4) machine use, (5) bullock labor and (6) working capital, which are independent variables. Management and fixed capital inputs are not included. In fact, most studies on farm production functions have not been able to include the management input, owing to the difficulty of measurement, which is essentially a qualitative rather than quantitive character.[14] As for the exclusion of fixed capital in the production analysis, this is due to the difficulty of measuring its value.

The procedure followed for standardizing and aggregating the variables is explained below:

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[13]Griliches, Z., op.cit. pp. 8-20.

[14]Heady, Earl O., and John L. Dillon, op. cit. p.224.

(1) Gross farm receipts: Gross farm receipts is the independent variable and consists of the value of different crop outputs during the year. Data on prices of individual products, and also of different qualities of the same product, were the basis for converting these quantities into the values for the gross farm receipts. In other words, the output was the aggregation of the value of different crop products produced during a given time period, because most farms produce either more than one type of product or several qualities of the same kind of product. Since the products were aggregated on a value basis, nothing can be said in regard to the input-output relations in the individual crops.

The price of farm products may change from time to time, and the output value in different years might not represent adequately the physical output in different periods.

There are generally two conceptions of agricultural product: gross product and net product. Their relation culd be represented by the following equation:

Net product = gross product - (depreciation of capital + expenses of intermediate goods)

Net product is an added value produced in a given period and is equivalent to the value of agricultural production after depreciation of capital and expenses of intermediate goods used in the production are deducted from the gross product. If depreciation of capital and expenses of intermediate goods in the production process are different in different periods, the percentage of net product in gross product will accordingly change over time. Because there are many difficulties in accurate measurement of expenses of intermediate goods used in production, as mentioned before, it is reasonable that gross farm receipts should be used in this study as an indicator of agricultural output.

(2) Land: Two kinds of measurement may be used to represent land as a factor of production. One is land value based on market price and the other is the physical quantity of land. In this study, physical quantity in terms of cropland in hectares is used as the measurement of land as one of the independent variables, bucause the valuation work is difficult.

(3) Human Labor: To measure the input of human labor in subsistence agriculture is a difficult problem, espicially in our area where surplus labor exists. In this study, the input of human labor is measured by man-days actually worked on the farm. A man-day is defined as one adult male, from the age of 15 to 60, working ten hours a day on a farm at direct crop production work. Days worked by female adults and young boys are converted to man-days by multiplying by 0.8 and 0.5, respectively.

By doing the above valuation problems can be partially avoided. There seems little problems in measuring hired labor by work days, since the farmers never hire labor unless the work is ablolutèly necessary. This is not true in the case of family labor, expecially during slack seasons when there are few off-farm employment opportunities.

(4) Machine use and bullock labor: Machine use and bullock labor have been considered to be the important sources of agricultural power. Bullock labor included the drivers of the animal was measured by days worked during the year. Machine use was measured by working hours of power tillers including the operator of the machine.

There were two ways prevailing in the area in hiring farm machine use and bullock labor, as far as the ways of payment was concerned. One is payment by hours of work and the other was by the area worked. In order to standardize the measurement, the latter one was estimated and converted into hours of work based on the area covered. In general, 11 hours are needed to plow one hectare of paddy field by a power tiller and 3.5 days by a bullock labor.

(5) Working capital: Working capital is a collection of physical items different from each other in many respects, and was viewed as the value of all components. Thus, aggregation of the single values is a necessary step. Aggregation is made according to the degree of correlation between items. Theoretically, as discussed previously, items highly correlated to each other should be aggregated into a single category and within a category all items are highly correlated to each other or highly substitutable. However, this is less possible in the case of the data obtained of non-experimental origin.

In this analysis, the independent variable of working capital includes seeds, fertilizers, irrigation charges, insects, pests and disease control, and miscellaneous farm expenses. They were converted into value forms by multiplying by the respective prevailing prices.

The outlays of human labor, machine use and bullock labor were not included in this input category, because these items are used as independent variables in the production function.

CHAPTER III

ESTIMATION OF PRODUCTION FUNCTION BY THE USE OF COBB-DOUGLAS TYPE

Production Function Estimation

The derived results for the production function based on the sample of 40 farms involved in this study are as shown in Table 4. The numerical values of the original observations were grouped under the proper variables, and are shown in Appendix Table I.

The constant, a and the regression coefficients b_i may be fitted into the production function, i.e.,

$$Y = 290.59\ X_1^{.2136}\ X_2^{.4614}\ X_3^{.0312}\ X_4^{.1276}\ X_5^{.2523}$$

or in logarithm form as:

$$\text{Log } Y = 2.4624 + .2136 \log X_1 + .4614 \log X_2 + .0312 \log X_3 + .1276 \log X_4 + .2523 \log X_5$$

Variables used in the model are defined in the following way:

(1) Y is the value of crop production, measured in New Taiwan dollars, and includes all crops produced in the year such as products sold, stored or used as an input for producing other crops or consumed by the farm family.

(2) X_1 is the input of cultivated land measured in hectares.

(3) X_2 is the input of human labor used on crops and is measured in days. It includes hired labor plus the labor by the operator and family members.

(4) X_3 is the input of machine use, measured in hours of work, mainly in preparation of soil, and transporting the farm products.

(5) X_4 is the input of bullock labor, measured in days of work, performed either by water buffalos or yellow cows, in preparation of soil or transporting the products.

(6) X_5 is the input of working capital used on crops and is measured in dollars. It does not include fixed capital and wages paid for human labor, bullock labor and custom rates for machine use. It represents the variable capital input; such as the expenses for seeds, fertilizers, irrigation charges, insects, pests and disease control and other miscellaneous outlays for crops during the period of production.

The parameters are estimated at the geometric mean level of each variable. But there were some zero observations in the inputs of machine use and animal labor in the original data. In calculating the respective geometric mean value, these zero observations were arbitrary set at 0.1 unit for the machine use and 1 unit for the human labor, or no geometric mean could be calculated due to the multiplicative nature of the mean.

TABLE 4

REGRESSION COEFFICIENTS AND RELATED STATISTICS FOR CROP PRODUCTION IN THE RICE REGION OF TAICHUNG AREA

Variables	Regression Coefficients (b_i)	Standard Error of Coefficients
Constant	2.4624[a]	0.3885
Cropland, X_1	0.2136[b]	0.1026
Human Labor, X_2	0.4614[a]	0.1204
Machine Use, X_3	0.0312[c]	0.0261
Bullock Labor, X_4	0.1276[d]	0.0678
Working Capital, X_5	0.2523[d]	0.1283

Sum of regression coefficients, 1.0861

Multiple correlation coefficient, $R = 0.9365$

Coefficient of multiple determination, $R^2 = 0.8771$

a, significant at probability level of 1%
b, significant at probability level of 5%
c, significant at probability level of 24%
d, significant at probability level of 10%

Statistics from Production Function Estimates

The regression coefficient of cropland is significant at a probability level of 5%, human labor is significant at 1%, machine use is significant at 24%, bullock labor and working capital are significant at 10% level. The logic of production suggests no basis for dropping any one of these variables from production function.

The multiple correlation coefficient is 0.9365, implying that the correlation between the dependent variable and the combined independent variables is quite high. The coefficient of multiple determination, usually expressed by the symbol R^2, measures the portion of the variation in the dependent variable associated with or explained by all the independent variables. The R^2 estimated in the sample farms is 87%, which indicates that the variation explained in output by all the five independent factors combined together is 87% on the sample farms.

The remaining 13% of the unexplained variation in the dependent variable may be caused by the variables excluded in the estimates, such as management, soil fertility, weather and so on. Sampling and measurement errors may also cause the unexplained variation in the output.

In order to test the nature of production function, we make the hypothesis that there is a linear homogeneous production function or that the sum of the regression coefficients is equal to 1. This is to say that there are constant returns to scale.

The sum total of the regression coefficients, Σb_i from the production function derived was 1.08, which may be considered as constant return to scale, because when all factor inputs are increased by 1% from the respective mean levels, the gross farm receipt increased 1.08%, slightly higher than the change of input.

The regression coefficients of the production function indicate the percent change in output which would, on the average, be associated with one percent increase in the input factor concerned while other factors are held constant.

For example, the regression coefficient of the logarithm of cropland hectares, X_1, on the logarithm of output, Y, for the 40 farms in the study area is 0.21 which indicates that, on the average, an increase in cropland input, X_1, by one percent, holding other factors constant, is associated with an increase of output of 0.21%. If the standard error of X_1, $\pm$ 0.1, is taken into consideration, one percent increase cropland, holding other factors constant, is associated with an increase of 0.11 to 0.31% of output.

Similarly, one percent increase in human labor, holding other factors constant is accompanied by a 0.34 to 0.58% increase in gross output. The responses from each of machine use, bullock labor and working capital can be interpreted by the same way that each of them may increase 0.05 to 0.57%; 0.06 to 0.19%; 0.12 to 0.38%, respectively, by increased use of 1% in each of the inputs.

In addition to the above mentioned overall measures, it is desirable to measure the importance of each of the individual variables taken separately. There are, in general, two different types of such measures. One is measured by coefficients of partial correlation. The other is measured by beta coefficients. Both measurements may serve the same purpose.

(a) Measurement of the coefficients of partial correlation:

Coefficients of partial correlation are useful in measuring the correlation between the dependent variable and each of the independent variables. The coefficients indicate what the correlation would be between the gross farm receipts and the input while holding other independent variables constant at their respective mean levels. Each of the coefficients of partial correlation is usually converted to squared forms and for comparative convenience, they may be expressed by the percentages of the coefficient of multiple determination (R^2) as shown in Table 5.

TABLE 5

COEFFICIENTS OF PARTIAL CORRELATION OF THE INPUTS, 40 FARMS, THE RICE REGION OF TAICHUNG AREA

Inputs	r	r^2	Percent of R^2 (=87%)
X_1	0.3364	0.1132	14.99
X_2	0.5492	0.3025	40.05
X_3	0.2003	0.0401	5.31
X_4	0.3070	0.0942	12.47
X_5	0.3196	0.1071	9.32
Total			87.00

Human labor was the most important variation explanation, which had about 40% of the variation observed in the gross farm receipts of the sample farms. The variations in gross farm receipts accounted for by other variables are approximately; land, 15%; bullock labor, 12%; working capital, 9%; and machine use 5%. There was 13% explained by unknown factors.

(b) Measurement of beta coefficients:

It might be interesting to examine which independent variable has the most influence on the variation of the output. The beta coefficients will be used for this test. The regression coefficients of the variables, converted into the unit of their respective standard deviations, are called beta coefficients. This is to compare the net regression coefficients between each independent variable and dependent variable by the units of its own individual standard deviations. The general formula is

$$B_i = b_i \frac{S_i}{S_y}$$

Where, B_i = Beta coefficient of X_i

b_i = Regression coefficient of X_i

S_i = Standard deviation of independent variable X_i

S_y = Standard deviation of dependent variable Y

The calculation is shown in Appendix Table II, and the result was shown in Table 6.

Converting the beta values into the percentage of the coefficient of multiple determination (R^2), we may see results similar to those obtained from the partial correlation coefficients, as discussed in preceding section. About 35% of the variation in the dependent variable can be explained by the variation in X_2, the input of human labor. This is followed by working capital and cropland, with 20% and 16%, respectively. Bullock labor and machine use contributed much less toward the explanation of variation in gross farm receipts.

TABLE 6

BETA COEFFICIENTS OF THE VARIABLES FOR THE 40 FARMS, THE RICE REGION OF TAICHUNG AREA

Beta	Values	Percentage of R^2 (=87%)
B_1 (Cropland)	0.2068	15.93
B_2 (Human Labor)	0.4543	35.01
B_3 (Mechine Use)	0.0902	6.95
B_4 (Bullock Labor)	0.1189	9.16
B_5 (Working Capital)	0.2585	19.92
Total		87.00

Both types of measurements, coefficients of partial correlation and beta coefficients, showed that human labor was the most important factor, followed by working capital and cropland. Machine use and bullock labor seemed less important but they could not be neglected in the production process because they help the other resources, such as land, labor and capital to be more productive. They cannot be shunted abruptly out of the farming.

Lastly, it is necessary to measure the simple correlation coefficients between each pair of variables as shown in Appendix Table III, indicate that gross farm outpot is more closely correlated with human labor and working capital, than with cropland, machine use and bullock labor.

Between independent variables, the correlation coefficient between human labor and working capital was 0.85, which is more closely correlated than any other pairs of the independent variables.

In an analysis of Cobb-Douglas type of production function, the independent variables should be categorized such that the correlation coefficients between each pair of independent variables should be small. This means the categories of inputs should be neither perfect substitutes nor perfect complements. In reality, it is true that greater labor use in production will accompany more working capital use. Thus, human labor and working capital posses a near-linear relationship.

The high simple correlation coefficients may result in an error in the regression coefficient. The regression coefficients of human labor and working capital may by interchangeably affected. One cuuld be higher while the other be lower. In order to make possible a comparison of the absolute output response per unit of factor inputs, it is necessary to compare the marginal value productivity of each factor input.

Marginal Productivities of Input

The marginal productivity refers to the amount added to total value of product by adding one more unit of the particular factor input, holding all other inputs at the geometric mean levels. In this case, the one unit addition refers to addition beyond the geometric mean level of inputs.

The marginal productivity, computed from the production function, are given in value terms. They are dollar returns per unit of input. The marginal value productivities were calculated by the method shown in Appendix Table IV, and the results together with the geometric mean and the average productivities are presented in Table 7.

The average productivities are computed from the actual product dividing by mean quantity of each resource. The average productivity includes the product returns of all inputs, and not simply the product retrun attributable to the single resource. Average returns are always greater than their marginal returns when marginal returns are diminishing as in the case of all the individual figures shown in the table. This indicates that the production in respect to each of the inputs were in stage II.

TABLE 7

GEOMETRIC MEAN, MARGINAL PRODUCTIVITY AND AVERAGE PRODUCTIVITY OF INPUTS USED IN PRODUCTION, THE RICE REGION OF TAICHUNG AREA

Item	Geometric Means	Marginal Productivities (NT $)	Average Productivities (NT $)
Gross Farm Receipts, (NT $)	76,921.67		
Cropland,(ha)	0.99	16,591.60	77,698.66
Human Labor,(days)	416.52	85.22	184.66
Machine Use,(Hrs)	1.06	2,254.05	72,567.61
Bullock Labor,(days)	19.87	494.01	3,873.78
Working Capital,(NT $)	14,427.67	1.35	5.33

On the other hand, from the production function, the constant a, has a positive sign while all of the regression coefficients are also positive. This also indicates that each of the inputs being used in the production were located in stage II, the rational stage.

Production stage II is characterized by decreasing average and marginal physical productivity of the input, and the marginal physical productivity is positive and always smaller than the average productivity. The total physical product increases but at a diminishing rate. This is an efficient stage of production.

The marginal value productivity of cropland was NT $16,591.60 per hectare, which implies that an increase of one hectare in cropland would be accompanied by an increase of NT $16,591.60 in gross farm receipts holding other input items constant at their respective mean levels. Comparing this estimated marginal value productivity of cropland with its marginal factor cost, shows whether or not it is worth-while to expand the cropland in production. A marginal value productivity lower than the corresponding marginal factor cost means that the particular input was over employed. In other words, the additional cost of the input unit exceeded the value of the additional output produced. This is an inefficient use of the factor, since its amount may be reduced without decreasing profit. This means an increased profit may result by reducing the amount over employed. On the contrary, a marginal value productivity larger than the corresponding marginal factor cost indicates that the particular input was under employed, and its use should be increased to obtain a greater profit.

The marginal factor cost of land is the average annual rent per hectare, which is, according to the prevailing official rent rate, the value of 37.5% of the annual major products. In the area under study the major product was rice. Two crops of paddy rice were grown annually. The average yield of paddy rice per crop was 3,289 kilograms.[15] A 37.5% of the annual product (two crops) gave 2,476.5 kilograms. The price of paddy rice in the area was NT $5.08 per kilogram,[16] during the study period. The total marginal factor cost of land was, therefore, NT $12,580.42 per year. This amount may be regarded as the opportunity cost of the land per hectare. The marginal value productivity of land was greater than the marginal factor cost. Thus, an increase of cropland to some extent in the production, holding other factors constant, would likely result in a higher gross farm receipt.

The marginal value productivity of human labor was NT $85.22 per work day, implying that a change of one work day, holding other factors constant, would be associated with a NT $85.22 change in the same direction in gross farm receipts. The human labor in this study included both hired and family labor. The female labor was converted into man labor. Wages paid to the hired man labor plus the food expenses provided was, on the average, NT $60.00. The marginal value productivity of human labor was greater than the marginal factor cost of labor or the wage rate. It is

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[15] Taiwan Agricultural Yearbood, op. cit. p. 61

[16] Ibid.

evident that an over intensive application of human labor in the area was not the situation. However, the higher marginal value productivity of human labor in relation to the wage rate may lead to the conclusion that an increase in the farm work days will bring forth an increase in net farm income.

The marginal value productivity of machine use was NT $2,254.05 per hour of work, which was extremely high as compared with the custom rate of machine paid. The custom rate or the marginal factor cost of power tiller, on the average, was NT $40.00 per hour. This suggests that machine use was very productive in the sense that potential returns were especially higher than the marginal cost. This was not a surprising finding because the machine use on the small farms was extremely under employed. In order to increase farm receipts, to apply more machine use may be strongly recommended.

It has been long argued and generally considered that mechanization was absolutely infeasible in Taiwan, which is characterized by small farms. Of course farm machinery may substitute for labor. But, which is more important that machinery may also be a substitute for certain biological forms of capital. For example, machine cultivation which may plow deeper and increase yields is a substitute for fertilizer, a biological form of capital.[17]

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[17]Heady, Earl O.,et. al. Roots of the Farm Problem, Iowa University Press, Ames, Iowa, 1965, p. 121.

The marginal value productivity of bullock labor, NT $494.01 per work day, as compared to the wage rate, NT $120.00, was larger than the marginal factor cost.

In this case, bullock labor was also under employed. therefore, increase use of bullock labor may be associated with a higher gross farm receipt. But the number of bullocks available for farming is decreasing year by year due to the shortage of feed supply.

The marginal value productivity of working capital invested was NT $1.35 per NT dollar which was 35% higher than the marginal factor cost, because the marginal factor cost for a unit of this input category was one NT dollar since one dollar of the marginal product is the recover of the original investment and the marginal productivity is computed in gross terms.

The value of working capital was an aggregation of different farm expenses which was utilized for production in fifferent periods throughout the year. It was a flow variable representing the accumulated amount of investment.

The original funds required in this category were actually one-half or one-third the amount of the annual average because the investment might turn over two or three times during the year, especially in the area where multiple cropping patterns were prevalent. The income of the first crop may be used as a source of funds to finance investment needs of the second. The aggregation of the farm expenses from different periods of time made the annual working capital larger than the real funds required.

The multiple cropping index of the sample farms was 304% (Table 1) which implies that three crops were grown on the same land during the year. In this sense we may consider that the working capital was originally about one third of the aggregated farm expenses truning over three times during the year. This result showed that a single crop production period, on the average, was about four months. Assuming that the average interest rate was 1.2% per month, then the interest charge on the single cropping period, was 4.8%. After deducting this 4.8% interest cost from the percentage of marginal value productivity of working capital exceeding the marginal cost, 35%, the balance was 30.2% per production period, or 90.6% per annum (30.2 x 3 = 90.6).

Every dollar of investment made in working capital generates, on the average, 30 cents net return per crop or 90 cents per annum. Such high marginal value productivity of working capital implies that there is substantial under investment in this input category, which is not reflected by the marginal value productivity derived from the production function.

All of these five independent variables, namely, cropland, human labor, machine use, bullock labor and working capital were under employed in the sense that all of the marginal value productivities are greater than the respective marginal factor cost. We may conclude that there was quite high potentiality for the farmers to strive for even higher farm receipts by adding more of the above mentioned resources in the production.

CHAPTER IV

FEASIBILITY OF AGRICULTURAL MECHANIZATION

The Feasibility Suggested by the Production Function

Assuming that all prices of the variables are constant, the optimum profit is reached only when all marginal value productivities of input factors equal their respective factor prices. Thus the equilibrium condition requires:

$$\frac{MVP_{X_1}}{P_{X_1}} = \frac{MVP_{X_2}}{P_{X_2}} = \ldots\ldots = \frac{MVP_{X_5}}{P_{X_5}} = 1$$

The economic meaning of this equilibrium condition is, assuming there is no constraint in each of the resource, that the variable resources should be allocated in such a way that the MVP from each resource should equal the cost of the last unit of each resource.

If there is a resource constraint, the optimum profit under this condition is that the ratio of MVP and its respective prices equal a constant value greater than 1.

As shown in Table 8, all marginal value productivities are higher than the corresponding factor costs. The value of the additional output produced exceeded the additional cost of the last input unit. Among the five input categories, the marginal value productivity of machine use was about 56 times higher than its marginal cost. This means that the farming operations in the area was highly under mechanized. The per dollar additional input used in machine use may earn NT \$56.36 gross return. According to the current farm organization, increase use of machine should be taken

TABLE 8

COMPARISON BETWEEN MARGINAL VALUE PRODUCTIVITIES AND THE RESPECTIVE MARGINAL FACTOR COSTS, THE RICE REGION OF TAICHUNG AREA*

Input	X_i	MVP_{X_i}	Price of X_i (MFC_{X_i})	$\frac{MVP_{X_i}}{MFC_{X_i}}$
X_1 (ha)	0.99	16,591.60	12,580.42	1.31
X_2 (dys)	416.52	85.22	60.00	1.41
X_3 (hrs)	1.06	2,254.05	40.00	56.36
X_4 (dys)	19.87	494.01	120.00	4.11
X_5 (NT \$)	14,427.67	1.35	1.00	1.35

*Estimated from the Cobb-Douglas production function.

as the first priority rather than the other resources. However, the marginal productivity estimate for an input may not be valid beyond the range of the original data.

The possible errors may involve in the estimates of marginal value productivities and regression coefficients. In order to find the feasibility of farm mechanization, we need to examine again carefully the relationship between machine use and other independent variables from the production function derived. In other words, it is necessary to see the reliability of the marginal value productivity of machine use.

An examination of the coefficients of multiple intercorrelation and simple correlation coefficients among the independent variables may indicate possible biases in the regression coefficients. Firstly, the required condition is the coefficients of multiple intercorrelation between a specific independent variable and the rest of the independent variables appear to be low (Table 9).

TABLE 9

THE COEFFICIENTS OF MULTIPLE INTERCORRELATION OF INPUTS, THE RICE REGION OF TAICHUNG AREA*

	Coefficients of Multiple Intercorrelation
$R_{1.2345}$	0.3364
$R_{2.1345}$	0.5492
$R_{3.1245}$	0.2003
$R_{4.1235}$	0.3070
$R_{5.1234}$	0.3196

*Derived from the production function.

The coefficient of multiple intercorrelation of machine use was as low as $R_{3.1245} = 0.2003$. This indicated no important correlation among machine use and the rest of the independent variables.

Secondly, a higher correlation coefficient between independent variables may result in a biased estimate of the regression coefficient, and hence may also cause some errors in the respective regression estimates. The effects of these possible errors will undoubtedly be carried into the marginal productivity estimates derived from the production function.

Relatively speaking, X_2, human labor is highly intercorrelated with X_5, working capital ($r_{25} = 0.85$, see Appendix Table III). Some biases are possible in the regression coefficient as well as the marginal value productivity of X_2 and X_5 estimated. The marginal value productivity of X_2 may be underestimated while the marginal value productivity of X_5 are overestimated, or the reverse may hold true. Thus, the multicollinearity problem exists among the inputs of human labor and working capital. However, the coefficient between these two inputs does not seem too high to be used in this study.

The coefficients of simple correlation between machine use and each of other independent variables, as shown in Table 10, ranged from -0.0650 to 0.5557. This also indicates no important relation with other independent variables.

Therefore, we may conclude that the marginal value productivity of machine use as well as the regression coefficient were fairly reliable.

TABLE 10

SIMPLE CORRELATION BETWEEN MACHINE USE AND EACH OF THE OTHER VARIABLES, THE RICE REGION OF TAICHUNG AREA*

	Coefficients of Simple Correlation
r_{31}	0.5557
r_{32}	0.5189
r_{34}	-0.0650
r_{35}	0.5015

*Estimated from the production function.

The reliability of the marginal value productivity and the regression coefficient, plus the fact that the highest ratio of MVP_{X3} to MFC_{X3}, indicate a high feasibility of farm mechanization in the area.

Therefore, a reorganization in the input combination toward higher profits by means of adding more machine use in the production process is essential.

Optimum Conditions

The marginal value productivities of each input factor estimated from the production function can be reasonably considered as an approximation of the actual marginal value productivities in the farm operation in the area of study.

As analyzed previously, the optimum condition of

farm operation in the sample farms was not yet achieved. The ratio of marginal value productivities to the respective marginal factor costs among the five input categories varies from 1.31 to 56.36. This means that there was a wide range in the return per additional dollar input among the five input factors. The return per additional dollar input on land was NT $1.31, and $56.36 on machine use (Table 7).

The optimum condition of reorganization farm production is to approach the condition that the return per additional dollar input in each input category is equal to $1.00 in the competitive economy. However, if there is an input constraint, the optimum condition will be that the return per additional dollar input is greater than $1.00. The higher degree of constraints, the greater is this value.

The marginal value productivities suggest that a reorganization in the input combination is necessary in order for farmers to operate in a more profitable manner. Theoretically, it is possible to shift some inputs that have a lower marginal value productivity to those that have higher marginal value productivity. More specifically, the equating of the ratio of marginal value productivities to their corresponding marginal factor costs is the key to reorganizing the farm for optimum profit.

Among the fove input categories, an increase in the use of machine should be regarded as the first consideration, because the potential return per additional dollar added to the machine use was NT $56.36, which was the highest of all input categories.

The second consideration as suggested by the marginal value productivity was the increase use of bullock labor. The potential return per additional dollar added to this input category was NT $4.11. But the number of draft animal available was constrained by the shortage of feed supply as discussed in Chapter I. Therefore, to consider increase use of bullock labor will be out of question.

Third consideration should be given to the possibility of increasing the human labor, or working capital, or cropland. The marginal productivities of each input was around 1.35 times higher than its respective marginal factor costs. But the total land available for cultivation was limited unless some farmers leave the farm. Increased use of human labor in farm production may also be limited due to rapid industrial growth and the absorption of labor by industrial sector. The average annual growth rate of industrial production during 1961 to 1968 was 16.0%, and agricultural production, 5.9% (Appendix Table V). Farmers usually supply a large amount of labor for industry and the transfer of labor from farm to factory constitutes one of the most significant

aspects of the process of industralization.[18] Increased use of working capital seems to be feasible, because there are different kinds of loans available through Farmers' Associations, the Cooperative Banks, the Land Banks, etc.

Possible Farm Reorganization

Estimation of the gross farm receipts at the respective mean levels of the inputs suggest by the production function may indicate the possibilities of reorganizing the farms for higher profit operation.

The production function derived previously was

$$Y = 290.59\, X_1^{.2136}\, X_2^{.4614}\, X_3^{.0312}\, X_4^{.1276}\, X_5^{.2523}$$

Substituting all $\overline{X}_i$ in the equation, the gross farm receipts estimated from the present farm organization gives NT $76,908.17 (Table 11).

As we have found previously, the first consideration in reorganizing the farm should be given to increasing the use of machine. Since the ratio of marginal value productivity and marginal factor cost of this input category was the highest of all (1:56), it may be possible to increase the machine use by 40 times (Table 12). In this case the total

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[18] Chang, Pei-Kang, Agricultural and Industrialization, Howard University Press, 1949, p. 127.

TABLE 11

ESTIMATED MARGINAL AND GROSS VALUE PRODUCT OF THE CURRENT FARM ORGANIZATION, THE RICE REGION OF TAICHUNG AREA

Input Factor (X_i)	Geometric Mean ($\overline{X}_i$)	Log $\overline{X}_i$	b_i	$b_i(\log\overline{X}_i)$	MVP	$\frac{MVP}{MFC}$
X_1	0.99	-.0044	.2136	-.0009	16,591.60	1.31
X_2	416.52	2.6195	.4614	1.2087	88.22	1.41
X_3	1.06	.0253	.0312	.0008	2,254.05	56.36
X_4	19.87	1.2928	.1276	.1657	494.01	4.11
X_5	14,427.67	4.1592	.2523	1.0494	1.35	1.35

Log constant $\underline{a}$ = 2.4624

Log Y = $\Sigma b_i \log(X_i) + \underline{a}$ = 4.8860

Y = 76,908.17

TABLE 12

ESTIMATED MARGINAL AND GROSS VALUE PRODUCTIVITY WITH MACHINE USE INCREASED BY 40 TIMES

(X_i)	($\overline{X}_i$)	Log $\overline{X}_i$	b_i	$b_i(\log \overline{X}_i)$	MVP	$\frac{MVP}{MFC}$
X_1	0.99	-.0044	.2136	-.0009	18,451.20	1.47
X_2	416.52	2.6196	.4614	1.2087	94.37	1.59
X_3	42.40	1.6274	.0312	.0508	63.50	1.58
X_4	19.87	1.2987	.1276	.1657	549.18	4.61
X_5	14,427.67	4.1592	.2523	1.0494	1.50	1.51

Log constant $\underline{a}$ = 2.4624

Log Y = 4,9360

Y = 86,289.26

cost is added by NT $1,696.00 while land, human labor, bullock labor and working capital remain at the usual level, will result an increase in the estimated gross farm income from NT $76,908.17 (Table 11) to NT $86,289.22, or NT $9,381.09 total increase. Subtract the added cost from the increased gross income, and the net income is increased by NT $7,685.09.

The ratio of each MVP to the respective MFC, except for the input of bullock labor which has been constrained by the feed supply, are almost equal to a constant value 1.5. So, by adding the machine use by 40 times more to the current farm operation may be highly considered.

Probably, it would be preferable to recommend that farmers increase the machine use by 30 times and working capital by 1.5 times simultaneously. Thus, the machine use will increased by 31.8 hours per year and working capital, NT $21,641.51, while using the usual quantities of the other inputs. The effect of the change of these input combinations is shown in Table 13.

Increasing the use of machine by 30 times and working capital by 1.5 times, the total cost added is NT $8,443.43 (machine use, NT $1,229.60; working capital, NT $7,213.83), which will result in an increase in the estimated gross farm income of NT $17,821.60. Thus, the net income is increased by NT $9,387.17. Obvioulsy, the ratios of each

TABLE 13

ESTIMATED MARGINAL AND GROSS FARM RECEIPTS WITH THE LEVEL OF INCREASING MACHINE USE BY 30 TIMES AND WORKING CAPITAL BY 1.5 TIMES

Input	Quantity (X_i)	Log X_i	b_i	$b_i(\log X_i)$	MVP	$\frac{MVP}{MFC}$
X_1	0.99	-.0044	.2136	-.0009	20,438.66	1.62
X_2	416.52	2.6196	.4614	1.2087	104.94	1.75
X_3	31.80	1.5024	.0312	.0469	92.94	2.32
X_4	19.87	1.2987	.1276	.1657	608.33	5.06
X_5	21,641.50	4.3353	.2523	1.0938	1.10	1.10

Log constant $\underline{a}$ = 2.4624

Log Y = 4.9765

Y = 94,729.77

MVP to the respective MFC are larger than 1. It is still possible to increase the use of some inputs level for higher profit.

However, one point should be kept in mind that the errors may increase rapidly as marginal productivity estimates are made further away from the geometric mean levels.[19] In other words, if the input level used is far from their mean levels, the estimated marginal value

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[19]Heady, Earl O., and John L. Dillon, _op. cit._ p. 231.

productivity may be biased or useless due to the nature of the Cobb-Douglas model.

It might be interesting to test the feasibility of resource combination from a different point of view. Assume a farmer has additional NT $1,200 available for production. The question is how he should use this capital for production. The first consideration, as we have analyzed, should be the increase use of machine. But, to what extent can the gross farm receipts be increased. What difference would there be, if this capital was added to other inputs.

To solve this problem, it is necessary to convert the available capital into physical unit of each inputs, except for the input of working capital. Then, add the tentative unit to the respective input separately and see the results. The computation method is shown in Appendix Table VI. The results are presented in Tables 14 and 15.

From Table 14, we may note that the most profitable way to use the additional available resource is to add to the machine use. The farm receipts may increase by NT $8,459.99 and is the highest of all. Its increased gross farm receipts is approximately eight times higher than the added cost.

The second consideration is to add to the input of bullock labor, its return was about three times higher than the added cost, but this input is constrained by the

TABLE 14

THE CHANGE OF GROSS FARM RECEIPTS BY ADDING NT $1,200 TO THE INPUTS SEPARATELY, THE RICE REGION OF TAICHUNG AREA

Changed Input[a]	Added Unit[b]	Total Unit Used	Gross farm Receipts (NT $)	Gross Farm Receipts Increased[c] (NT $)
$X_{1/2345}$	.0954	1.08	78,350	1,443.83
$X_{2/1345}$	20.0000	436.52	78,620	1,681.81
$X_{3/1245}$	30.0000	31.06	85,420	8,459.99
$X_{4/1235}$	10.0000	29.87	80,850	4,104.40
$X_{5/1234}$	1,200.0000	15,627.67	78,510	1,462.93

[a]Only one input was changed at a time, the rest of the inputs were held constant at their respective mean levels.

[b]NT $1,200 divided by respective marginal factor costs.

[c]Gross Farm Receipts Increased = Gross Farm Receipts - Original Gross Farm Receipts (NT $76,908.00).

possible feed supply. The other three alternative uses, namely adding to working capital, human labor and cropland, showed that the returns are much less than that of adding to machine use.

As for the ratio of marginal value productivities of inputs to their respective marginal factor costs, by adding NT $1,200 to one input at a time, we find that adding to the macnine use has higher profit because the ratios of marginal value productivities to marginal factor cost of each input are rather uniform and closer to 1 than other alternatives (Table 15, column 4).

TABLE 15

THE RATIO OF MARGINAL VALUE PRODUCTIVITIES OF INPUT AND ITS RESPECTIVE MARGINAL FACTOR COSTS BY ADDING NT $1,200 SEPARATILY TO THE INPUT, THE RICE REGION OF TAICHUNG AREA

X_i	Changed Input[a]				
	$X_{1/2345}$	$X_{2/1345}$	$X_{3/1245}$	$X_{4/1235}$	$X_{5/1234}$
X_1	1.23	1.34	1.46	1.38	1.31
X_2	1.45	1.38	1.57	1.49	1.44
X_3	57.65	57.82	2.21	59.61	32.74
X_4	4.19	4.20	4.56	2.83	4.19
X_5	1.37	1.37	1.49	1.42	1.27

[a]Only one input was changed at a time, the rest were held constant at their respective mean levels.

A more theoretical approach to allocating the available resources under a given total outlay for an optimum profit is to compute the quantity of each input used based on the production function and cost function.

The production function derived is:

$$Y = 290.59\ X_1^{.2136}\ X_2^{.4614}\ X_3^{.0312}\ X_4^{.1276}\ X_5^{.2523}$$

The cost function for a given outlay, while holding all other excluded inputs constant, can be expressed as:

$$C = 12{,}508.42\ X_1 + 60\ X_2 + 40\ X_3 + 120\ X_4 + X_5$$

Where, C is the given outlay. Under current organization, the total given outlay is NT $54,345.28.

Thus,

$$L = 290.50\ X_1^{.2136}\ X_2^{.4614}\ X_3^{.0312}\ X_4^{.1276}\ X_5^{.2523}$$
$$+ \lambda(54{,}345.28 - 12{,}580.42\ X_1 - 60\ X_2 - 40\ X_3$$
$$- 120\ X_4 - X_5)$$

To maximize the profits, all of the partial derivatives with respect to each of the unknowns (X_1, X_2, X_3, X_4, X_5 and λ) have to be equated to zero. The computational method is shown in Appendix Table VII. The results are presented in Table 16.

TABLE 16

OPTIMUM INPUT MAGNITUDES FOR A GIVEN OUTLAY OF FUNDS, AND THE ESTIMATED MARGINAL VALUE PRODUCTIVITIES, THE RICE REGION OF TAICHUNG AREA

X_i	Magnitude	MVP_{X_i}	MFC_{X_i}	$\lambda = \frac{MVP_{X_i}}{MFC_{X_i}}$
X_1 (ha)	0.85	16,382.81	12,580.42	1.3
X_2(Dys)	384.80	78.13	60.00	1.3
X_3(Hrs)	39.02	52.09	40.00	1.3
X_4(Dys)	53.21	156.27	120.00	1.3
X_5(NT $)	12,638.44	1.30	1.00	1.3

C = NT $54,345.28

Y = NT $77,487.24

Under optimum conditions the current farm organization of the area under study suggested is to use 0.85 hectares of cropland; 384.80 work days of human labor; 39.02 hours of machine use (power tiller); 53.21 work days of bullock labor and NT $12,638.44 working capital. The total gross farm receipts under those conditions are NT $77,487.24.

Comparing the suggested farm organization with the original one (see Table 11), we may note that the biggest change in the resource allocation is the amount of machine use; which is suggested to be increased from 1.06 hours per farm to 39.02 hours.

The gross farm receipts are increased from NT $76,908.17 to NT $77,487.24. A net increase of NT $579.07 is obtained by reallocation of the inputs.

From the above analysis, we have found that, for optimum profit, the power tiller should be used approximately 40 hours per farm per annum (Table 16) on crop production, or approximately 40 hours per hectare per annum, since the average size of farm was 0.99 hectares.

We assume based on general estimate that in addition to crop production, the power tiller will have an equal amount of use on other than crop production, such as for livestock production, transporting farm products to the market, potato slicing, feed cutting, etc.

The economic working capacity of a power tiller is about 800 hours per year (will be discussed in Chapter V). Thus each power tiller would cultivate approximately 10 hectares of land under the condition of reallocating the inputs for optimum profit.

CHAPTER V

AGRICULTURAL MECHANIZATION

The Needs of Agricultural Mechanization

The man-land ratio in Taiwan is among the highest in the world (Appendix Table VIII), and it is getting higher. Increased food production must come from new and more efficient methods to production. Since it is clear that increased machine use is essential and feasible for any substantial increases in production, it is now appropriate to discuss the promotion of mechanization.

Mechanization in this study implies mainly the application of power tillers on the small-sized paddy farms. The power tiller can pull any kind of farm implement just like the larger tractors; only these implements are smaller in size as well as in working capacity. The engine can be used for different kinds of farm work, for instance, pumping water, spraying, pulling trailers and so on. The power tiller may also serve as a small power plant to do other work on the farm. Another point which is more important is that by changing to different kinds of wheels, the tiller can be used in muddy fields, upland fields, and on roads.

The power tiller for paddy fields was first developed and widely adopted in Japan, because Japanese consider paddy rice as their major crop. After World War II, many machinery manufacturers in Japan, originally ingaged in war supplies and weapons, were converted into factories for the manufacture of macnines for peaceful use.

Generally speaking, the use of modernized, improved power machines is now very limited in Taiwan. Most of the farm operations are done by hand, by the use of animal labor and with simple tools. Some of the operations are done exclusively by hand, particularly the transplanting of rice seedlings and the harvesting of rice. Notwithstanding that, these are primary and important operations in peak labor seasons. In the spring, summer, and fall peak labor seasons, farmers are rushed with such seasonal operations as harvesting the first crop by reaping, threshing, husking, winnowing, sorting, then preparing for the second by plowing, sowing, and transplanting.

Since rice is the most important crop grown and the one where the power tiller is likely to be used the most in Taiwan, it is necessary to know how much labor is needed for rice cultivation. With a brief look at Table 17, we may see that about 100 man days of labor are used in production of one hectare of rice. The distribution of labor is approximately 23% for plowing; 25% for weeding; 24% for harvesting and the remaining 28% is used in fertilizing, disease control, cleaning the rice and in transporting straw.

TABLE 17

THE HUMAN LABOR DISTRIBUTION PER HECTARE FOR RICE CULTIVATION, TAIWAN

Items	First Rice Crop	Second Rice Crop
1st dry plowing	4.6	4.4
2nd dry plowing	3.9	-
Basic fertilizer	4.4	4.4
Land preparation	14.3	14.0
Translanting (including removal of seedling)	10.5	11.9
1st fertilizer	1.3	1.3
1st weeding	8.5	8.5
2nd fertilizer	1.3	1.3
2nd weeding	8.0	8.0
1st disease control	1.3	1.3
3rd weeding	8.4	8.4
3rd fertilizer	1.3	1.3
Removing barn yard grass	3.4	3.0
2nd disease control	1.3	1.3
Harvesting	24.3	23.2
Cleaning, winnowing, storage	4.0	4.0
Transporting straw	3.8	3.8
Total	1o4.6	98.8

Source: Summarized from Chang, Chen-Chang,"Agricultural Engineering Analysis of Rice Farming Methods in Taiwan," National Taiwan University, Taiwan, 1963, pp.32-3.

Labor used for water irrigation or drainage was not included in the above table, because it should he done frequently during the whole period of production. The amount of labor required for irrigation is fifficult to estimate. In drought deasons labor requirement for irrigation will be much higher. All of the human labor required, except for removing barn yard grass from the paddy field, may be replaced or reduced by machine use. It is hard to estimate the extent to which the human labor can be reduced. But, it is likely, in the beginning stage that most plowing and transporting work may be mechanized; in the second stage, harvesting work; and in the third stage, weeding, fertilizing and disease control, etc.

However, it might be worthwhile to predict the years required to mechanize Taiwan's agriculture. From Table 18, we may see that the total number of power tillers in 1967 was 15,523 units. The number of power tillers is increasing year by year. The total number of bullocks in 1967 was 331,878 head, which is decreasing year by year. The rate of change during 1960-1967 of power tillers was, on the average, an increase of 1,754 units per year, while bullocks were decreasing 12,177 head per year. The ratio of change between power tillers and bullocks was 1 ; 7. This means every seven bullocks decreased was replaced by one power tiller.

Projecting the rate of change in the above period 20 years in the future, the total number of power tillers in use by 1987 would be 50,000 units(Figure 5). The total number of bullocks at that time will be 120,000 head.(This projection is rather weak because of the shortage of data).

TABLE 18

THE NUMBER OF BULLOCKS AND POWER TILLERS IN TAIWAN: 1960 - 1967

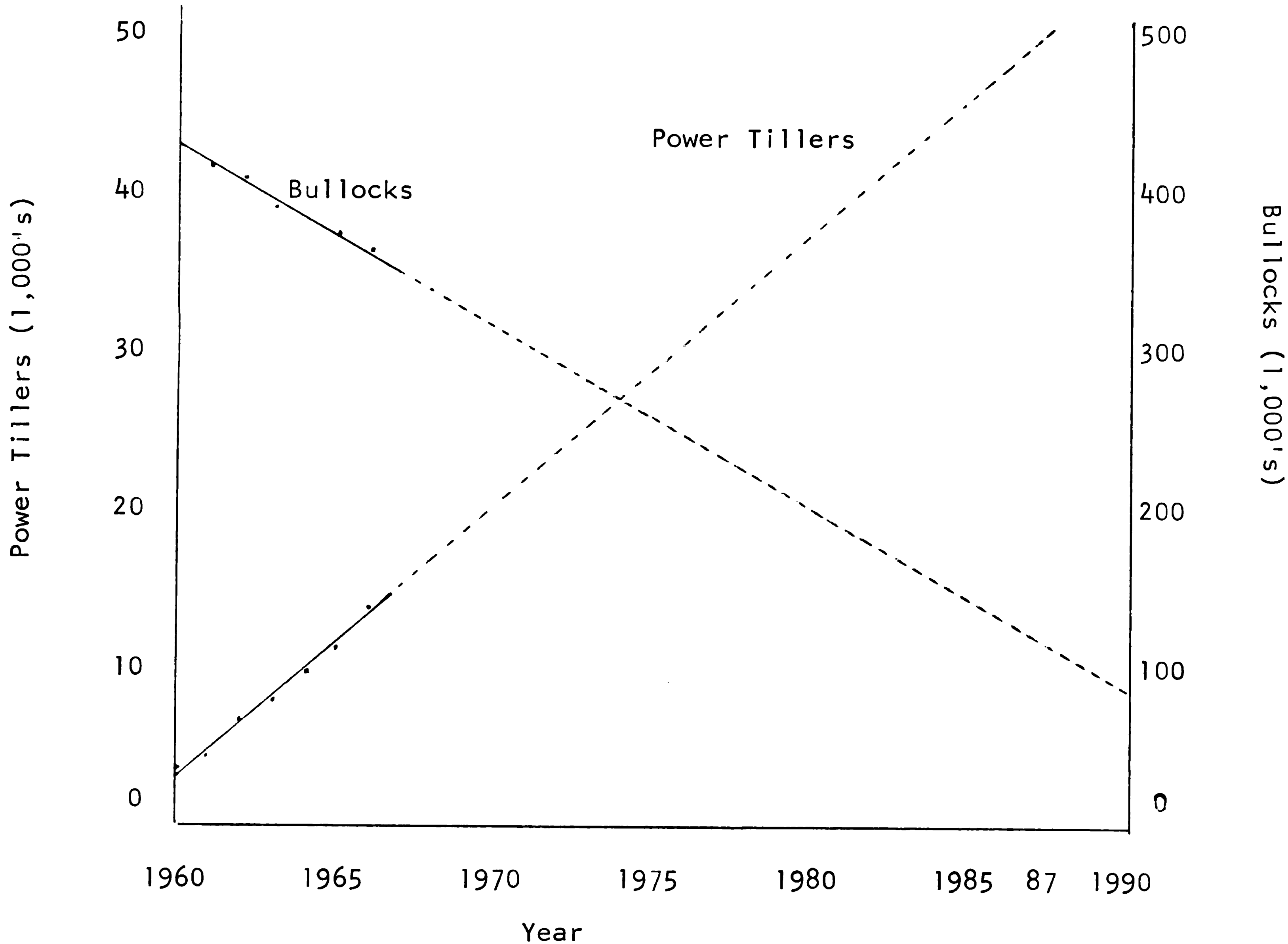
Year	Bullocks (head)[a]		Power Tillers (units)[b]	
	Number	Change	Number	Change
1960	417,122		3,242	
1961	414,208	-2,914	4,414	+1,199
1962	405,026	-9,182	6,145	+1,704
1963	389,448	-15,578	7,756	+1,611
1964	379,073	-10,375	9,367	+1,611
1965	370,361	-8,757	11,379	+2,012
1966	360,294	-10,022	13,438	+2,059
1967	331,878	-28,416	15,523	+2,085
Rate of Change per year		-12,177		+1,754
Ratio of Change		7		1

Source: [a]<u>Taiwan Agricultural Yearbook: 1967,</u> PDAF, Taiwan.

[b]Esmay, Merle L., "The Introduction of Two-wheeled Tractors in Japan and Taiwan," p. 4, which was sourced from JCRR, Taipei, 1967.

FIGURE 5

TRENDS AND PROJECTIONS OF BULLOCKS AND POWER TILLERS IN TAIWAN



Costs and Working Capacity of Power Tiller

It is fifficult to accurately compare the cost of use of bullocks and that of power tillers, because it is not easy to calculate the cost of keeping a bullock on the farm and the daily cost of use of bullocks for field work. At the beginning stage, the method of using the power tiller was to do only the same work as the bullock and therefore only part of the capacity was utilized. This gave the power tillers no opportunity to work with their maximum efficiendy. Furthermore, the operatiors of these power tillers had little training and their skill and ability in utilization of the power tiller was not uniform and was poor. Under such conditions, the depreciation and maintenance costs of the power tiller may be higher.

However, we may calculate the theoretical cost of the power tiller by the number of hours of service it may render the farmer per year. In general, within the capacity of the power tiller, the more working hours in a year, the lower is the cost per working hour. This can be illustrated in the following formula:

$$C = \frac{F_c}{X} + V_c$$

Where, C = total cost per hour of use

F_c = annual fixed costs

X = working hours per year

V_c = variable cost per hour

The fixed cost includes the following items:

a. Depreciation of power tiller: the purchase price of power tiller is NT $45,000 (including all attachments and a trailer) and its service life is generally figured as seven years. Assuming no salvage value, its depreciation will be NT $6,430 per year (simple straight line method).

b. Interest of investment: the prevailing interest rate is 10 per cent per annum. The interest on envestment will be NT $2,250 per year ($45,000 \times \frac{1}{2} \times 0.1$).

c. Tax, insurance, storage cost, etc.: approximately 1.5% of the purchase price, or NT $675 per year.

d. Repair, lubrication, and regular maintenance: assuming 4% of the purchase price, or NT $1,800 per year.

The variable costs include the following items:

a. Fuel: the power tiller with 7.5 HP (an average type) consumes an average of about 0.6 gallon of gasoline per hour, or NT $11.4 per hour (NT $19.00 per gallon).

b. Operator's wages: NT $8.75 per hour (NT $70 per day).

c. Lubricant, grease, and miscellaneous: approximately NT $0.50 per hour.

Thus, the average total cost curve is:[20]

$$C = (9126/X) + 20.65$$

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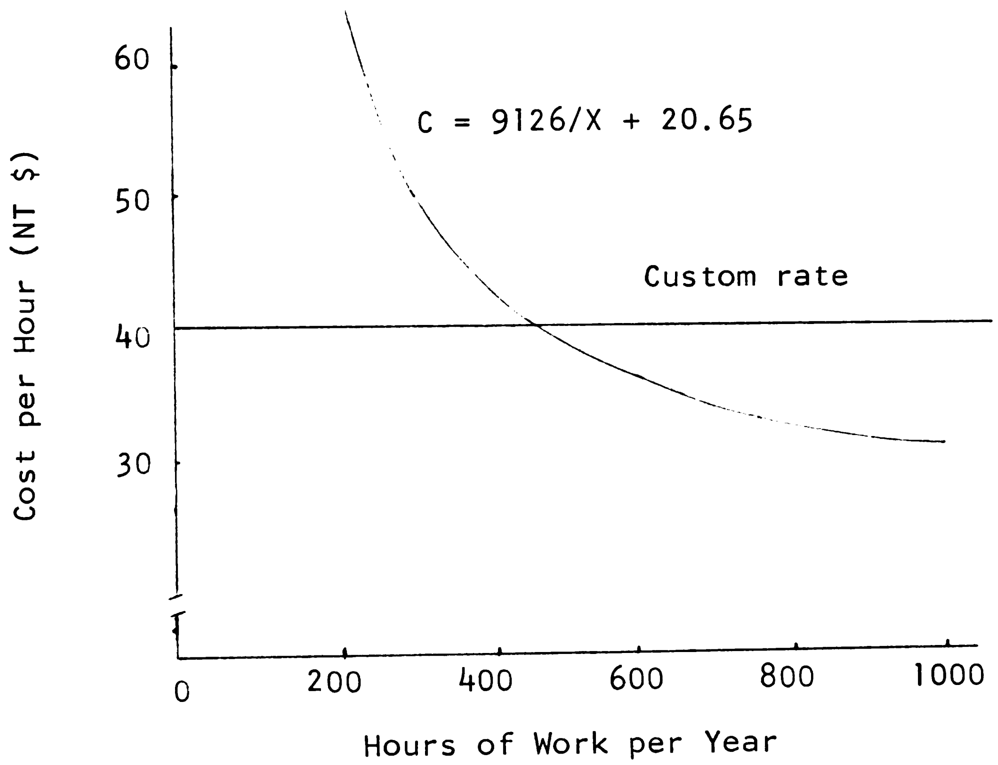
[20] $$C = \frac{45{,}000 \times (14.28\% + 0.5\% + 1.5\% + 4\%)}{X} + (11.40 + 0.50 + 8.75)$$

The average total cost curve per hour is illustrated in Figure 6.

FIGURE 6

AVERAGE TOTAL COST CURVE PER HOUR OF POWER TILLER USE



The power tiller is being used about 500 hours a year according to a 1963 study.[21] The total cost per hour is NT $38.90 on this basis, which is quite close to the prevailing custom rate (NT $40.00). Roughly speaking, the economic range of using a power tiller as indicated in the diagram, is around 800 to 900 hours per year, while the total cost per

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[21] Chang, Chen-Chang, " Agricultural Engineering Analysis of Rice Farming methods in Taiwan," National Taiwan University, Taiwan, 1963.

hour may reduced to around NT $32.

One hectare of crop production under the current type of operation, needs approximately 90 hours of power tiller use per year.[22] In order to be able to cover the total cost, a power tiller should be used at least 490 hours per year (read off from Figure 6) or about 5.5 hectares. For more economic operation, a power tiller may be used about 800 hours or enough to handle 8 to 9 hectares per year.

A small farm in Taiwan (about 1 hectare) is not big enough to keep the power tiller working up to the minimum economic annual working hours, thus investment made in a power tiller becomes uneconomical unless custom work for other farmers is available.

Therefore, it is not sound economics to persuade every farmer to purchase a power tiller. Rather it is feasible that one power tiller be purchased cooperatively by several farmers.

Economic Advantages of Agricultural Mechanization

As discussed previously, the increased production must come from an efficient and intensive use of land in farm production. Therefore, in the first place, the soil prepared for a crop should be plowed well and turned over completely, thus both the upper and lower parts of soil can be used efficiently by succeeding crops. Green manure, compost and

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[22] Derived from Chang, Chen-Chang, op. cit., i.e. two crops of rice per year = 64 hours, (1st dry plowing, 11 hours per crop; 2nd dry plowing, 11 hours per crop; pulverizing, leveling and misc., 10 hours per crop) winter crop = 26 hours.

other basic fertilizers also should be turned down into the soil.

A study made by Taichung District Agricultural Improvement Station showed that the yield of rice increased with an increase in the depth the soil was plowed (Table 19 and Figure 7).

TABLE 19

THE RELATION OF THE DEPTH OF SOIL PLOWED AND THE YIELD OF RICE, TAICHUNG AREA

Depth of Soil Plowed (cm)	Rice Harvested per Ha. of paddy field (kg)*
10.5	4,025
13.5	5,257
16.5	5,669
19.5	5,848

* 1 kilogram = 2.2 pounds

Source: Taichung Agricultural Imprivement Station, 1966.

According to Chang,[23] the average depth of cultivation by draft animal was 12 centimeters, while the depth plowed by power tiller in the same field was 15.8 centimeters, or 3.8 centimeters deeper than thet of draft animals. The increase in yield of rice was 880 kilograms(read off from Figure 7).

The rate of increase was about 18.6%. Stout[24] also points

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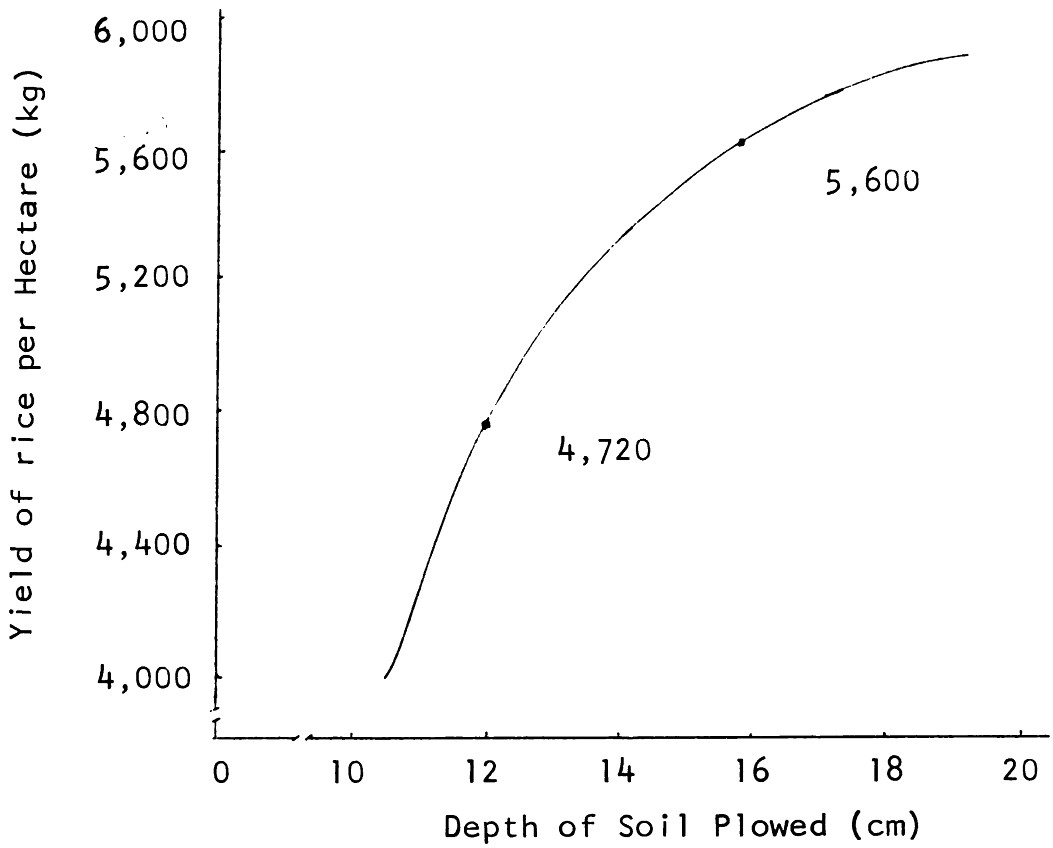
[23]Chang, Chen-Chang, op.cit.

[24]Stout, B. A.,"Equipment for Rice Procuction," FAO, Rome, 1966, p. 47.

FIGURE 7

THE RELATION OF THE DEPTH OF SOIL PLOWED AND THE YIELD OF RICE, TAICHUNG AREA



Source: Same as Table 10.

out that depths greater than 20 centimeters can result in decreaded yield. This is probably due to the fact that the organic matter becomes buried too deeply for the root systems to reach the plant nutrients.

Making a conservative estimate, each power tiller would cultivate eight hectares per season. Fifty thousand tillers would cultivate 400,000 hectares of land per season (the total cultivated land in Taiwan was 899,926 hectares, see Table 2). The output increase in rice production would be 352,000 metric tons,[25] (400,000 x 880). The total increase for the two crops per year from the 400,000 hectares of land cultivated by power tillers would be over 704,000 metric tons. Even if the increase is cut down to 10%, we still have 328,900 metric tons in increased rice output. This additional 328,900 metric tons of rice from no extra land will have undeniable effect on improvement of the food supply. If this quantity of rice is exported to foreign countries it would earn foreign exchange amounting to 34.5 million US dollars (assuming that 70% of the paddy rice will become polished rice and sold at US $150 per metric ton).

On the other hand, let us calculate the amount of foreign exchange to be spent for purchase of 50,000 power tillers. At present, assuming we have to buy the whole machine from Japan, each power tiller costs us about $500.[26]

Taking into consideration home production of 2,000 tillers a year, it is estimated that we would have to import 20,000 whole units from Japan. Later we only have to pruchase the engines and some of the parts from abroad, at a cost of US $300 per unit. We assume that 15,000 such tillers will be sold in the rural area at this stage. In a still later

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[25] 1 metric ton = 1000 kilograms

[26] The whole sale price of a power tiller in Japan was US $335, (Shin-norin Sha Co. Ltd., Farm Machinery Yearbook, 1970, p. 109), the shipment fee, tax, etc. was estimated US $165 per tiller.

period, most of the parts may be manufactured in Taiwan, except for the engines and some inportant materials each power tiller will then cost us only about US $100. The 50,000 tillers will cost Taiwan a total of US $16 million, which is 46.3 percent of the increased value of rice derived from the use of the power tiller in one year.

Setting the serviceable life of a tiller at 7 years, the total increased value of rice in that period would be 241.5 million US dollars (34.5 x 7). If one hectare of rice required 64 hours of machine use (see footnote 23), and the operating cost is NT $36 per hour, or US $0.90 (assuning the tillers reach certain economic use), the total cost would be US $57.60 per hectare annually. The total cost for 400,000 hectares will be 23 million US dollars. For the estimated seven years of machine life, the total operating costs for the 50,000 tillers would be US $141 million. The total net increased value of rice during the seven year period is:

Total increased value of rice	US $241.5 million
Total operating costs	US $141.0 million
Total net value increased	US $100.5 million

Dividing the total net value increased of US $100.5 million, by seven years we would have 14.28 million US dollars net profit per year. We can well see the actual profit of using power tillers.

These calculations do not include the value created by using the power tiller for possible increased intensity of land utilization, from crops other than rice, and other farm work, which is hard to estimate but should not be neglected. Furthermore, Taiwan has now two power tiller manufacturing factories, producing 2,000 tillers per year. Thus the increased use of power tillers may help in the development of rural industries.

Secondly, to increase farm incomes from a given acreage of land, a farmer should, in general, increase land utilization in terms of the multiple cropping index. In so doing, all harvesting, plowing, and transplanting are limited to within a very short time period, thus the supply of labor or power must be sufficient to meet the demend in that period. Tsui[27] indicated the time required per hectare for preparing rice paddy was 3.5 days at 8 hours per day for a tiller and 10.5 days at 10 hours per day with bullock labor.[28] This means that the second crop can be planted 7 days earlier.

Judging from all criteria, mechanization of agriculture would be beneficial in all respects. The important ones may be summarized as follows:

(1) Increase crop yields per unit of land, to meet the growing demand of foods.

(2) Increase farm intensification, or multiple cropping

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[27] Tsui, Young-Chi, "A report on Economic Analysis of Farm Mechanization", JCRR, 1962.

[28] Land preparation is defined as consisting of the operations of plowing, breaking, pulverizing and leveling.

index. The use of power tillers may permit an additional crop by more rapid harvesting the first crop or land preparation for the succeeding crops.

(3) Reduce the amount of land devoted to the production of feed and forage for bullocks.

(4) Break the bottle neck of seasonal peak labor requirements, such as harvesting the first crop and planting the succeeding crops in March, July and November.

(5) Help in the development of the farm machinery manufacturing industry as well as overall economic development.

Some Difficulties to be Recognized

There are several problems which should be solved before any program of trying to mechanize the farm operation is undertaken. The most important problem is the farm people who are largely composed of small, independent, tradition - bound farmers. The characteristics of being small and indepent have become increasingly universal since the completion of the land reform program in 1953.[29] By small, it is meant that the farm owned and operated by a

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[29]Yang, Martin M.C., "Social Factors in the Joint Cultivation of Rice", National Taiwan University, Taiwan, 1968, p. 4.

family and the farming operation on it are all small in size, as mentioned in Chapter I. The use of power tillers, if limited to use on one farm, would be very much limited.

In Taiwan, farm operation practices are affected by the shape and size of fields, which in turn are partly influenced by the land inheritance system and partly by the nature of farm practices. The influence is particularly important in areas where population growth outstrips available farm land. Even after the enforcement of land reform program, the law still gives equal right of land inheritance among several heirs. The situation has caused farm holdings to become even smaller, as an average, and particularly when there are several heirs.

In rice cultivation, for example, paddy fields must be irrigated and the irrigation water must be adjusted as rice plants grow. For this, the size of each plot of paddy field should not be too large. If the size of a plot of paddy field is too large, it will be impossible to maintain the desired water level above the surface of the ground after the paddling. Thus the water depth would become different in different parts of the same paddy feild, with the mud being exposed in some parts of the field. Thus weeds will spring up.

Therefore, even when several plots of arable land are consolidated into one plot, it must be partitioned into smaller plots by border ridges.

On the other hand, it is usual that a farmer's paddy fields are widely scattered and the shape of each plot is frequently not regular. If the holdings are widely scattered and each plot is not regular in shape, labor efficiency may not be increased much, even if the operation is done with a power tiller. It is also very troublesome to convey the power tiller from place to place.

Operating practices are affected by the above factors. For this reason, in order to introduce power tillers, projects for water use improvements, consolidation of fragmented holdings, and the rearrangement of local roads and farm roads have been planned and carried out in many parts of the island in the past few years. Some of the above projects are serving as a basis for the more intensive use of farmland. However, to encourage the use of power tillers, we cannot avoid exerting great efforts to make attitudinal changes on the part of farmers toward faster adoption.

Processes of Agricultural Mechanization

To develop agricultural mechanization, the government must make provision for spending a great deal of capital to encourage, organize and set it to work, especially in an area characterized by small holdings like Taiwan. A cooperative venture, as being successfully done in Japan, might apply to Taiwan. However, local conditions, and farmer's attitude, for instance, may dictate the method of implementing the mechanization project.

The ways of adopting the power tillers may differ according to the farmer's purchasing power and size of his farm. In general, there are three ways: (1) Individual ownership and use on his own farm. (2) Partner ownership and joint use, and (3) Individual ownership, and, when possible, doing custom work for other farmers. Each of the three ways has its merits and shortcomings which we shall compare and discuss briefly in the following:

(1) Individual ownership and for use in his own farm:

a. Merits: The owner will constantly and strenuously study the ways to utilize the power tiller on his farm. This will greatly extend the working scope of the power tiller in his farm. On the other hand, he will be attentive to the proper maintenance and repair of the power tiller.

b. Shortcomings: When the owner's farm is not big enough to heep the power tiller working up to the minimum economic annual working hours, i.e. 800 to 900 hours per year, investment made on the power tiller will be uneconomical.

(2) Partner ownership and joint use:

a. Merits: Farmers who do not have sufficient money to buy a power tiller individually may pool their funds and all enjoy the use of power tiller. In this case, the working capacity of the power tiller will be fully utilized.

b. Shortcomings: Every owner has equal right in use of the power tiller. During busy seasons it becomes fifficult to make the power tiller available to all the owners satisfactorily. None of the owners will pay attention to the proper repair and maintenance of the power tiller.

(3) Individual ownership and doing custom work for others:

a. Merits: Work schedule will be well arranged by owneraccording to priority, and the working capacity of the power tiller is fully utilized.

b. Shortcomings: Individual ownership may delay the adoption of power tillers. The custom rate may change in different seasons.

Based on above comparison and analysis, we think that if an individual can afford to buy a power tiller, it is best for him to buy one for his own use. If the area of his farm is limited and cannot utilize the power tiller fully, he can do custom work for neighbors. If the individual does not have or cannot raise the money to buy a power tiller, he can pool his funds with his nearby neighbors for purchase of a power tiller. But the number of parters in this case should not be many. As we have mentioned before, the power tillers can be éffectively used over 7 to 8 hectares of land. Therefore if 5 to 10 persons have a total farm area of 7 to 8 hectares, the power tiller may be very efficiently used in the small group cooperatively.

In view of the shortcomings of joint use, an ingenious working plan covering all fields of member farmers is required to be laid down in advance. If the tiller is operated by member farmer himself, sufficient knowledge and skill for operating the power tiller are the primary requirements. Which type of ownership and use to be adopted may depend on the local situations.

Bunkel[30] points out that prviding for adequate educational facilities, including qualified instructors, is an important prerequisite for mechanized agriculture. In this regard, the Farmers' Associations would seem to be able to carry out this phase of mechanization projects. In every towndhip and village in Taiwan there is set up a voluntarily organized and democratically run farmers' association. These organizations serve local farmers in matters of credit, wholesale purchasing, cooperative marketing, warehousing, and agricultural extension and education. The associations are managed by officers elected by their members. In the last decade, the associations have been actively engaged in agricultural extension and education work, under the assistance of the Joint Commission on Rural Reconstruction (known as JCRR) and the Provincial Department of Agricultural and Forestry with promising results.

Farmers' Associations may provide a sound foundation for agricultural mechanization, such as providing credit for purchase of the machines, training the farmers to operate power tillers, establishing machine shops, and helping to

[30]Gunkel, Wesley W., "Implementation and Over Mechanization in Developing Countries," ASAE Annual Meeting, paper No. 68-508,1968.

organize the farm machinery cooperative teams, etc. In Taiwan, there is no other organization which is so closely related to all farmers.

Power tillers, to be used effectively, must fit into the agricultural conditions. We must be careful in selecting the right type of power tillers, such as (1) Tractive type: may pull various farm implements, i.e. plows, harrow, cultivators and trailers. This type of power tiller is suitable for dry fields, (2) Rotary type: rather bulky and heavy, difficult for traveling on the narrow footpaths, and (3) Screw type: equipped with track laying ground driving devices. This type is suitable on the deep mud paddy field.

The use of small power tillers is likely the key to the solution of the problem of overall agricultural mechanization. We should allow sufficient time for farmers to learn how to use power tillers to replace present cultivation tools, even if we want to extend the use of power tillers as rapidly as possible. Besides, an adequately trained supply of extension workers to give the necessary guidance and supervision to farmers is also needed.

In starting intensified promotion of power tillers, we ought to advocate concentrated efforts in selected localities where we can consentrate available efforts in training farmers how to operate the power tillers. When success is attained in these experimental localities, the work can be gradually extended to other areas.

To summarize, to successfully implement the agricultural mechanization program, the following steps have to be taken:

(1) Demonstrate power tillers of suitable type in selected areas. The essential thing is to show the farmers the results of and advantages of using power tillers and to tell them how to use power tillers the year around to do different kinds of work in their own farms.

(2) Design new farm implements attachable to the power tillers and adaptable to the conditions of the localities.

(3) Train technical workers to assure adequate number of extension and repair personnel.

(4) Train the farmers how to operate and maintain the power tillers.

(5) Provide long thrm loans at reasonable interest rate to help the farmers purchase the power tillers.

(6) Guide and assist farmers in organizing joint use teams and set up the working plans for the groups.

(7) Provide competent servicemen and adequate repair facility at places convenient to farmers.

The above comprise the necessary processes for the agricultural mechanization. They are all indispensable and supplementary to each other. Shortage of either one of them will affect the sound development of the whole program. No single element should be ignored.

CHAPTER VI

CONCLUSION

The production function derived from the sample farms was fairly reliable as indicated by the relatively small standard error of estimate (the standard error is 0.13), highly significat levels of each independent variable, and specified by other statistics. The production indicated by the positive sign of constant value as well as positive regression coefficients of each independent variable showed that each of the quantities of inputs being used were located in Stage II, the rational stage. But the ratio of the marginal value prodictivity estimates to their respective marginal factor costs, clearly indicated that the resources were not properly allocated to obtain optimum profit.

The sum of regression coefficient was 1.08, which implies that the production was near constant return to scale. Among the five inputs used, human labor had the most influence (40%) on the variation in the output, followed by working capital (about 20%) and land (16%), others have less influence.

The marginal value productivities of all inputs were higher than their respective marginal factor costs. This means that increased use of each input will result in higher farm profits.

The possibility of increasing the use of power tillers should be considered first among the other possibilities, because the ratio of the marginal value productivity of machine use to its marginal factor cost, 56:1, was by far the largest of any inputs. In other words, any change to be made in input combination for higher profits, increased use of power tillers should be given first consideration.

The second possible consideration of input combination for higher profit. as suggested by the production function, was the increased use of bullock labor. But in view of the real situation, the total number of bullocks has been decreasing year by year, due to the shortage of feed supply. Increased use of bullock labor will be out of the question. Increased use of power tillers not only may replace the bullock labor but also may provide more power for more highly intensified farming operation.

By adding an additional given amount of input (in value terms) to each input separately, we also see that the highest profit could only be attained by adding to machine use. Reallocation of the present input combination for optimum profit also indicated that the biggest change could be made by increased power tiller use from 1.06 hours per year to 40 hours per year. These facts showed that mechanization in terms of use of power tiller is highly feasible and desirable.

In earlier years, it was conceived that labor force was an abundant agricultural resource in Taiwan, and that there was a considerable amount of excess labor or under-employed labor in the agricultural sector. Actually instead of an excess labor supply, even on an annual basis, there has been a shortage of labor in the last two or three years.[31] Agricultural mechanization would partially solve the problems of labor shortage.

In the long run, with the increase in population, there will be growing need for more food production, but there is little chance for expansion of farmland. Consequently, higher output per hectare will be needed. Use of farm machinery will be one step forward toward the long range goal of more intensive utilization of farmland to get more food. With power tillers speeding up the land preparation work, the farmers can time their crop planting and harvesting to their best advantage, and, in most cases, realize production potential of crops that was previously unattainable, due to delay in planting caused by the shortage of animal or man power for land preparation. Thus, in a sense, farm incomes may be increased with a high multiple

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[31] Wu, T. C., "On the Research Diminution of Winter Crop Acreage in Taiwan," JCRR, Taiwan 1969.

cropping index, made possible by having more adequate power.

Esmay[32] points out "If a country is to prosper over a long period of time, its resources of manpower must be utilized carefully. From a physical standpoint, man can develop only about one tenth of a horse power. From a power standpoint he is overpaid. Man was created as a thinking creature and this potential must be developed. Even in view of this, engineers realize that in manpower-surplus and land-deficient countries, mechanization must justfy by either reducing costs or increasing yield per hectare." Thus, to increase the yield of crops, mechanization is extremely essential, even if the farms are small in size. Further, it is important to relieve farm labor from over-work by the use of machinery. The labor saved by the use of mechanical power may be used in other types of work on the farm or part-time work, or the reduction of time needed would make possible participation in cultural and social activities. This is important in modern life.

The extension job of promoting power tillers is difficult. The farmers of Taiwan are accustomed to bullocks and they know how to treat and drive them. As power tillers are totally new to them, they would hardly know sound selection and operation. Improvement in farm mechanization requires

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[32]Esmay, Merle L., "Rice Mechanization," Sixth Semi-Annual Report of Michigan State University Advisory Group to the Rep. of China and AID, 1963, p. 50.

adoption of changes which should be accepted by individual farmers as well as groups of farmers.

Taiwan's agricultural mechanization as indicated by the introduction of power tillers is starting a pattern similar to Japan's with a time lag of about twelve years.[33] In view of the success there, mechanization in Taiwan should be promoted strongly. Local demonstrations showing the results of using power tillers compared with bullocks should be put on to convinence farmers of the economic advantages of power tillers. The types of power tillers to use must be such that they can fit into the agricultural situations of the localities. Farmers should have sufficient knowledge of how to operate power tillers. In other words, research and education are prerequisites to large scale extension of agricultural mechanization in Taiwan.

Power tillers may be jointly owned and used among small groups of nearby farmers. But the overall working plans have to be arranged in advance. This kind of organization should be supervised by farmers' associations. This will ensure profitable utilization of the investment.

Therefore, in achieving the objective of agricultural mechanization, social service organizations, the government, the farmers associations and farmers themselves have their

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[33]Esmay, Merle L, "The Introduction of Two-wheeled Tractors in Japan and Taiwan," Mimiograph, Agr. Eng. Dept., MSU, 1967, p. 4.

important roles to play to help Taiwan to achieve the desired success.

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APPENDICES

APPENDIX TABLE I

DATA USED FOR REGRESSION ANALYSIS FROM THE SAMPLE FARMS IN THE RICE REGION OF TAICHUNG AREA, TAIWAN

Gross Farm Receipts (NT $)	Croplang (ha)	Human Labor (Dys)	Machine Use (Hrs)[a]	Bullock Labor (Dys)[b]	Working Capital (NT $)
138,000	2.3	1,403	0.0	35.0	32,820
15,977	0.1	67	0.0	12.0	2,632
32,775	0.4	230	0.0	23.0	5,755
40,325	0.5	138	0.0	25.0	5,950
67,248	1.3	342	0.0	31.0	13,728
34,500	0.6	204	6.0	17.0	5,174
25,400	0.8	215	4.5	8.5	9,776
32.550	0.6	147	0.0	9.0	6,117
45,720	1.0	264	0.0	12.0	7,360
35,400	0.8	164	3.0	19.0	5,168
31.890	0.5	186	0.0	32.0	6,390
112,400	1.1	375	0.0	44.0	8,750
342,220	3.2	2,802	52.0	51.0	62.807
81,725	0.8	227	9.5	10.0	9,500
41,100	0.6	190	0.0	18.0	11.390
114,920	1.0	800	8.5	24.5	24,750
117,160	2.5	1,115	20.0	13.0	43,984
164,420	1.7	545	19.2	19.2	15.253
108.251	0.9	589	0.0	50.0	28,368
108,260	1.5	534	4.5	17.0	30,469
51,335	1.0	236	0.0	12.0	15,007
80,200	1.5	629	0.0	11.0	20.140
181,675	2.5	750	0.0	27.5	39,765
53,400	1.0	266	4.0	18.0	10,030
38,450	0.4	299	0.0	23.0	5,423
141,360	2.2	806	9.5	45.5	30,695
267,600	0.8	1,120	14.5	69.0	29,200
216,500	2.5	580	3.5	59.5	29,725
53,030	1.8	287	4.0	15.0	10.648
9,950	0.1	177	0.0	9.0	4,170
47,250	0.5	250	0.0	21.0	9,680
144,900	0.7	630	1.0	54.5	55,958
90,000	1.8	400	4.5	16.5	14.400
414,450	2.7	2,237	114.6	0.0	83.880
262,300	2.8	728	26.0	59.0	41,860
51,525	1.5	242	8.0	12.0	7,585
124,365	2.3	1,025	12.0	15.5	19,630
156,945	1.3	1,061	20.5	34.5	26,710
85,040	0.4	814	0.0	8.0	5,185
75,250	1.0	321	0.0	26.0	20,494

APPENDIX TABLE I (continued)

Σ	4,235,766	51.0	23,395	349.30	1,006.7	816,326
M_a	105,894.5	1.28	584.88	8.73	25.17	20,408.15
M_g	76,921.67	0.99	416.52	1.06	19.87	14,427.67

[a]Zero values were converted to 0.1 for culculating the M_g.

[b]Zero values were converted to 1.0 for culculating the M_g.

M_a = arithmetic mean, M_g = geometric mean.

APPENDIX TABLE II

CALCULATION OF BETA COEFFICIENTS

General formula = $B_i = b_i \cdot \frac{S_i}{S_y}$

$$B_1 = (.2136)\frac{.34924}{.36068} = .2068 = 17.99\%$$

$$B_2 = (.4614)\frac{.35510}{.36068} = .4543 = 39.52\%$$

$$B_3 = (.0312)\frac{.04338}{.36068} = .0902 = 7.85\%$$

$$B_4 = (.1276)\frac{.33631}{.36068} = .1189 = 10.34\%$$

$$B_5 = (.2523)\frac{.36962}{.36068} = .2585 = 22.49\%$$

ΣB_i = 1.1287 = 87%

Unknown = 13%

Total = 100%

APPENDIX TABLE III

CORRELATION COEFFICIENTS BETWEEN VARIABLES

Y	1.0000					
X_1	.7948	1.0000				
X_2	.8861	.7056	1.0000			
X_3	.5628	.5557	.5189	1.0000		
X_4	.2734	.1561	.1532	-.0650	1.0000	
X_5	.8776	.7688	.8540	.5015	.2257	1.0000
	Y	X_1	X_2	X_3	X_4	X_5

APPENDIX IV

CALCULATION OF MARGINAL VALUE PRODUCTIVITIES

General formula = $MVP_{X_i} = b_i \dfrac{\overline{Y}}{\overline{X}_i}$

$$MVP_{X_1} = (.2136)\frac{76{,}921}{0.99} = 16{,}591.60$$

$$MVP_{X_2} = (.4614)\frac{76{,}921}{416.52} = 85.22$$

$$MVP_{X_3} = (.0312)\frac{76{,}921}{1.06} = 2{,}254.05$$

$$MVP_{X_4} = (.1276)\frac{76{,}921}{19.87} = 494.01$$

$$MVP_{X_5} = (.2523)\frac{76{,}921}{14{,}427.67} = 1.35$$

APPENDIX V

ANNUAL GROWTH RATE OF AGRICULTURAL AND INDUSTRIAL PRODUCTION, TAIWAN

Year	Agricultural Production (%)	Industrial Production (%)
1961	8.5	15.2
1962	2.1	11.2
1963	-0.5	9.2
1964	12.7	19.2
1965	7.4	18.9
1966	5.2	16.0
1967	5.9	16.8
1968	6.1	21.4
1961 - 68 Average	5.9	16.0

Source: Taiwan Statistical Data Book, Council for International Economic Cooperation and Development, Executive Yuan, Taiwan, 1968.

APPENDIX TABLE VI

VI-A ESTIMATED MARGINAL AND GROSS FARM RECEIPTS WITH THE LEVEL OF INCREASING CROPLAND BY NT $1,200 (.0954 ha.) WHILE HOLDING OTHER INPUTS CONSTANT

Input	Quantity	Log X_i	b_i	b_i(log X_i)	MVP	$\frac{MVP}{MFC}$
X_1	1.08	.0335	.2136	.0071	15,495.06	1.23
X_2	416.52	2.6196	.4614	1.2087	86.79	1.44
X_3	1.06	.0253	.0312	.0008	2,306.22	57.65
X_4	19.87	1.2982	.1276	.1657	503.16	4.19
X_5	14,427.67	4.1592	.2523	1.0494	1.37	1.37

$\underline{a}$ = 2.4624

Log Y = b_i (log X_i) + $\underline{a}$ = 4,8941

Y = 78,352.00

APPENDIX TABLE VI (continued)

VI-B ESTIMATED MARGINAL AND GROSS FARM RECEIPTS WITH THE LEVEL OF INCREASING HUMAN LABOR BY NT $1,200 (20 Dys) WHILE HOLDING OTHER INPUTS CONSTANT

Input	Quantity	Log X_i	b_i	$b_i(\log X_i)$	MVP	MVP/MFC
X_1	0.99	-.0044	.2136	-.0009	16,956.38	1.34
X_2	436.52	2.6400	.4614	1.2183	83.07	1.38
X_3	1.06	.0253	,0312	.0008	2,313.21	57.82
X_4	19.87	1.2982	.1276	.1657	504.68	4.20
X_5	14,427.67	4.1592	.2523	1.0494	1.37	1.37

a = 2.4624

Log Y = 4.8954

Y = 78,589.98

VI-C ESTIMATED MARGINAL AND GROSS FARM RECEIPTS WITH THE LEVEL OF INCREASING MACHINE USE BY NT $1,200 (30 Hrs) WHILE HOLDING OTHER INPUTS CONSTANT

Input	Quantity	Log X_i	b_i	$b_i(\log X_i)$	MVP	MVP/MFC
X_1	0.99	-.0044	.2136	-.0009	18,418.83	1.46
X_2	416.52	2.6196	.4614	1.2087	94.57	1.57
X_3	30.06	.0253	.0312	.0461	88.61	2.21
X_4	19.87	1.2982	.1276	.1657	548.21	4.57
X_5	14,427.67	4.1592	.2523	1.0494	1.49	1.49

a = 2.4624

Log Y = 4.9313

Y = 85,368.16

APPENDIX TABLE VI (contunued)

VI-D ESTIMATED MARGINAL AND GROSS FARM RECEIPTS WITH THE LEVEL OF INCREASING BULLOCK LABOR BY NT $1,200 (10 Dys) WHILE HOLDING OTHER INPUTS CONSTANT

Input	Quantity	Log X_i	b_i	$b_i(\log X_i)$	MVP	$\frac{MVP}{MFC}$
X_1	0.99	-.0044	.2136	-.0009	17,479.07	1.38
X_2	416.52	2.6196	.4614	1.2087	89.74	1.49
X_3	30.06	.0253	.0312	.0008	2,384.52	59.61
X_4	19.87	1.4753	.1276	.1882	346.14	2.88
X_5	14,427.67	4.1592	.2523	1.0494	1.42	1.42

a = 2.4624

Log Y = 4.9086

Y = 81,o12.57

VI-E ESTIMATED MARGINAL AND GROSS FARM RECEIPTS WITH THE LEVEL OF INCREASING WORKING CAPITAL BY NT $1,200 WHILE HOLDING OTHER INPUTS CONSTANT

Input	Quantity	Log X_i	b_i	$b_i(\log X_i)$	MVP	$\frac{MVP}{MFC}$
X_1	0.99	-.0044	.2136	-.0009	16,390.71	1.31
X_2	416.52	2.6196	.4614	1.2087	86.93	1.44
X_3	1.06	.0253	.0312	.0008	2,309.71	32.74
X_4	19.87	1.4653	.1276	.1657	503.92	4.19
X_5	15,625.16	4.1938	.2523	1.0581	1.27	1.27

a = 2.4624

Log Y = 4.8949

Y = 78,471.01

APPENDIX TABLE VII

THE COMPUTATION TO SOLVE FOR THE OPTIMUM INPUT COMBINATION AT A BIVEN OUTLAY OF FUNDS

Costs at the Means of the Original Input Combination:

Input	Geometric Mean	MFC	Cost
X_1	0.99	12,580.42	12,454.62
X_2	416.52	60.00	24,991.20
X_3	1.06	40.00	42.40
X_4	19.87	120.00	2,384.40
X_5	14,427.67	1.00	14,427.67

Total Cost[a] = 54,345.28

[a]Costs of the inputs included in the production function.

The production function and cost function are:

$$Y = 290.59\, X_1^{.2136}\, X_2^{.4614}\, X_3^{.0312}\, X_4^{.1276}\, X_5^{.2523} \quad . \;. \; (1)$$

$$54{,}345.28 = 12{,}580.42\, X_1 + 60\, X_2 + 40\, X_3 + 120\, X_4 + X_5 \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; (2)$$

Thus,

$$L = 290.59\, X_1^{.2136}\, X_2^{.4614}\, X_3^{.0312}\, X_4^{.1276}\, X_5^{.2523} + \lambda(54{,}345.28 - 12{,}580.42\, X_1 - 60\, X_2 - 40\, X_3 - 120\, X_4 - X_5)$$

λ is a Lagrange Multiplier which is unknown value.

The necessary condition to maximize Y is all of the partial derivatives with respect to each of the unknowns have to be equated to zero. For computational convenience, we shall use general notations such as

$$L = (\text{antilog } \underline{a}) X_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} X_5^{b_5} + \lambda (C - X_1 P_1 - X_2 P_2 - X_3 P_3 - X_4 P_4 - X_5 P_5)$$

Where X_1, X_2, . . . X_5, and λ are unknowns. The partial derivatives are:

$$\frac{dL}{dX_1} = (\text{antilog } \underline{a})\, b_1 X_1^{b_1 - 1} X_2^{b_2} \ldots X_5^{b_5} - \lambda P_1 = 0$$

$$(\text{antilog } \underline{a})\, b_1 X_1^{-1} X_1^{b_1} X_2^{b_2} \ldots X_5^{b_5} - \lambda P_1 = 0$$

$$(\text{antilog } \underline{a})\, X_1^{b_1} X_2^{b_2} \ldots X_5^{b_5} = \frac{P_1 X_1}{b_1}$$

$$Y = \frac{\lambda P_1 X_1}{b_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Same for $\frac{dL}{dX_2}$, $\frac{dL}{dX_3}$, . . . $\frac{dL}{dX_5}$, thus we get

$$\frac{\lambda P_1 X_1}{b_1} = \frac{\lambda P_2 X_2}{b_2} = \frac{\lambda P_3 X_3}{b_3} = \frac{\lambda P_4 X_4}{b_4} = \frac{\lambda P_5 X_5}{b_5}$$

Or, $$\frac{P_1 X_1}{b_1} = \frac{P_2 X_2}{b_2} = \frac{P_3 X_3}{b_3} = \frac{P_4 X_4}{b_4} = \frac{P_5 X_5}{b_5}$$

Therefore, $X_2 = \frac{P_1 b_2}{P_2 b_1} X_1$, $\quad X_3 = \frac{P_1 b_3}{P_3 b_1} X_1$,

$X_4 = \frac{P_1 b_2}{P_4 b_1} X_1$, $\quad X_5 = \frac{P_1 b_5}{P_5 b_1} X_1$, Substituting X_2, X_3, X_4, and X_5 in the partial derivative of Y with respect to λ:

$$\frac{dL}{d\lambda} = C - P_1 X_1 - P_2 X_2 - P_3 X_3 - P_4 X_4 - P_5 X_5 = 0, \text{ then}$$

$$C = P_1 X_1 + \frac{P_1 b_2}{b_1} X_1 + \frac{P_1 b_3}{b_1} X_1 + \frac{P_1 b_4}{b_1} X_1 + \frac{P_1 b_5}{b_1} X_1$$

$$= \frac{P_1 X_1 (\Sigma b_i)}{b_1}$$

Then, $$X_1 = \frac{C b_1}{P_1 (\Sigma b_i)}$$

Therefore, $$X_1 = \frac{54{,}345.28\ (.2136)}{12{,}580.42\ (1.08)} = 0.85.$$

By the same method we get:

$X_2 = 384.80$

$X_3 = 39.03$

$X_4 = 58.93$

$X_5 = 12{,}609.11$

Substituting the values of X_i to (1)

$$Y = 290.5\ (.87)^{.2136}\ (384.80)^{.4614}\ (39.03)^{.0312}\ (58.93)^{.1276}\ (12{,}609)^{.2523}$$

Log Y = 4.8897

Y = 77,487.24

Substituting the value of X_1 and Y to (3)

$$\lambda = \frac{77{,}487.24\ (.2136)}{12{,}580.42\ (0.85)} = 1.3022$$

Fit to the condition of optimum profit

$$\frac{MVP_{X_1}}{P_1} = \frac{MVP_{X_2}}{P_2} = \frac{MVP_{X_3}}{P_3} = \frac{MVP_{X_4}}{P_4} = \frac{MVP_{X_5}}{P_5} = \lambda$$

Thus, $\frac{MVP_{X_1}}{12,580.42} = \frac{MVP_{X_2}}{60} = \frac{MVP_{X_3}}{40} = \frac{MVP_{X_4}}{120} = \frac{MVP_{X_5}}{1} = 1.3022$

So, the MVP estimated are:

$MVP_{X_1} = 16,382.82$ $\quad MVP_{X_2} = 78.13$ $\quad MVP_{X_3} = 52.09$

$MVP_{X_4} = 156.27$, and $MVP_{X_5} = 1.3$

APPENDIX TABLE VIII

POPULATION PER HECTARE OF ARABLE LAND IN DIFFERENT COUNTRIES

Countries	Population per Hectare of Arable Land
Japan	16.5
Taiwan	14.3
U. K.	7.3
West Germany	7.0
Philippine	4.2
Italy	3.4
India	3.1
France	2.4
U.S.A.	1.1
U.S.S.R.	1.0
Canada	0.5

Source: FAO Production Yearbook 1967