PRODUCTIVITY GROWTH AND FARM MACHINERY ADOPTION IN THAI AGRICULTURE

Nongluck Jongsuwat

MASTER OF ECONOMICS

(ENGLISH LANGUAGE PROGRAM)

FACULTY OF ECONOMICS

THAMMASAT UNIVERSITY

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by

NONGLUCK JONGSUWAT

A Thesis submitted in partial fulfilment of the requirements for the degree of

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(English-Language Program)

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Is Hereby Approved by:

Chairman, Thesis Committee :	Chesada Loohawenchit	31 March 1980
	(Dr. Chesada Loohawenchit)	Date
Member, Thesis Committee :	George E. Delehanty	31 March 1980
	(Dr. George E. Delehanty)	Date
Member, Thesis Committee :	Dow Mongkolsmai	31 March 1980
	(Dr. Dow Mongkolsmai)	Date
Dean, Faculty of Economics :	Gosah Arya	April 1, 1980
	(Dr. Gosah Arya)	Date

ABSTRACT

PRODUCTIVITY GROWTH AND FARM MACHINERY ADOPTION IN THAI AGRICULTURE

Farm mechanization has been widely adopted and diffused in Thai agriculture since the 1960s. However, there are regional variations in the level of farm machinery adoption. This study has attempted to identify some factors which affect farm machinery adoption with special reference to farm tractors and water pumps. Specific objectives of the study include: (1) description of the historical development of farm tractors. (2) investigation of changes over time in resource endowments and productivities in connection with farm machinery adoption. (3) indentification of factors which affect the utilization of farm tractors and water pumps.

The introduction of farm machinery before the 1950s was limited to the Government experimental fields since imported farm machines in those days were large in scale, costly and required a high level of technical knowledge. It was not until the 1960s that farm machinery began to generate public interest with the emergence of a local industry producing small-scale farm machines.

Investigation of variations in agricultural resource endowments as well as changes in their productivities in the study covers the period after the Second World War, (1950-1975), partly because of data deficiencies in prior years. Labor productivity as measured by agricultural output per worker in the Thai agricultural sector rose at a substantial rate of 4.5 per cent per annum during this period. The land-labor ratio and land productivity (agricultural output per rai)

reveal an equal rate of growth during the same period. However, the land-labor ratio reveals a faster growth rate from the mid 1960's onwards. One of the reasons which supports this finding is the explanation that the achievement of a higher level of mechanization in agriculture permitted the worker to cultivate a greater amount of land. It is unfortunate that statistical analysis of the relationships over time of changes in relative factor prices and their uses cannot be studied because of deficiencies in time-series data.

Some major factors which may influence farm machinery utilization were instead investigated by using cross-sectional data. The hypothesized relationships were studied with the use of regression analysis employing farm level data of the 19 agro-economic zones obtained from the Division of Agricultural Economics.

Three types of farm machines were tested as dependent variables, i.e., four-wheel tractors, two-wheel tractors and water pumps. Independent variables in the regression models include the price of labor, the price of animal power, the percentage of upland crop area, the percentage of double crop area, the average farm income and the average rainfall.

The variable concerning double cropp area was found to be positively related to all three categories of farm machines. This implies that multiple-cropping enhances the use of farm machinery. The upland crop area was found to be positively related to the number of four-wheel tractors and water pumps whereas it was negatively related to two-wheel tractors. With respect to the scale basis of the machines, four-wheel tractors are more suitable for upland cultivation because they possess greater power for dry land tillage whereas two-wheel tractors were mostly

used for puddling in rice cultivation. Additional water for upland crop production is also obtained through pump irrigation. The price of labor was found to be positively related to the number of both types of farm tractors. This seems to verify the hypothesis that regions with higher labor costs tend to be more mechanized. In addition, the higher income regions were more able to afford tractorization. However, regional variations in water pump utilization resulting from variations in farm income and labor cost were found to be not important.

To

My Parents,

My Sister, Nongkran,

and

"Weraphan"

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I am fully responsible for any mistakes in this thesis and criticisms from the readers are invited.

Thammasat University — Nongluck Jongsuwat

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CHAPTER 1

INTRODUCTION

A. Introduction

Most of the increase in crop production in Thai agriculture in the past was due to the expansion of cultivated areas. However, it is now recognized that the potential for future growth based on such a process is limited. Data from the recent surveys and reports of the Ministry of Agriculture and Cooperations indicate that only 2.6 million hectares of forest are still suitable for agricultural use.[1] This is equal to only 10 per cent of area currently under agriculture. The continuing growth of agricultural production will therefore depend more on the intensive use of the limited land or higher yields. During the last two decades, farm mechanization together with biological and chemical innovations have been introduced in the hope that they would increase land productivity.

The use of farm machinery is said to reduce the drudgery of farm tasks. Farm machines in the form of tractors offer the advantage of more timely tillage than would have been possible with traditional power sources. Therefore, it can increase the intensity of land use through multiple crooping system by reducing the time required in certain farm tasks, and in return increase productivity of both land and labor. However, one may argue on the extent that farm machines are capital-intensive and possess negative effect of replacing the use of labor, and it becomes a major controversy concerning the appropriateness of farm machinery to a labor abundant country like Thailand.

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[1] World Bank: East Asia and Pacific Office, "Thailand: Toward a Development Strategy of Full Participation," Unpublished report May 1978, p. 63.

In spite of this, it is inevitable that certain farm machines have been widely adopted and the prospects are for an increase in demand especially in the Central Plains. Information provided by the Division of Agricultural Economics, Ministry of Agriculture and Agricultural Cooperatives (DAE/MOAC) reveals that there are various categories of farm machines utilized by Thai farmers, such as: two-wheel tractors, large and small four-wheel tractors, water pumps, water wheel engines, rice threshers, corn shellers, motor rollers, and feed mixing machines.

Of all these categories of farm machines, tractors and water pumps are the most widely used. In addition, the use of farm machines in Thailand varies broadly from one region to another. Information presented in Tables I-1 and I-2 reveal that almost all types of farm machines have been mostly accepted in the Central Region. The North, Northeast, and the South are sequentially ranked for the degree of mechanization. Differences in category of farm machinery employed in Thai agriculture as well as regional differences in its utilization lead us to believe that there are certain economic factors and enviormental conditions which induce farm machinery adoption and diffusion.

This study is therefore aimed at finding out the different utilization and diffusion pattern for farm machinery throughout the country. Furthermore, the study may also help indentify areas for further studies concerning farm mechanization in Thailand.

TABLE I-1

FARM MACHINES BY REGIONS IN 1975/1976

(Units)

Region / Category	Northeast	North	Central	South	Total	Rank
Four-wheel Tractor > 45 Hp.	3,014	4,624	4,957	743	13,338	5
Four-wheel Tractor < 45 Hp.	1,306	4,204	10,752	530	16,792	4
Two-wheel walking trator	3,003	11,275	66,961	8,762	30,001	3
Water pump	4,501	59,479	122,631	24,163	251,288	1
Water wheel engine	2,207	1,716	52,875	93	56,891	2
Corn sheller	998	3,852	700	171	5,721	6
Rice thresher	94	177	3,564	120	3,955	7

Source: DAE/MOAC, Selected Economic Indicators Relating to Agriculture, No. 84 (3), 1978., p.12.

TABLE I-2

DISTRIBUTION OF FARM MACHINES BY REGIONS
IN 1975/1976

(Percentage)

Region / Category	Northeast	North	Central	South	Total
Four-wheel Tractor > 45 Hp.	22.59	34.67	37.16	5.58	100
Four-wheel Tractor <45 Hp.	7.78	25.04	64.03	3.15	100
Two-wheel walking tractor	3.34	12.53	74.39	9.74	100
Water pump	17.91	23.67	48.80	9.62	100
Water wheel engine	3.88	3.02	92.94	0.16	100
Corn sheller	17.44	67.33	12.24	2.99	100
Rice thresher	2.38	4.48	90.11	3.03	100

Source: DAE/MOAC, Selected Economic Indicators Relating to Agriculture, No. 84(3), 1978, p. 12.

B. Objectives of the Study

This study will be concerned with the following:

1. To study the development of farm mechanization in Thai agriculture with special reference to farm tractors and water pumps.

2. To investigate changes over time in resource endowments and productivity in connection with farm machinery adoption.

3. To investigate factors which affect the utilization of farm tractors and water pumps.

4. To provide information about present utilization patterns of farm machines and other related materials.

C. Methodology and Scope of the Study

Information employed in this study will be based on secondary data. A historical approach will be applied with the investigation of farm machinery development in Thai agriculture and changes in resource endowments being carried out for the post World War Two period (1951-1975).

Due to inadequate time-series data, regression analysis of factors affecting farm machinery utilization will be based on cross-sectional data of 19 agro-economic zones in Thailand in the 1975/1976 crop year.

D. Organization of The Study

This study is organized into six chapters. After this chapter of introduction, traditional implements employed in Thai rice farming as well as historical background on farm machinery development will be summarized in Chapter II.

In Chapter III, the relevant literature concerning technological change especially regarding mechanical innovation will be reviewed.

Chapter IV contains an analysis of changes over time in resource endowments and productivity growth in connection with farm machinery adoption.

Factors which affect the utilization of farm tractors and water pumps will be studied in Chapter V.

Finally, Chapter VI contains the summary and conclusions of the study.

CHAPTER II

HISTORICAL BACKGROUND ON THE INTRODUCTION OF FARM MECHANIZATION IN THAI AGRICULTURE

Before going into detail on the adoptive process of modern farm implements employed in Thai farming, it is interesting to look at some basic traditional implements still in use today. Traditional implements specifically employed in rice farming can be used to represent an overall picture of farm implements employed in Thailand's crop production since Thai agriculture is basically specialized in rice cultivation.

A. Traditional Farm Implements Employed in Rice Farming

For centuries, traditional farm implements used in Thai agriculture have been extremely simple, mostly made from bamboo, rattan or hard wood. These local materials made it convenient for the farmer to make his own tools. Even with the introduction of modern implements in the last decade, traditional ones can still be found in a number of farming activities and sometimes are used in combination with the modern ones. Despite the differences between broadcasting and transplanting techniques of rice cultivation, basic farm tools employed in each technique are similar. These traditional farm tools are classified according to their uses as follows:

1. Equipment for Irrigation

Thai farming has long been dependent on the monsoon rains. In areas where the land is slightly sloped and in times of drought,

farmers have to irrigate their land with water from nearby water sources. Simple implements used for this purpose are water scoops and water wheels. (See Figure II-1) The water scoop is much more simple in structure but not much water can be moved from one place to another by this tool. Although it is portable, it is not very suitable for irrigating plots which are very far away from a water source.

The water wheel is larger in scale and is permanently fixed at the best location on the farm. It is made out of bamboo and hard wood and is suitable for irrigating plots which are near water sources. It can either be operated by human or draft animal power to generate puddlers. Nowadays, the existing wooden water wheels are operated by engines.

2. Equipment for Land Preparation

A rice field is made up of many individual rice plots especially if the rice land is not flat. Bunding the land divides the total land area into sections of equal level and flatness. The bunds serve to keep the water in each plot at a uniform depth and also serve as walking paths from one plot or field to another. In preparing the bunds, farmers use tools such as shovels, spades, hoes, as illustrated in Figure II-2. These tools are still essential for farm task nowadays. Following the early rain when the soil is wet enough to permit plowing, a farmer will use his buffalo or oxen to draw a plow through his rice field. Usually one buffalo is enough whereas two oxen are required to draw a plow. A plow is a wooden beam with a handle on one end and two pieces of rope tied to the other end. The rope is then fastened to a yoke which has

already been put around the animal's head. The bottom part of a plow is made out of a thick piece of hard wood curved up like a shoe which is called the "pighead",[1] see also Figure II-2. An iron blade is attached to the end of the pighead to break up the soil as the plow is drawn across the field. These so-called "Shovel Plows"[2] used in Thailand are derived from a hand hoe. According to a survey of Chancellor in 1960,[3] the average weight of a plow was 10 kilograms (22.4 lbs) and cost about 77 baht. Average reported life was 11.6 years and frequent damage to a plow was usually caused by striking stumps, roots, rocks or more resistant soil. The average stated rate of plowing is about one rai per day. The traditional wooden plow and draft animals are not adequate for the additional load imposed by dry soil. At one time, an iron plow was introduced for its deeper plough and better performance on resistant soil. However, it was not widely accepted at that time for it was too heavy and difficult to operate in the submerged field and too heavy for draft animals to draw.[4]

Usually, a rice field is tilled two times in order to loosen up the soil and turn down the grass and weeds for natural manure decomposition.

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[1] Anumarn Rajadhon, Life and Ritual in Old Siam: Three Studies of Thai Life and Customs, Translated and edited by W.S. Gedney. (New Haven: HRAF Press, 1961), Appendix.

[2] H.J. Hepfen and E. Bicsalski, Small Farm Implements (Rome: FAO 1953), reprinted in 1978, p. 12.

[3] W.J. Chancellor, "Survey of Indigeneous Farm Implements," (Report of Initial Phrase for Evaluation and Improvement of Small Tools in Thai Agriculture, San Francisco: Calif., July 1961.) pp. 6-7.

[4] Anumarn Rajadhon, op.cit., p. 20.

Harrowing is sometimes practiced if there is enough time left. In general, a harrow is operated on a field already submerged with surface water by drawing it around the field. The soil after harrowing is well stirred and ready for planting.

3. Equipment for Planting, Harvesting, Threshing and Milling

For broadcast rice, seeds are carried in small baskets and cast by hand. The transplanting process requires that seedlings are prepared in a nursery plot which is located as close as possible to a water source for easy nourishment. When the main fields have been plowed, the farmer then pulls up the small rice plants from the seedling plots, bundling them with bamboo strips and transporting them to the main plots.

In transplanting, groups of small rice plants are pressed with the thumb into the wet soil. The mud around the plants will keep the buried rice plants from loosening up and floating away. Farmers are rather skilled at maintaining straight rows of uniform spacing. Such skill is developed through experience. The process of planting is usually carried out by women. The least farm tools are used in the transplanting process and thus it is the most laborious farm task. It is a backbreaking farm operation which ironically has not at all been mechanized as yet.[5]

Weed control is required after the planting is done. A weeding knife or sickle is used for cutting the weeds. After a few months of

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[5]Transplanting machines, both IRRT and the Chinese designs, are now under experiment by the Division of Agricultural Engineering.

rain, the fresh green rice plants start to flower and eventually become rice grain. Farmers then wait for the grain to ripen and prepare for harvesting. In almost all regions of Thailand except in the South, harvesting is done by a sickle. (In the South, harvesting involves cutting only the rice panicles.) A sickle is a curved steel blade with one end attached to a short handle. The use of a sickle for harvesting is rather slow. However, it is best suited for rice since the ripened grain can easily fall off. Furthermore, the ripened rice, due to its heavy sheaves, always falls down in a tangled condition. This becomes a major obstacle in trying to apply western harvesting machines into Thai rice farming. The slow process of using a sickle usually requires more labor than the available family supply. A problem usually arises where there is inadequate labor for harvesting and the longer the delay in harvesting, the larger the loss due to the falling off of ripened grain from the plants.

The harvested rice is delivered to the threshing ground which is usually prepared from a mixture of earth and clay. The threshing ground is baked in the sun into a concrete hardness and then covered by a rattan mat before sheaves of rice are piled on it. Traditionally, two main methods of threshing rice are followed. In one method, the farmers use two pieces of wood tied together with a long rope at one end. This long rope is formed onto a loop around the bundle of rice sheaves. Then, the farmer will hold onto the pieces of wood at another end. The rice sheaves which are tied into bundles will be struck against the floor of the threshing ground thus loosening the rice grain from its stalk. (See Figure II-4)

Another method of threshing which is commonly practiced in the Central Plains is to employ oxen or buffaloes to trample on the rice piles by walking in a tight circle. The grain then falls from the stalks. Although there is more dirt and other particles mixed with the grain, this primitive method is rather effective. The use of a threshing machine requires that rice sheaves be orderly arranged whereas with the traditional way of threshing this is not a problem. An obstacle in employing this traditional method nowadays is the inadequate supply of both animals and labor. Therefore, it takes many days before the huge piles of rice sheaves are all threshed. Generally, the drier the rice sheaves, the larger the amount of broken grains obtained from the threshing process. Furthermore, many people are complaining about the impure rice grain obtained from animal threshing while others comment on the loss due to animals eating some of the grain while they are at work.

Nowadays, the use of threshing machines seems to be widely accepted especially among farmers in the Central region. One study done by Kasetsart University[5] on the use of the IRRI axial flow threshing machine in comparison with the traditional methods favored these modern threshing machines. Furthermore, with a threshing contractor system, the use of threshing machines has been more widely adopted.

The threshed grain has to be winnowed in order to purify it. Traditionally, farmers pour the grain against the wind which will blow

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[6]Sriaroon Rasanond et.al., "A Survey of the IRRI Axial Flow Threshing Efficiency Compared with the Traditional Methods of Threshing, (Unpublished Report, Faculty of Economics and Business Administration, Agrobusiness Management Program, Kasetsart University, 1977).

away rice brans and dust. A winnowing basket is used. A portion of the grain will be shaked and poured against the wind in the winnowing basket. To date, winnowing equipment is attached to a threshing machine making it more convenient for farmers to clean the rice husks.

The grain is now ready to be kept in the barn. In the old days, when rice was produced only for household consumption a farmer would only pound grain sufficient for his family's daily intake. This is one way to preserve the quality of rice as long as possible. Wooden mortars with wooden pestles for hand pounding are the most original implements in traditional rice milling. Lever-pestle mortars and household rice mills come with innovation. (Figure II-3) However, after commercialization of rice production, farmers began to sell their surplus grain to the merchants who then sent the grain to the rice mills. To date, the rice milling process in Thailand has become so industrialized that the old implements for rice milling are rarely seen in farm households.

Before going on to the next section, it is interesting to present a working rate for the previously described farm tools. Information concerning working rates are available in Table II-1 and are based on the average reported information of Chancellor's survey in 1961.[7] Concerning work rates of buffalo and tractor plowing, another survey conducted by Greene[8] reveals that on the average both for the first

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[7] W.J. Chancellor (1961), Op.cit., pp. 75-77.

[8] Brook A. Greene, "Rate of Adoption of New Farm Practices in the Central Plains, Thailand," (Occational Paper No. 41. Dept. of Ag. Econ., Cornell University, Ithaca, New York, 1970) Table 11.

TABLE II-1

SELECTED FARM WORKING RATES

Type of Farm Operation	Working Rates
Plowing (using an average 1.2 animals per plow)	4 hrs./rai
Harrowing	3 hrs./rai
Pulling weeds	$\frac{1}{3}$ rai/man-day
Water movement by scoop	17 man-hrs./rai or 2.5 days/rai
Cutting rice with sickle	.55 rai/man-day
Threshing rice by flailing	41 tang/man-day
Threshing rice by animal trampling	40 tang/man-hr.

Source: W.J. Chancellor (1961), op.cit., p. 77.

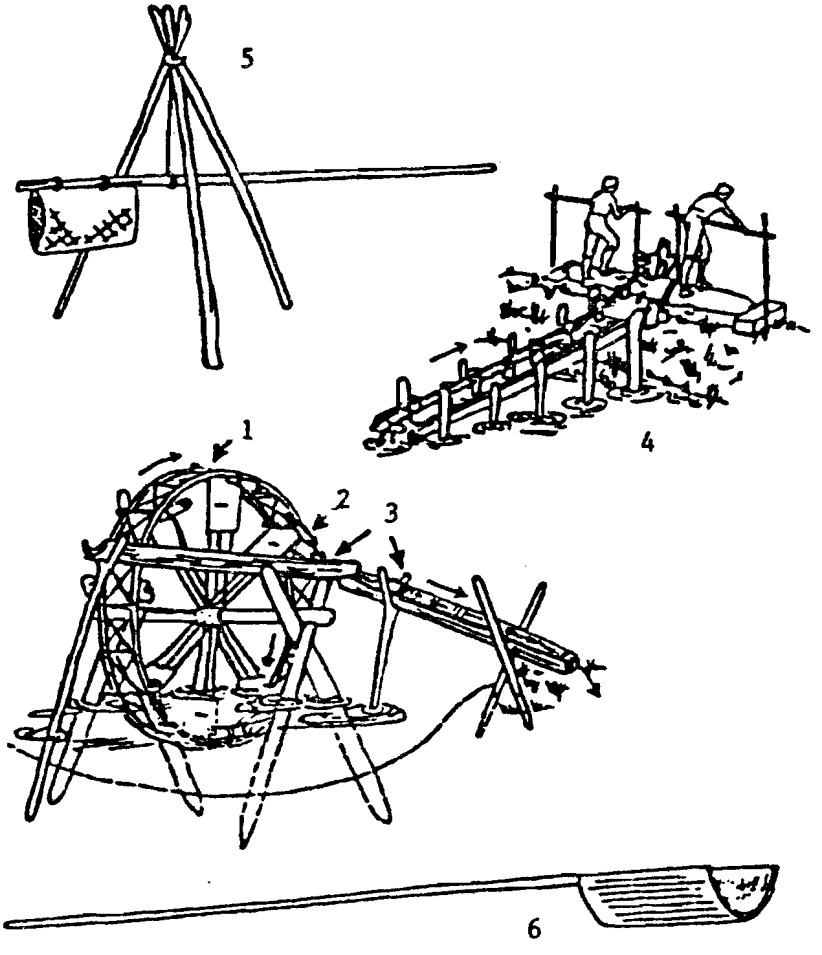
Note: 1 tang in this case is equal to 12.4 kg.

and second plowing, a buffalo was able to plow at the rate of 8.7 hours/rai whereas 0.36 hour/rai was the work rate given for tractor plowing. The discrepancy on buffalo work rates in the two studies may be due to different sampling techniques and different points in time of the studies. Conclusion of Greene's survey further reveals that one tractor can plow land 24 times faster than a buffalo. A comparison of efficiency between the buffaloes and tractors obviously requires more information other than just work rates and is thus beyond the scope of this study.[9]

[9] More detail concerning this matter is available in Songsak Sriboonchitta, "The Private Cost of Using Tractors Versus Buffaloes: A Case Study of Farmers in ChaChoeng Sao Province," (Unpublished M.A. Thesis, Faculty of Economics, Thammasat University, 1975.).

FIGURE II-1

EQUIPMENT FOR IRRIGATION

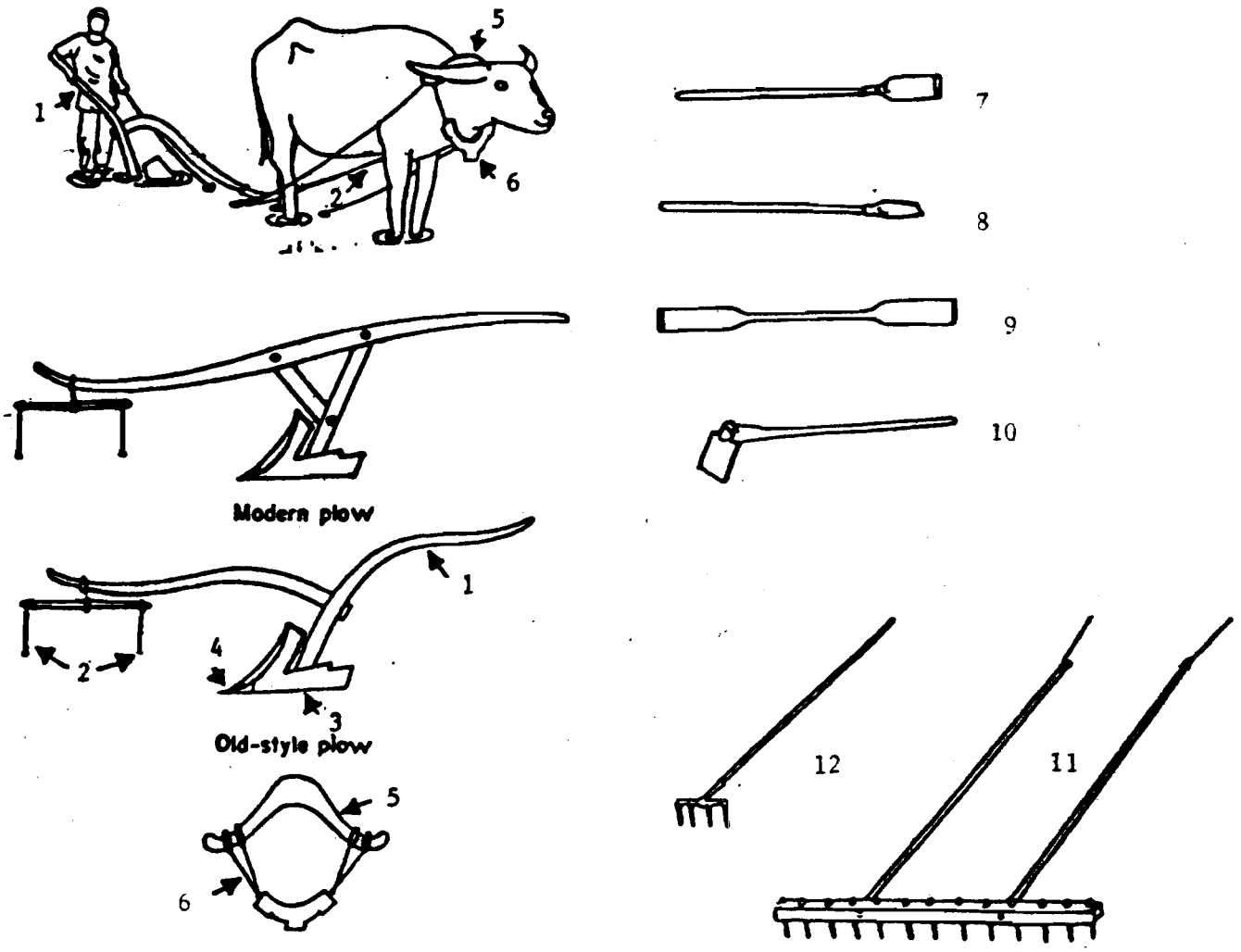


1. water wheel.
2. bamboo tube for dipping up water.
3. conduit for receiving water, made out of sugar palm tree or bamboo.
4. drag-type water wheel made of bamboo and hardwood.
5. tripod water scoop.
6. half-dipper.

Source: Anumarn Rajadhon, op.cit., Appendix A.

FIGURE II-2

EQUIPMENT FOR LAND PREPARATION

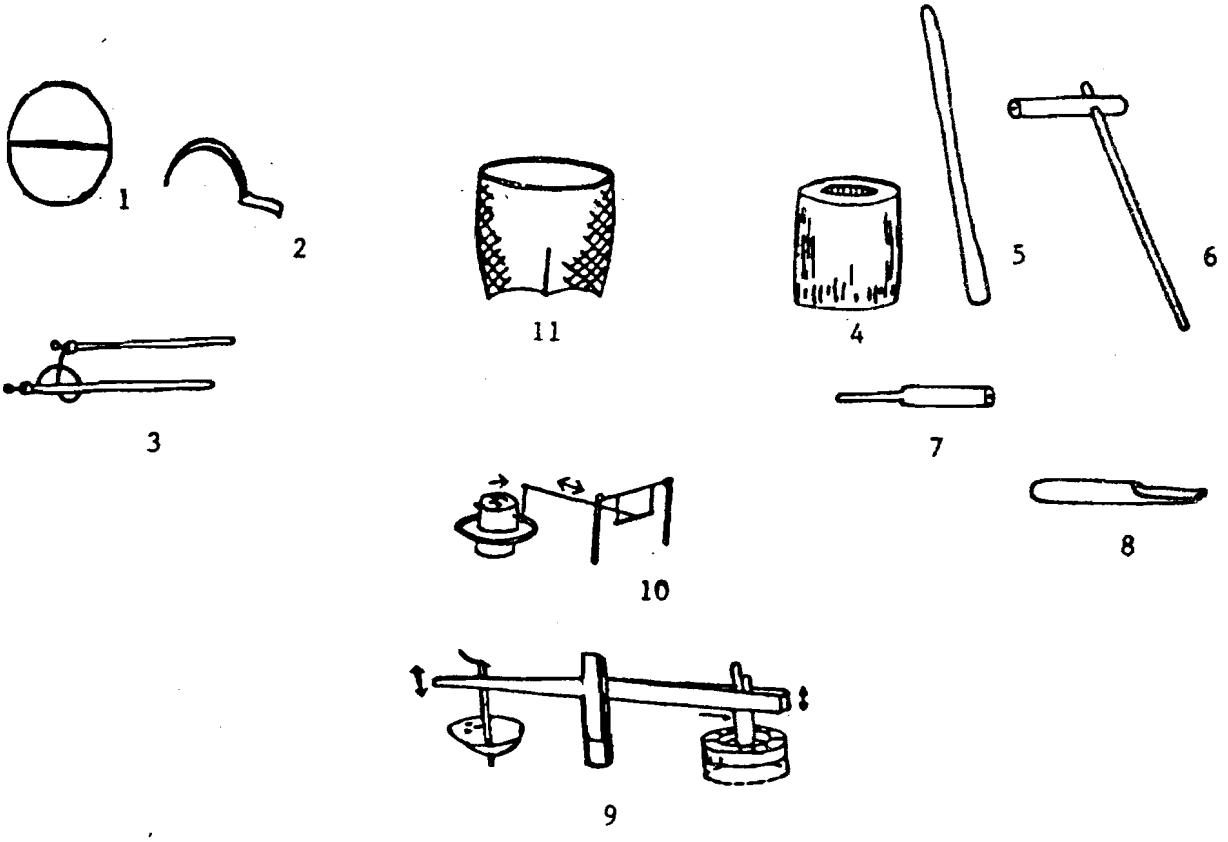


1. handle of the plow.
2. rope.
3. "pighead"
4. iron share.
5. yoke.
6. hitching rope.
7. iron shovel.
8. spade.
9. wooden shovel, old style.
10. hoe.
11. harrow.
12. iron rake, chinese style.

Source Anumarn Rajadhon, op.cit., Appendix A.

FIGURE II-3

EQUIPMENT FOR HARVESTING, WINNOWING, THRESHING AND MILLING



1. winnowing basket, flat rounded shape woven of bamboo.
2. sickle.
3. threshing sticks made of hardwood or bamboo for holding rice sheaves.
4. wooden hand mortar.
5. pestle for hand mortar.
6. big hammer-shaped pestle for hand mortar.
7. another shape of wooden pestle.
8. pestle for pounding.
9. level pestle for pounding.
10. household rice mill.
11. basket for containing rice.

Source: Anumarn Rajadhon, op.cit., Appendix A.

FIGURE II-4

FARMERS THRESHING RICE WITH TRADITIONAL THRESHING STICK.

However, it is accurate to recognize that tractor plowing is now gaining popularity among farmers.

B. The Introduction of Tractor Plowing

Among the early imported machines for farming, the steam powered tractor was privately experimented with in Samut Prakarn in 1891/92.[10] It was recorded that, in 1907, the government of Australia sent an expert to Thailand in order to introduce the Australian engine plow which would enable farmers to prepare land before the monsoon rain started.[11] The proposed engine plow was tested in the Rangsit area and found to perform well. Around 1910, an engine plow from Austria was also privately tried by Yai Suphan Sanitwonge and Dr. Adamson. However, there is no record on further adoption of such a machine. This is probably because the imported steam plow was costly and faced some technical constraint. The imported machines used for land preparation were accepted to perform better than native implements in the dry season when the soil became sun-baked. However, during the rainy season, the imported steam plows was too heavy and cumbersome in the submerged rice fields.

The first Bangkok Agricultural show in 1910 gave an opportunity for imported farm implements to be put on display. Among other farm inputs the American iron plow, steam plow, pump engine and disc plow were recorded to be on display.[12] Another exhibition was organized in

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[10] David Feeny, "Technical and Institutional Change in Thai Agriculture, 1880-1940," (Unpublished Ph.D. Dissertation, University of Wisconsin, Madison, 1976) p. 115.

[11] Letter from Chao Phya Pravet to the King, (Rama V), R.5 Ks 1/10, National Archieves.

[12] J.C. Bernett, Report of the First Annual Exhibition of Agriculture and Commerce Held in Bangkok, April 1910 (Bangkok: Ministry of Agriculture, 1910) pp. 30-40.

the following year together with a competition on the performances of modern farm implements. As a result of the performance on the experimental field, the American iron plow won the first prize for being able to plow the land deeper and maneuver itself in the field better than the traditional wooden plow. Although this modern iron plow was effective in use, farmers often commented on its heavy weight and higher cost than that of the traditional wooden plow.[13]

In response to a proposal to improve the technology of rice farming, the government decided to establish an agricultural experimental station in the Rangsit area in 1919/1917. The experiments involved improvement in rice varieties, fertilizers, farm machinery as well as soil testing.[14]

The station experimented with imported tractors, harvesters, threshers and combine machines which were large in scale. Reports from the experimental stations supported farm machinery performance particularly for its ability to save time. However, it was also recorded that these foreign machines needed to be adapted to Thai wet rice farming conditions.[15] There had to be a good water control system to prevent the heavy machines from sinking. Proper provision of bunds was necessary to allow water to move from field to field. Furthermore, tractor plowing was recommended

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[13]Carle C. Zimmerman, Siam: Rural Economic Survey 1930-1931, (Bangkok: Bangkok Times Press, 1931), pp. 305-315.

[14]David Feeny, op.cit., 109-114.

[15]Thumnong Singkamwanich, "Farming by Machine," in Kasikorn Journal, Vol. 21, No. 2 (March, 1948), pp. 109-114. (in Thai).

in combination with water pumps which helped in controling water levels in the fields. However, the initial cost of investment was also extremely high, thus, preventing farmers from privately employing any of this new farm machinery.[16]

Due to both technical and financial constraints, it is not surprising to find that most of the early imported machines were limited only in use on the government's experimental fields. Two important events likely to have contributed to the slow introduction of farm machinery in Thailand are the Great Depression of the 1930's and the Second World War. Hence, it was not until after the Second World War that farm mechanization began to generate public interest. Meanwhile, the expansion of irrigation facilities, the expansion of government research work and its extension service and the development of local farm machinery production are other important factors which facilitated the rapid expansion in farm machinery adoption and diffusion. More detail concerning these factors are reviewed as follows:

1. The Expansion of Irrigation Facilities

A series of canals constructed in the Rangsit area in the latter half of the 19th century, were considered to be the beginning of an irrigation system in Thailand. The first extensive irrigation system, the Pasak Scheme, was developed at the beginning of the 1940's. The development of an irrigation system around this period for the most

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[16]Department of Cultivation, Ministry of Agriculture, "Farm Machinery Experiment in Rangsit" in Kasikorn Journal, Vol. 19, No. 3, 1947, pp. 291-303.

part failed to control the level and timing of water or to provide water storage for a second crop.[17] In 1950, the construction of a diversion dam at Chainat, north of Bangkok, began with the assistance from the International Bank for Reconstruction and Development. The dam and distribution canals were completed in the 1960's. Continuing projects under this irrigation development scheme are still being carried on to this day.

Integrated programs such as land consolidation, ditch and dike projects as well as a water pumping system during the latter half of the 1960's led to significant changes not only in farming techniques but also in farm input use. There was a rapid increase in the use of modern farm inputs such as fertilizer, pesticides, water pumps, tractor plowing, high yielding varieties, etc..

The better on-farm water control brought about by irrigation development not only caused farmers to shift from broadcasting to transplanting rice but also enabled farmers to grow two rice crops a year.[18] Timing of operations in a double-cropping system is very critical since a delay in one crop operation will impede the operation of the following crop. Usually, a wet-season rice crop must be harvested as soon as possible or sometimes in conjunction with the seedling process for the following crop. Therefore, there is an overlapping period of work for the first and the second crops.

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[17] J.R. Behrman, Supply Response in Underdeveloped Agriculture, A Case Study of Four Major Annual Crops in Thailand, 1937-1963. (Amsterdam: North-Holland Publishing Co., 1974), pp. 47-48.

[18] Ronald C.Y. Ng., Supplementary Report on the Development Attitude Survey Chao Phya Irrigation Improvement Project, Stage-II. (Report prepared for the IBRD, January, 1977), pp. 119-121.

The shortened working period thus caused a labor shortage by raising labor demand. To meet the increase in labor demand, farmers were induced to use a greater number of hired labor and tractors. Somchart found in his survey that the increase in tractor use and ownership were wholly due to double-cropping since the use of buffaloes was too slow given the existing average farm size and household labor supply.[19] Evidence from the same survey also reveals that threshing and transportation of the harvested crop were also highly mechanized with the use of tractors. Therefore, it is possible for us to recognize that the use of tractors and other farm machines is a matter of necessity in double-cropping.

2. The Expansion of Government Research Work and Its Extension Service

Since the establishment of the Agricultural Experimental Station in the Rangsit area around 1910, imported farm machinery were experimented with under the direction of the Department of Agriculture, Ministry of Agriculture. However, budgetary and technical constraints limited the extent to which farm machinery were experimented with at that time.

The extension on tractorization can be traced back to the early 1950's when a tractor station was started. This station rented out imported tractors to farmers in nearby areas such as Rangsit and Pathumthani. The service charge per rai at that time was about

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[19] Somchart Komate, "Labor Problems of Double-Cropping in Channasutr Land Consolidation Project" (Unpublished M.A. Thesis, Faculty of Economics, Thammasat University, 1976) p. 91.

15-18 baht.[20] Such service was initiated mainly for demonstration purposes. However, due to inadequate funds, the station had to discontinue this service shortly after its initiation. Furthermore, the use of tractors at that time was not very attractive to the farmers because of various reasons. The farmers at that time believed that the heavy tractors would press down the soil on their land, which in turn, would reduce yields. Some thought that tractors plowed too deeply and, thus would turn the underground lime onto the surface. Many farmers also worried that dripping oil from the tractors during their operation would spoil the quality of their soil. With respect to the technical side, tractor operation in those days was not very successful also because there were too many tree stumps buried underneath the ground. Furthermore, these large imported tractors were difficult to move from field to field.

After the establishment of the Rice Department in 1953, research work on farm machinery was given to the Engineering Division. Research and development of farm machinery in this division involved not only improving the imported machines but also inventing farm machines better suited to local conditions.[21]

The most popular farm machine promoted by the division was the "Debaridhi" low-lift propeller pump and the well-known "Iron Buffalo." The innovator of these machines was M.R. Debaridhi Thevakul.

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[20]Recorded from an interview with Mr. Metha Ratchapiti, the director of Rain Making Project who used to be in charged in this work at that time.

[21]M.R. Debaridhi Thevakul, "Agriculture with the Nation's Economic Securities," (Unpublished Personal Research Paper, Bangkok: Division of Agricultural Engineering, Ministry of Agriculture and Agricultural Cooperation, Dec. 1966) p. 31.

The "Debaridhi" pump was a modification of the traditional wooden water wheel using an engine instead of manual or animal power in puddling. The engine used was around 4-5 horsepower. The "Debaridhi" pump was adopted in 1957, two years after its invention, and is still widely used today.

Around 1953, M.R. Debaridhi started working on a small walking tractor with the hope that the new machine to be used for land tillage could be driven by the small engines which were already available for "Debaridhi" pumps. Therefore, the early models of his walking tractor used a small Lister diesel engine of 4.5 horsepower. Modifications on this earlier model of the walking tractors were made as experimentation with it continued until a small four-wheel tractor known as the "Iron Buffalo" came along. Since there was a seat attached for the driver in a latter model of Iron Buffalo, the power of the machine was therefore increased to around 12.75 hp., still using a Lister diesel engine. Around the mid 1960's, improvements on the Iron Buffalo were terminated when it was released to private producers. It was not successful due to the inefficient production capacity. The latest model of the iron buffalo was driven by a Toyota water cooled 25 hp. engine. (Figure II-7)

After 1970, further research on small-scale farm machinery has been carried out by the Engineering Division in collaboration with the International Rice Research Institute. The most successful machines introduced by this cooperative project is the axial flow thresher.[22] The resulting designs have been diffused to many small

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[22]Chak Chakkaphak and Ben R. Jackson, Farm Mechanization in Thailand Report to the International Symposium on Farm Mechanization in Asia, July 3, 1978. (Tokyo, Japan, 1978), p. 6

local producers. Meanwhile, the two-wheel tractors or power tillers were already commercialized by some local producers.

3. The Development of a Farm Machinery Industry

It is accepted that a key to the increased adoption of farm machinery is that of assuring farmers that new machines can provide them with higher returns and are locally suitable. Furthermore, they should be simple in design, easy to repair, and have spare parts available. This can come about if there exist local production firms. Nowadays, there are a number of firms involved in both large four-wheel and small two-wheel tractor production. Attached implements for large tractors are also included in the product line of these firms. Of all the farm machines produced by local firms, the power tillers or small two-wheel tractors have gained the most popularity among farmers especially in the Central Plains. The development of two-wheel tractor production in Thailand can be traced back to the mid 1960's. The most widely known producer was Kamnan[23] Prung Farkaew of the Singkru Usahagrum factory in the Prapradaeng area. An early model of Kamnan Prung's two-wheel walking tractor excluding engine cost about 3,200-3,500 baht. By the end of the 1960's, there were at least three to four firms producing walking tractors. During the 1970's, the production of two-wheel walking tractors became very competitive and was mainly concentrated around the provinces surrounding the Bangkok Metropolitan area. It is also important to note that the local production firms still have to

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[23]Kamnan is a title for village headman.

rely on imported engines. A recent survey by the Bank of Thailand[24] reveals that there were around 100 firms concentrating in farm machinery production. More than 75 per cent of the total firms are located in the Central Plains. Two-wheel tractor production is about 40,000-45,000 units per year. The average power of an engine used is around 6-9 horsepower.

In summary, traditional farm implements employed in Thai cultivation are simple in structure and mostly made of rattan or hard wood. Nowadays, these old farm tools have been used in combination with modern ones. In the past large farm owners in the Central Region showed interest in substituting farm machines for labor. However, the introduction of farm machines particularly tractors were limited in use only at government experimental stations and a few wealthy large farm owners. It was not until a decade after the Second World War that farm mechanization became better known and used by Thai farmers particularly in the Central Plains. The government sector has also put some effort into the research and development of farm machines which would be adaptable to local conditions. However, due to inadequate funds, government research projects not only proceeded slowly but also have to depend upon the private sector for commercialization. The private commercial sector through its own initiative have provided less expensive and small scale two-wheel tractor to the farmers. Therefore, the technological revolution in Thai agriculture in the 1960s involve the increased use of mechanization as well as improvements in water conditions, the

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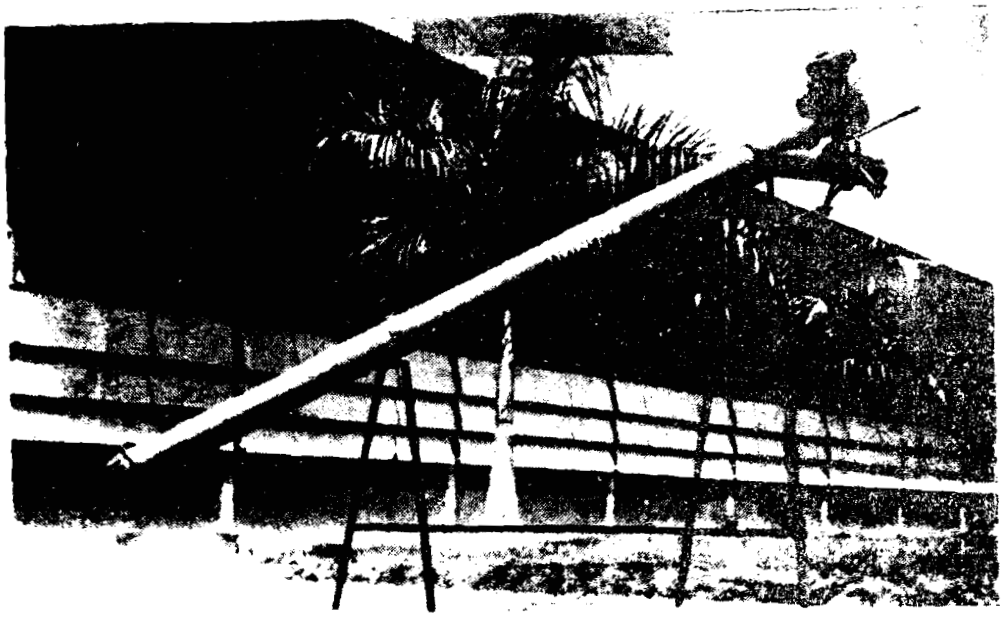
[24] Bank of Thailand, "Report on Power Tiller and Tractor for Rice Farming," an Unpublished Report, 1978.

increasing use of fertilizer and the introduction of new crop varieties. The success of four-wheel tractors is also due to the availability of a tractor contractor system. Small two-wheel tractors introduced in the latter period are better suited to Thai rice cultivation in the Central Plains. Furthermore, local small factories are being opened in the region which assemble and repair tractors and produce tractor parts and accessories and hence, contribute to the progress of farm mechanization.

FIGURE II-5

THE "DEBARIDHI" WATER PUMP



The "Debaridhi" water pump, designed by M.R. Debaridhi Thevakul, is appropriate for rice land which is not more than three meters higher than its water source.

FIGURE II-6

THE "IRON BUFFALO" WITH CAGE WHEELS ATTACHED.

A 12.75 hp. Lister diesel engine was used.

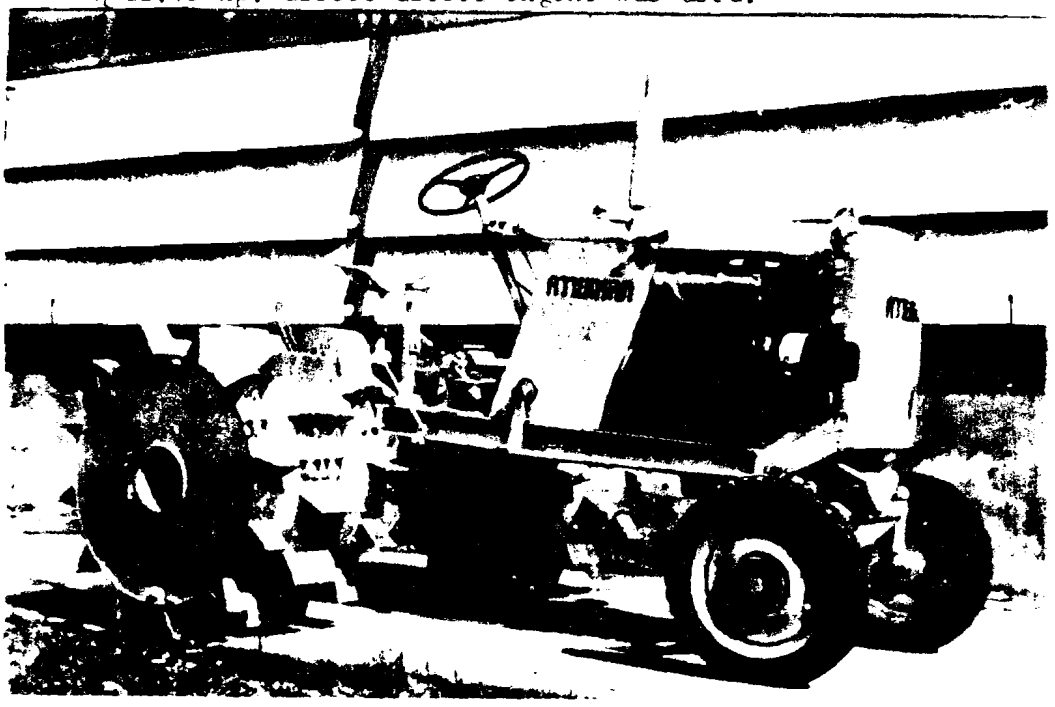


FIGURE II-7

THE LATEST DESIGN OF THE "IRON BUFFALO".

A 25 hp. Toyota diesel engine was used.

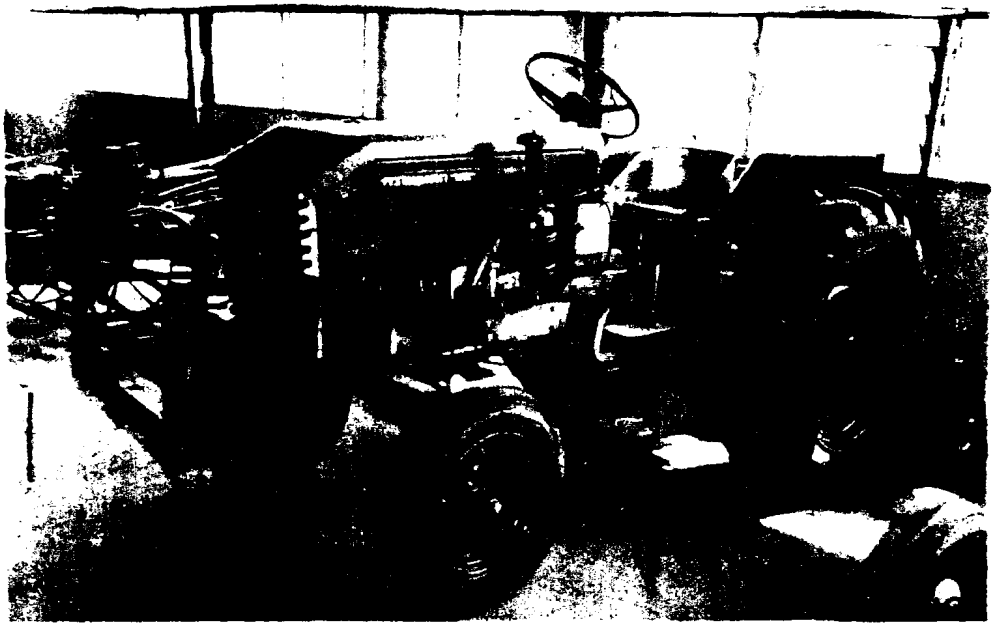


FIGURE II-8

AN EARLY MODEL OF THE TWO-WHEEL WALKING TRACTOR.

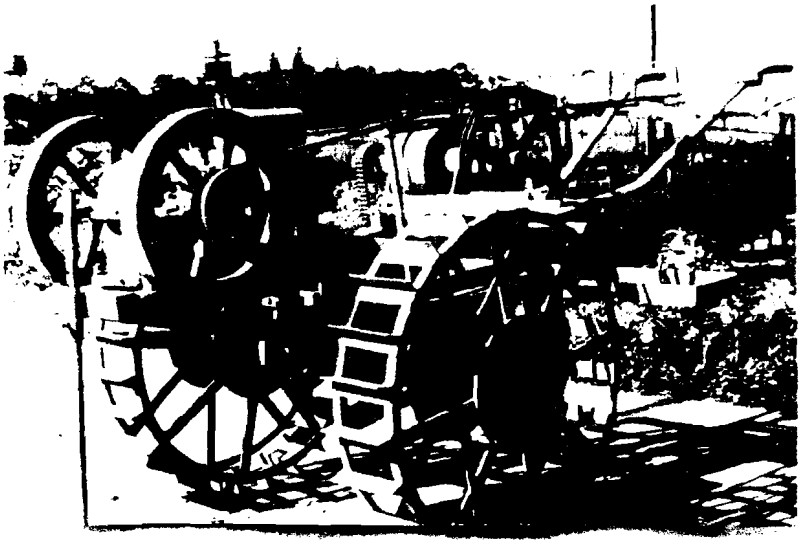
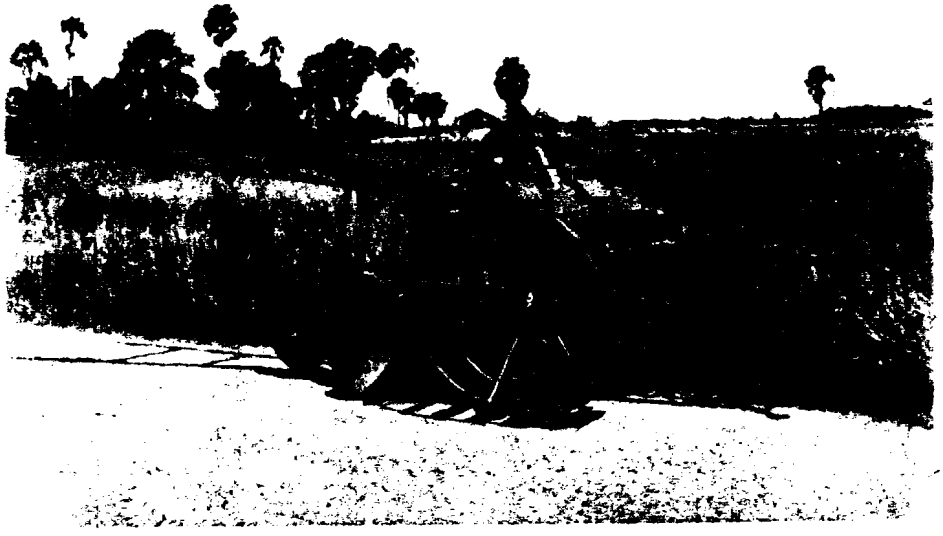


FIGURE II-9

A PRESENT MODEL OF THE TWO-WHEEL WALKING TRACTOR.



CHAPTER III

REVIEW OF LITERATURE, THEORETICAL FRAMEWORK AND METHODOLOGY

A. Review of Literature

The importance of technical change in economic growth has been pointed out by many economists. Among the earliest studies related to this topic, Solow[1] showed that about 12½ per cent of the growth in real private non-farm GNP per capita in the United States during 1909-1949 can be "explained" by the increased use of capital per unit of labor. The remaining 87½ per cent was attributed to an unexplained source which he called "technological change." Due to its importance, various studies concerning economic growth cannot neglect this so-called technical change factor as another engine of economic growth. Technical progress consists of the invention of new methods or new products which will eventually be introduced into the processes of production in a society.[2] The term "innovation" commonly refers to the stage of putting new constructs into effect. This technical change can take place in either the industrial or agricultural sectors.

Ames and Rosenberg[3] have done a study on the U.S. and U.K. gun-making industries focusing on the two countries' factor endowments and demand conditions during the mid-nineteenth century. They found that the U.K. gun-making industry employed labor-intensive techniques whereas

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[1] Robert Solow, "Technical Change and The aggregate Production Function," in The Economics of Technical Change, ed. by Nathan Rosenberg (Baltimore: Penguin Books, Inc., 1971), pp. 314-362.

[2] Everett E. Hagen, The Economics of Development (Illinois: Richard D. Irwin, Inc., 1975), p. 252.

[3] Edward Ames and Nathan Rosenberg, "Enfield Arsenal in Theory and History," Economic Journal, Vol. XXX VIII, No. 312 (Dec. 1968), pp. 827-842.

the U.S. used more interchangeable parts as well as more machines in the effort to economize on relatively expensive labor. In addition, the U.S. producers were also facing a long range price elastic market which enhanced the use of mass production whereas the U.K. producers were mainly confined to an upper class consumer market where products were usually produced and sold by orders. The conclusion drawn from this study is that the interaction of factor endowments and industrial demand conditions to some extent can explain the type of technology employed in their production processes. Other economists had also tried to point out the process of "technical change" through the increase in efficiency and quality of the traditional factors. Schultz[4] was one of the economists who based his analysis on the capability of the economy to provide improved inputs into production by way of better human capital or better intermediate inputs. Other economists also made great efforts to study factors which enhance the changes in technology as well as its transition process. Hicks[5] emphasized the importance of changes in the relative prices of inputs in the adoption and diffusion of new technology from which he stated that "changes in relative factor prices will stimulate the search for new methods of production which will use more of the now cheaper factor and less of the expensive one."[6]

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[4]T.W. Schultz, Transformation of Traditional Agriculture (New Haven: Yale University Press, 1968).

[5]J. Hicks, The Theory of Wages (New York: St. Martin Press, 1963).

[6]Ibid., p. 120.

Hayami and Ruttan[7] have done an analytical study on the induced innovation theory. The substance of this theory involves an explanation of the mechanism by which a society chooses an optimum path of technical change in the agricultural sector. They emphasized the mechanism which the society employed in order to enhance the adoptive process for the changes in technology.

An example on the changes in relative factor prices was given as an inducement to technological change in the U.S. and Japanese agriculture . Showing the historical experience of agricultural development in both countries for the period 1880-1960, Hayami & Ruttan proved that the extreme differences in the two countries' resource endowments-land and agricultural labor - as well as their relative prices does not seem to prevent rapid growth in their agricultural productivities. During the entire eighty-year period, both countries were able to obtain a favarable rate of growth in their agricultural sectors as can be summarized in Table III-1. Information in Table III-1 shows that both countries obtained a substantial increase in their agricultural labor productivity which indicate that they had undertaken some technological changes in their production processes.

They concluded that "land area per worker explains more than 80 per cent of the labor productivity in the U.S. whereas it explains less than 40 per cent in Japan."[8] Using regression analysis, they also

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[7] Y. Hayami and V. Ruttan, Agricultural Development: An International Perspective (Baltimore: Johns Hopkins Press, 1971)

[8] Y.J. Hayami & V. Ruttan, Op.Cit., p. 115.

TABLE III-1

ANNUAL COMPOUND RATE OF GROWTH IN OUTPUT, INPUT AND PRODUCTIVITY IN U.S. AND JAPANESE AGRICULTURE, 1880-1960

	U.S. (%)	Japan (%)
Agricultural Output	1.5	1.9
Total input	0.8	0.6
Total factor Productivity	0.7	1.0
Output per male worker (Labor productivity)	2.4	1.9
Output per arable land (Land productivity)	0.4	1.3
Arable land area per male worker	2.0	1.9

Source: Y. Hayami and V. Ruttan, op.cit., p. 114.

found that variation in land area per worker (A/L) in the U.S. is explained by changes in their price ratios. The implication of this analysis is that along the developmental path the prices of the less elastic factor (labor) tend to rise relative to the prices of the more elastic factor (land). Furthermore, prices of a substitutable input for labor such as farm machinery were relatively cheaper than the price of labor. Therefore, mechanical or labor-saving innovations were induced to a greater extent. With more application of mechanical innovation, rises in labor productivity is expected, since it is possible for a given area of land to be worked by fewer people, and that enhances an increase in arable land per worker (A/L).

A similar pattern of analysis was also tested in other countries' historical experiences, such as Germany, France, Denmark, and the United Kingdom, by other economists.[9] The overall conclusion supports the hypothesis that changes in factor use in each of these countries have been responsive to change in relative factor prices. Moreover, mechanical innovation has been developed in these European agricultures later than in the U.S.

The induced innovation theory is in general consistent with the substitution viewpoint with regard to farm machinery especially in the form of tractors. This viewpoint considers tractors and human labor

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[9]Vernon W. Ruttan and Others, "Factor Productivity and Growth: A Historical Interpretation," in H. Binswanger and Others, Induced Innovation, (Baltimore: The Johns Hopkins University Press, 1978), pp. 44-87.

including animal power as different power sources perfectly substitutable for one another. Therefore, the switch from one source to another is primarily generated by factor prices which in turn is related to factor scarcities.

Another viewpoint considers farm mechanization is the Net Contributor.[10] The counter argument is that power is a constraint to agricultural production regardless of factor prices. Therefore, the greater power of farm machinery, tractors in particular, as well as its speedy task would allow more timely operations which countribute to both yields and more extensive practice of double-cropping without necessarily displacing labor. This viewpoint supports the proponents of farm machinery in the LDCs where labor is relatively abundant compared to capital. Furthermore, available evidence also supports the complementarity between the use of tractor and high-yielding varieties. Many instructive studies on this topic are available for the case of Indian and Pakistani Punjab.[11] Rijik[12] in his article concerning farm mechanization in

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[10] Hans P. Binswanger, The Economics of Tractors in South Asia (New York: Agricultural Development Council, Inc., 1978), p. 3.

[11] Among the many studies concerning the case of Indian and Pakistani Punjab are John P. Mc.Inereny and Graham F. Donaldson, The Consequences of Farm Tractors in Pakistan, Staff Working Paper No. 210 (Washington: IBRD, Feb. 1975), Richard H. Day and Inderjet Singh, Economic Development as a Adaptive Process: The Green Revolution in the Indian Punjab (London: Cambridge University Press, 1977). William H. Bartsch, "Employment Effects of Alternative Technologies and Techniques in Asian Crop Production: A Survey of Evidence," provisional draft (Geneva: International Labor Office, 1973).

[12] A. G. Rijik, "Appropriate Agricultural Mechanization for Northern Thailand," in Rural Development Technology, an Integrated Approach, ed. by Gajendra Singh and J.H. De Golde (Bangkok: AIT, 1977), pp. 145-163.

Northern Thailand found that farm mechanization was complementary to the application of HYV's. Land preparation by tractor provides thorough soil tillage which facilitates better seedling while better water control can be achieved through water pumping system. Another village study done by Moreman[13] in Northern Thailand also found that tractor-plowed rice plots were noticeably more bountiful than any of the others.

The practice of double-cropping further creates a higher demand for labor and places a more binding time constraint on each farm operation. According to a survey of Somchart Komate[14] on labor problems of double-cropping at Channasutr Land Consolidation in Thailand, he found that tractor utilization and ownership in that area were wholly due to the development of double-cropping system.

In some countries, public policies also have influences on factor and product markets in order to induce substitution of mechanical power for animal power and for labor. Sanders and Ruttan[15] found that there were price distortion policies in Brazilian agriculture which led the economy to favor farm mechanization. Dong Hi Kim[16] also pointed out that the Korean government around the mid 1960's became more active in providing large amounts of credit and subsidizing farmers for purchasing

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[13] Michael Moreman, Agricultural Change and Peasant Choice in Thai Village (Berkely and Los Angeles: University of California Press, 1968), p. 66.

[14] Somchart Komate, op. cit., Chapter V.

[15] John H. Sanders and V.W. Ruttan, "Biased Choice of Technology in Brazilian Agriculture," in H. Binswanger and Others, Induced Innovation op., cit, (1978), pp. 276-296.

[16] Kong Hi Kim, "The Farm Mechanization Process in Korea," in Farm Merchanization in East Asia. ed. by Herman Southworth (Singapore; ADC. Inc., 1972), pp. 50-60.

farm machineory. In Burma, Uhla Tin[17] found that government guidelines toward the development of cash crops; sugar-cane, cotton and jute in the more arid zone creates a greater demand for tractor operation in their cultivation processes.

Empirical tests for many developed countries such as the U.S. supported the induced innovation hypothesis. However, the widespread diffusion of farm machinery in LDCs today cannot be determined only by the above hypothesis. Some other crucial variables should also be considered since most of these modern implements are acquired by way of importation. Other aspects of farm machinery especially for tractors which induced farmers to adopt them are their greater power which provide deeper and more thorough soil tillage, timely operation, and their multi-purpose uses such as threshing and transportation. Sometimes, some machines such as the water pump become essentially important in order to obtain irrigatable water into the field. This is when the functioning of the machine itself becomes the first priority when deciding to buy rather than its substitution effects. Other factors influencing farmers to use farm machinery are institutional factors, government policies toward farm mechanization, the establishment of domestic farm machinery production, availability of more adaptable machines including demonstration effects. Some of these factors should also be considered.

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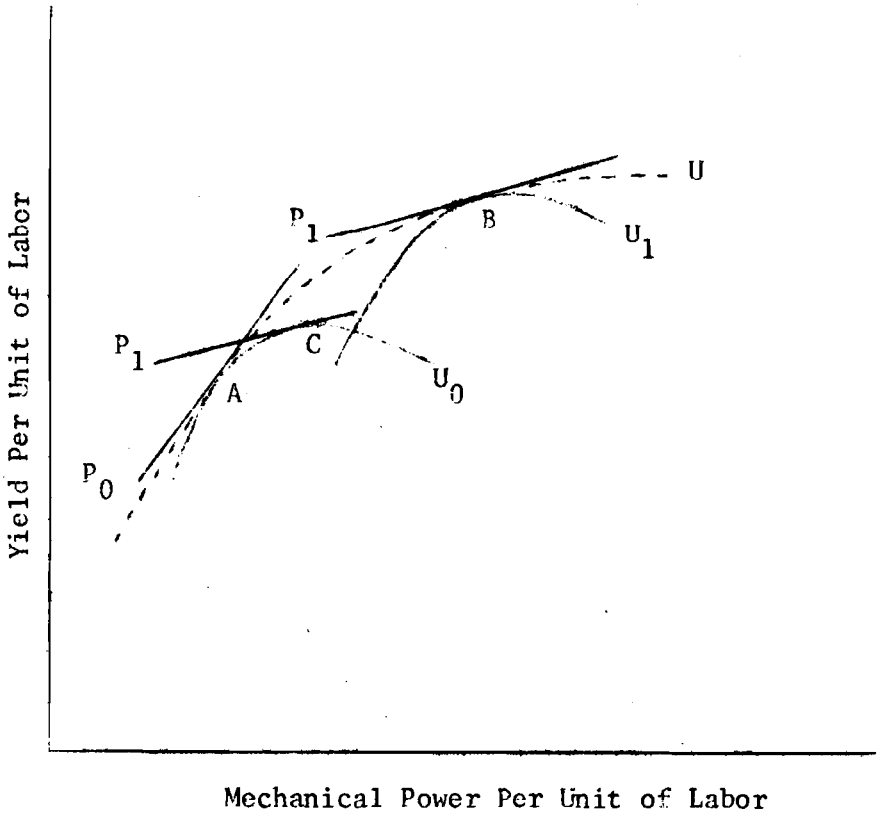
[17] U. Hla Tin, "Status of Agricultural Mechanization in Burma," in International Agricultural Machinery Workshop., proceeding the International Rice Research Institute (Sept., 1978), pp. 69-79.

B. Theoretical Framework of the Study

If a country is endowed with relatively scarce labor and abundant land, the price of land will be relatively low as compared to the price of labor. The use of mechanical power may be induced in order to save the use of relatively scarce labor and thereby increase the land-labor ratio and yield per unit of labor. The relationship between mechanical use and yield may be drawn graphically in Figure III-1, where U_0 and U_1 represent the mechanical response curve of different factor price sets along the metaproduction curve (U).

FIGURE III-1

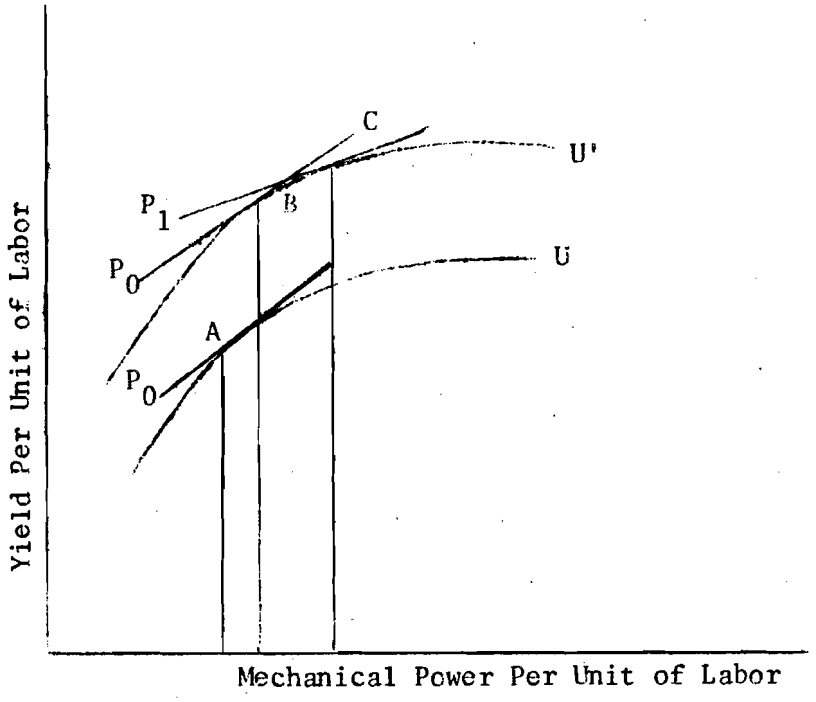
SHIFT IN FACTOR-OUTPUT PRICE RATIO ALONG THE METAPRODUCTION CURVE



A decline in the price of machinery relative to the price of agricultural output from P_0 to P_1 would be expected to result in the increased use of machinery since it means that machinery has become relatively cheaper than labor, given that price of output does not change. The full impact of the lower relative prices of modern inputs such as farm machinery on yield can be fully realized only if U_1 or a more productive technology is made available to the farmers. At the same time, farmers must be capable of absorbing the new technology. Point B in Figure III-1, therefore, represents the new optimum point with the highest yield per unit of labor available under the new set of prices. It involves an increased use of mechanical power per unit of labor. The U curve which envelops many response curves is defined as "metaproduction function" or a "potential production function" by Hayami and Ruttan. The above analysis of the substitution of mechanical power for labor probably adequately reflects the U.S. agricultural sector. For the case of Thailand, mechanical technology in the agricultural sector is directly transferred from developed countries and may not be a result of domestic pressures resulting from factor scarcities. There may be other determinants affecting mechanical utilization besides changes in relative factor prices over time. These factors should, therefore, be taken into consideration. If there is no significant change over time of relative factor and product prices, the substitution of mechanical power for labor is still possible. This came about through a shift in the metaproduction function as shown in Figure III-2, the new technology may be made available to the agricultural sector by way of institutional or non-price factors and the direct transfer of technology from abroad.

FIGURE III-2

SHIFT IN FACTOR-OUTPUT PRICE RATIO AND METAPRODUCTION CURVE



Under such circumstances, it is possible for the U curve or the original metaproduction curve to shift up toward U' and point B will represent the more efficient point of production given that farmers are able to absorb the new technology at point B. Later adjustment on relative prices is also possible as presented by point C although it is not the only prerequisite to the adoption of farm machinery.

Some of the posible non-price factors contributing to the adoption and diffusion of farm mechanization in Thai agriculture include;

1. The development of multiple-cropping technology which appears to have brought with it an increasing pressure for machinery application especially for land preparation in order to solve the problem of time constraint.

2. The expansion of upland crop production in certain areas created demand for mechanical power in land preparation. For instance, the greater power of tractors which enables farmers to reclaim land and prepare land with heavy texture in the dry season that cannot be effectively cultivated with draft animal. Therefore, tractors could contribute to the increased production both by higher yield and extensive farming.

3. The availability of irrigated water in dicth and dike canals creates a demand for water pumps of the farmers in order to obtain water for their fields. The uneven rainfall distribution also require water pumps in order to pump out excessive water from farmers' fields. Therefore, water pumps become the most common type of farm machinery obtained by most Thai farmers.

4. There are problems in using animal power which has a low capacity and higher cost of operation and maintainance as compared to mechanical power.[18] Furthermore, the transition to modern inputs would free land previously required for animal feeding to more crop production.

5. Another factor which should be considered as a benefit of using farm machines, especially farm tractors, is that they reduce the drudgery of farm tasks. In addition, they are often used in other

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[18]For more detail see Songsak Sriboonchittra, "The Private Cost of Using Tractors Versus Buffaloes: A Case Study of Farmers in Chachoengsoa Province,"(unpublished M.A. Thesis, Faculty of Economics. Thammasat University, 1975).

activities such as threshing and transportation. The attached motor engines are sometimes capable in generating electricity or operating water pump.

6. The last factor which should affect farmers' decisions to adopt farm machines is the so-called demonstration effect. Generally, it is possible for any micro-study to find out that certain farm machines are operated at the rates lower than the break-even point. However, if one takes into consideration the psychic benefits according to the theory of consumer choice, it is possible that certain machines are still rationally surchased by the farmers. More often than not, observers may find that a farmer is using modern inputs because his neighbor or relatives or friends are using them.

C. Methodology and Sources of Data

Analysis in the following chapters is devided into two parts. First, trends in labor productivity will be analyzed since it is considered as a consequence of technical change in the agricultural sector. Following the work of Hayami & Ruttan, labor productivity (Y/L) will be partitioned into two variables, namely land productivity (Y/A) and land area per worker (A/L). It is expected that the major source of increase in A/L has been the progress in mechanical technology whereas the major source of increase in land productivity (Y/A) has been the progress in biological technology. Applying such a model with the Thai agricultural data over time, it may inform us of the major sources of change in Thai agriculture, whether it is mechanical or biological factors or both. Another part of analysis, provided in Chapter V, involves the analysis of factors which affect farm machinery adoption

in Thai agriculture. Multiple regression analysis will be employed with cross-sectional data obtained from a nation-wide survey in 1975/1976.

Major time-series data for the Thai agricultural source endowment analysis are obtained from many sources. Major sources of data include;

Division of Agricultural Economics, Ministry of Agriculture and Agricultural Cooperatives. (DAE/MOAC).

Customs Department, Ministry of Finance

Bank of Thailand

The National Statistical Office

The National and Economic and Social Development Broad (NESDB)

To complete as much as possible the series for a number of variables, data from various sources will be adjusted for consistency (See Appendices).

CHAPTER IV

RESOURCE ENDOWMENTS AND TECHNOLOGICAL CHANGE IN THAI AGRICULTURE

This chapter attempts to analyze Thai agricultural development by investigating variations in agricultural resource endowments as well as changes in their productivity. The analysis will be focused on the post World War Two period, 1950-1975, partly because Thai agriculture has become dependent on science-based inputs such as fertilizer and farm machinery, and partly because of data deficiency in prior years. Trends in agricultural inputs and output will be described in the first section whereas trends in agricultural productivity are described in the following section. Finally, influences of technological change on agricultural productivity growth over time will be explored in the last section.

A. Trends in Agricultural Inputs

1. Labor

Agricultural occupation has always been preferred by the Thais and the increase in farm workers since the expansion in rice cultivation in 1850 is due to the increase in population.[1] Available statistics on the occupational distribution of the labor force, as shown in Table IV-1, may help to indicate the importance of agriculture in Thailand. About 80 per cent of the labor force are employed in agriculture with a small proportion engaged in forestry and fishing.

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[1] James C. Ingram, Economic Change in Thailand 1850-1970 (Stanford: California, Stanford University Press, 1971), pp. 54-55.

TABLE IV-1

TOTAL LABOR FORCE AND AGRICULTURAL LABOR IN CENSUS YEARS

Census Year	Total Labor Force (unit in million)	Number in Agriculture, Forestry & Fishing (unit in million)	Percentage in Agriculture, Forestry & Fishing
1929	7.5	6.3	84
1937	6.8	6.0	89
1947	8.9	7.6	85
1960	13.8	11.3	82
1970	16.6	13.2	79

Source: Figure for 1927 and 1937 are from James C. Ingram, op. cit., p.57. Figure for 1947, 1960 and 1970 are from National Statistical Office, Population Census.

Since rice has always been the most important crop in Thai agriculture, as its production expanded the demand for labor in agriculture also increased. Responding to a foreign demand for rice in the latter half of the nineteenth century, a significant increase in areas under rice cultivation took place. The expansion of cultivated areas around the turn of this century increased rapidly in the Central Plains where improvements in water distribution through a canal system were already underway.[2] Around 1905-1909, about 6.8 million rai

[2]David B. Johnston, "Rural Society and the Rice Economy in Thailand 1880-1930," (Unpublished Ph.D. Dissertation, Yale University, 1975), pp. 39-41.

in the Central Plains and 2.4 million rai in the other regions were reported to be planted to paddy.[3]

At the same time, additional peasant labor was made available through the gradual abolition of debt slaves (that) and corvee' peasant (Phrai).[4] The dismantling of this old social system allowed these people to migrate between regions. Tension between demand and supply of labor arose for the large land owners in the Central region, since they could no longer depend on the work of debt slaves or corvee' peasants. They found that the availability of family labor at that time could not satisfy the large demand for labor especially during the peak season.

There is also evidence to support the believe that labor to some extent was scarce for large scale farming in the Central region during the first half of this century. It was recorded that hired labor was additionally supplied from the North and the Northeast regions. They were referred to as "Laos Workers."[5] Furthermore, it was recorded in the First and Second Rural Economic Survey during the 1930s that hired workers in the Central Plains accounted for the highest percentage of total farm cost. These figures are shown in Table IV-2. According to this evidence, we are led to believe that labor was a bottleneck in the Central Plains, especially for the large land-owners.

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[3]James C. Ingram, op.cit., Table IV.

[4]Thaveesilp Subwattana, "Rice Production and Trade in Central Thailand from the Region of King Rama V to King Rama VII (1868-1932)" (Unpublished M.A. Thesis, Department of History, Chulalongkorn University, 1976), pp. 37-38. (in Thai).

[5]Memorandum on "How to Improve Farming," R.5, KS 13/319, File #17 Nation Archieves.

TABLE IV-2

PERCENTAGE OF HIRED LABOR COST IN RICE PRODUCTION BY REGIONS

Region	1st Siam Rural Economic Survey	2nd Siam Rural Economic Survey
Northeast	18.06	21.06
South	42.82	22.94
North	40.32	40.09
Central	54.19	59.00

Source: Calculated from Carle C. Zimmerman, The First Rural Economic Survey, 1931 (Bangkok: The Bangkok Time Press, 1931), and J.M. Andrews, Siam Second Rural Economic Survey, 1934-1935 (Hongkong: The Bangkok Time Press, Ltd., Dec. 1935).

In fact, farm workers were seasonally supplied from other regions to the Central Plains. However, it was not as available as it seemed to be. This is because farm workers in other regions could generally employ themselves on the unused land if they wanted to since land was still relatively abundant at that time.[6] Moreover, uncertainty of the working conditions in the Central Plains seemed to obstruct farm workers from migrating to work in this area.[7] Hence it is possible that the

[6] James C. Ingram, op.cit., p. 55.

[7] Letter from Chao Phya Wongsanuprapat to the King (Rama V), R. 5 Ks. 3.1/2, National Archieves.

uncertain conditions of labor supply led large land owners, who usually were also the wealthy elites or noble officials, to seek labor-saving implements. As Feeny found in his study that seed selection and mechanization were two prominent subjects discussed by many government officials and private investors with respect to technical change in Thai agriculture. To quote:

> "During the rice boom of the 1890s, many government officials and private investors felt that a labor shortage impeded the more rapid extension of rice cultivation in the Central Plains. They therefore concluded that if machines could be substituted for labor exports would grow faster."[8]

Nevertheless, information concerning the number of labor in the agricultural sector during the post World War II period as provided in Table IV-3 reveals that these was an increase in agricultural labor of around 2 per cent annually.

TABLE IV-3

ESTIMATED LABOR FORCE IN THAI AGRICULTURE FOR SELECTED YEARS

Year*	Number of Agricultural labor in 1,000	Index	Compound Annual rate of Growth (in per cent)
1953	9,352	100	-
1958	10,465	112	2.3
1963	11,875	127	2.5
1968	12,820	137	1.5
1973	13,845	148	1.5
1953-1973	-	-	2.0

Source: Calculated from Table A-1.

*Five-year average figures centered at the year shown.

[8]David Feeny, "Technical and Institutional Change in Thai Agriculture 1880-1940," (Unpublished Ph.D. Dissertation, University of Wisconsin, Madison 1976), p. 114.

However, this rate of growth appears to decline slightly from the mid 1960's to present. This may be due to labor migration from the rural agricultural sector to the urban industrial sectors.

2. Land

The total area of Thailand is approximately 321 million rai, with 35 per cent (114 million rai) classified as "farm holding land" and 38.6 per cent (123.9 million rai) as forest land.[9] Of all the land available in farm holdings, paddy land comprised about 65 per cent of the total farm land with 22 per cent for upland crops and 10 per cent for tree crops. In general, arable land represents available supply of land for farming whereas planted area indicates the actual amount of land utilized. Two series of land area are presented in Table IV-4.

TABLE IV-4

ARABLE LAND AND PLANTED AREA TO ALL CROPS IN SELECTED YEARS

Year	Arable land (1,000 rai)	Index	Planted area (1,000 rai)	Index	Annual compound rate of growth in per cent	
					Arable land	Planted area
1953	46,998	100	41,652	100	-	-
1958	49,187	105	45,126	108	1.0	1.6
1963	58,283	124	55,347	133	3.4	4.3
1968	73,845	157	67,290	162	4.8	4.0
1973	98,476	209	78,559	189	5.9	3.1
1953-1973	-	-	-	-	3.7	3.2

Source: Calculated from Table A-2.

*Each year is five-year average centered at the year shown.

[9]Department of Agricultural Economics, Ministry of Agriculture and Agricultural Cooperatives, Agricultural Statistics of Thailand Crop Year 1977/1978 (Bangkok: Thailand, No. 100) Section XII.

Although the overall rate of growth of both arable land and planted area are about the same (around 3 per cent), the amount of planted area throughout the whole period of the study was lower than the amount of land available which is what should be expected without an extensive practice of multiple-cropping. The under utilization of land may be explained by the extensive farming system in Thailand where some portions of the land were found to be unsuitable for cultivation. Furthermore, it also implies that parts of the available land are devoted to residential areas. In order to avoid the underestimation of land productivity, planted areas of all crops are therefore chosen for the study.

3. Draft Animals

Another source of power in Thai agriculture which is worth mentioning is the power derived from draft animals. Buffaloes and oxen have always been the major source of power in Thai agriculture. They are suitable for work in muddy and submerged fields. The normal weight of a buffalo is around 400-900 kilograms and can create power equivalent to 0.75 hp.[10] Although these animals are very helpful in farm tasks, they possess some limitations in their capacity to work for they require long periods of rest during the afternoon, thus limiting the plowing rate of one buffalo to about one rai per day. Farmers with large land areas for cultivation but few draft animals thereby often have to leave part of their land unused. Another problem involving the use of draft animals is that these animals can easily be stolen or succumb to animal diseases.

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[10] W.R. Cockrill, "The Working Buffaloes" in The Husbandry and Health of the Domestic Buffalo, FAO (ed.) 1974, pp. 313-327.

Despite limitations of their uses, prices of these draft animals, particularly the buffalo, rose significantly during the beginning of the twentieth century as presented in Table IV-5. The price of buffalo in the Central Plains tripled between 1893-1919. The increased price of buffalo to some extent reflected the increasing demand for draft animals which serve not only as a source of power but also as a source of food.

TABLE IV-5

PRICE OF BUFFALO IN THE CENTRAL PLAINS FOR SELECTED YEARS

Year	Price of buffalo (Baht/head)
1893	40- 50
1900	50-100
1905	70-120
1910	90-150
1911	80-120
1919	120

Source: Data from 1893-1910 are obtained from Suntharee Arsawai, the Role of Government and Private Individual in Developing: A Study of the History of Rangsit Project (1888-1904), (Bangkok: Thai Khadi Suksa, Thammasat University, 1978), p. 162. (in Thai).

Data for the years 1911 and 1919 are obtained from Thavesilp Subwatana, op.cit., p. 168.

In the past, it seemed reasonable for farmers to employ draft animals as their cheap source of power since only one crop was usually cultivated per year. Nowadays, the development, especially in the Central region, is towards multiple-cropping as well as diversification of crops. Land tillage in the dry season as a consequence of changes in cropping schedule may impose the use of draft animal power and, hence, encourage farmers to employ tractor plowing. In addition, the number of buffalo and oxen in Thai agriculture further shows a rather slow rate of change throughout the period of study as compared to other inputs mentioned previously. (Table IV-6).

TABLE IV-6

NUMBER OF BUFFALO AND OXEN IN SELECTED YEARS

Year*	Buffalo & oxen (1,000 heads)	Index	Annual rate of growth (per cent)
1953	7,272	100	-
1958	7,979	110	0.9
1963	8,826	121	1.0
1968	9,876	136	1.1
1973	10,058	138	0.2
1953-1973	-	-	1.3

Source: Calculated from Table A-3.

*Each year is five-year average centered at the year shown.

B. Trends in Agricultural Output

Since the 1950's, Thailand has been experiencing a significant rate of growth of 4.5 per cent in crop production. The significant growth rates in crop production during the 1960s as shown in Table IV-7 were realized partly due to the increase in demand for export-oriented crops. Within the crop sub-sector, rice remains dominant, representing about

TABLE IV-7

GROSS DOMESTIC PRODUCTS ORIGINATING FROM CROPS IN SELECTED YEARS

Year*	GDP originating from crops at 1962 price (million baht)	Index	Annual rate of growth (in per cent)
1953	11,839.2	100	-
1958	13,732.2	116	3.0
1963	18,391.2	155	6.0
1968	23,340.2	197	4.9
1973	28,477.4	241	4.1
1953-1973	-	-	4.5

Source: Calculated from Table A-6.

*Each year is five-year average centered at the year shown.

50 per cent of the total value of all crops. However, the structure of crop production since the 1960's has been more diversified. Information provided in Table IV-8 reveals that other crops except for rubber had been increasing at a faster rate of growth than rice. This implies that there should have been a shift in the relative crop price in favor of other export-oriented crops. In addition, the price of rice is known to be suppressed down by the rice premium as a result

TABLE IV-8

GROSS DOMESTIC PRODUCT ORIGINATING FROM SIX MAJOR CROPS IN SELECTED YEARS

Year*	Rice	Maize	Sugar-cane	Cassava	Rubber	Kenaf	Other crops
1953	5,652.2	61.4	211.8	30.6	1,674.2	34.3	4,171.2
1958	7,274.0	209.6	443.8	227.4	1,190.8	153.8	4,252.8
1963	9,552.6	552.4	423.8	537.6	1,308.0	571.6	5,458.0
1968	10,944.0	1,031.0	477.8	674.4	1,686.0	847.2	7,416.4
1973	11,401.8	1,632.6	1,158.4	1,629.2	2,423.6	791.2	9,440.6
			ANNUAL RATE OF GROWTH (in per cent)				
1953-1958	5.2	27.8	15.9	49.3	-6.6	34.9	0.4
1958-1963	5.6	21.4	-0.9	18.8	2.0	30.0	5.1
1963-1968	2.7	13.3	2.4	4.6	5.2	8.2	6.3
1968-1973	0.8	9.6	19.4	19.3	7.5	-1.3	4.9
1953-1973	3.6	17.8	8.9	22.0	1.9	17.0	4.2

Source: Calculated from Table A-6.

*Each year is five-year average centered at the year shown.

of the Government's policies to stabilize and provide cheap rice for domestic consumption and diversify crop production. Therefore, it is reasonable for farmers to cultivate other crops which would provide them with higher revenues. Although detailed description of each crop is not included in this study, it is nevertheless clear that Thai agriculture has become dependent not only on rice cultivation but other cash crops as well.

C. Mechanization and Productivity Growth in Thai Agriculture

The growth in labor productivity in agriculture may be decomposed into a change in land productivity and the land area per labor unit by using the following relationship:

$$Y/L = (Y/A)\ (A/L)$$

where, Y = Agricultural output

L = Agricultural labor

A = Agricultural land

Y/L = Labor productivity

Y/A = Land productivity

A/L = Land area per worker

The impact of technological changes on agricultural productivity can be investigated through changes of these ratios. Economically, combinations of primary inputs utilized in agriculture (land and labor) should be guided by their relative prices. If land is abundant relatively to labor, output growth should be achieved by employing more land into

the production process and, hence, result in an increase in the land-labor ratio. Such an increase may be accomplished through the use of farm machinery. However, if land is a scarce factor whereas labor is abundant, increase in labor productivity may be achieved by improving land productivity through applying more labor and bio-chemical inputs.

Data for the Thai agricultural sector provided in Table IV-9 do not clearly indicate the dominant source of growth in labor productivity. Over the entire period of the study, 1951-1975, agricultural labor and planted area all increased at substantial rates of growth. Labor productivity (Y/L) grew at a rate of growth of 2.5 per cent per annum. Both land productivity (Y/A) and area per worker (A/L) reveal an equal rate of growth of 1.2 per cent per annum over the entire twenty-five year period.

Dividing the period of study into two subperiods, 1953-1963 and 1963-1973, land productivity (output per rai) grew faster than land area per worker in the first subperiod whereas the reverse situation is found the second subperiod. The higher rate of growth of land productivity in the first subperiod than in the latter period (1.6 per cent compared to 1.0 per cent) may be explained by the fact that Thai farmers during the earlier period could expand into more fertile land coupled with the beginning of fertilizer application.

Fertilizer consumption per rai (Table IV-10) also shows a faster rate of growth during the first subperiod, although the actual amount of fertilizer used per rai was increasing throughout the whole period of the study. The rate of growth of fertilizer comsumption per rai declined in the latter subperiod when the Government gave protection to domestic production which led to higher prices of

TABLE IV-9

TRENDS IN OUTPUT, INPUTS, AND PRODUCTIVITY IN THAI AGRICULTURE, 1951-1975, SELECTED YEARS

	Index 1953=100					Annual compound rate of growth (%)		
	1953	1958	1963	1968	1973	1953 to 1963	1963 to 1973	1953 to 1973
Output (Y)	100	116	155	197	241	4.5	4.5	4.5
Agrucultural labor (L)	100	112	127	137	149	2.4	1.6	2.0
Planted area (A)	100	108	133	162	189	2.9	3.6	3.2
Output per labor (Y/L)	100	104	122	144	106	2.0	2.9	2.5
Output per planted area (Y/A)	100	107	117	122	128	1.6	1.0	1.2
Planted area per worker (A/L)	100	96	105	118	128	0.5	2.0	1.2

Source: Data are collected from Table IV-3, Table IV-4, and Table IV-7.

Note: All variables are five-year average centered at the year shown Agricultural output including only agricultural crops.

TABLE IV-10

FERTILIZER CONSUMPTION IN THAI AGRICULTURE IN SELECTED YEARS

Year*	Fertilizer per planted area (kg./rai)	Annual rate of growth (%)
1953	0.1497	
1958	0.8475	25.7
1963	1.4746	
1968	3.6905	12.7
1973	4.8752	
1953-1973	-	19.0

Source: Calculated from Table A-2, and Table A-4.

*Each year is five-year average centered at the year shown.

fertilizer.[11] It is also important to note that the rapid growth of fertilizer use per planted area in the first subperiod partly results from a smaller base. Nevertheless, greater yield in the early application of fertilizer should be realized since it is not applied with marginal land. Hence, it may lead to a higher land productivity.

From Table IV-9, area per worker (A/L) reveals a greater rate of growth in the second subperiod. Four reasons can be provided to explain this finding. First, the increased land brought under cultivation

[11] Almost all chemical fertilizers consumed in Thai agriculture were imported with small portion of domestic production which started in 1966 with strong support from the Government through protection. See also Sompop Manarungsun, "The History of Fertilizer Policies in Thailand: An Economic Study, 1960-1975" (Unpublished M.A. Thesis, Faculty of Economics, Thammasat University 1978), pp. 40-41.

was of poorer quality than land previously cultivated. In other words, the most fertile land which were more suitable for cultivation would have already been exhausted in the earlier period. Since farmers had to work with the marginal land in the latter period, more land had to be cultivated in order to maintain subsistence level of farm income which enhanced the expansion of planted area (A).

Secondly, with the expansion in irrigated area realized in the late 1960s, (Table IV-11), there was a greater potential for double-cropping as well as diversification in crops leading to further increases in planted area. The rapid increase in percentage of planted area in

TABLE IV -11

IRRIGATED AREA FROM 1910 TO 1978

Year	Irrigated area (rai)	Remarks
1910	300,000	End of King Rama V Reign.
1925	980,000	End of King Rama VI Reign.
1931	2,560,000	
1947	3,800,000	
1957	8,100,000	
1966	11,700,000	End of the First National Plan.
1971	13,300,335	End of the Second National Plan.
1976	15,298,784	End of the Third National Plan.
1977	15,600,000	
1978	16,098,330	

Source: Data from 1910-1977 are obtained from Sukti Krachangyao "Irrigating in Thailand," Bangkok Bank Pamphlet, Jan.-June, 1978. p. 31 (in Thai)
Data for 1978 are from DAE/MOAC, Agricultural Statistics of Thailand Crop Year 1977/78, p. 133.

dry-season rice to total planted area provided in Table IV-12 further support this idea. During the second subperiod (1963-1973), the percentage of dry-season rice to total planted area expanded about 30 per cent annually.

TABLE IV-12

PLANTED AREA OF WET AND DRY-SEASON RICE IN SELECTED YEARS

Year *	Planted area		Total Planted area	% of Dry-season rice to total Planted area
	Wet-season	Dry-season		
1958	35,990.2	63.4	36,053.6	0.18
1963	40,553.8	97.0	40,650.8	0.24
1968	45,787.4	459.2	46,246.6	1.00
1973	48,133.2	1,828.4	49,961.6	3.66

Source: Calculated from Table IV-7.

*Each year is five-year average centered at the year shown.

The third reason for a more rapid increase of area per worker in the latter subperiod was the tendency for agricultural worker to seek jobs in the urban industrial sector with a resulting decline in the growth rate of agricultural labor (L). Data on the distribution of employment by various sectors in 1960 and 1970 are presented in Table IV-13. Information from the table reveals that there was a slight decline in the share of agriculture in total employment in 1970, and the growth rate was relatively low as compared to those in other sectors.

TABLE IV-13

DISTRIBUTION OF EMPLOYMENT BY MAJOR SECTOR IN 1960 AND 1970 CENSUS YEARS

Sector	1960		1970		Compound growth rate (per cent)
	Person	Shares	Person	Shares	
Agriculture	11,334,882	82.30	13,201,901	79.28	1.5
Mining	29,568	.22	86,647	.52	11.4
Manufacturing	471,027	3.42	682,640	4.10	3.8
Construction	68,813	.50	181,477	1.09	10.2
Electricity	15,535	.11	25,287	.15	5.0
Commerce	779,904	5.66	875,798	5.26	1.2
Transport	165,939	1.20	268,398	1.61	4.9
Service	655,271	4.76	1,184,207	7.11	6.1
Unknown	251,665	1.83	145,912	.88	-
Total	13,772,104	100.00	16,652,267	100.00	-

Source: National Statistical Office, Population Census 1960, and National Statistical Office, Population and Housing Census 1970.

Furthermore, according to the Labor Force Survey, the percentage of agricultural employment to total employment declined steadily from 1970 onward (Table IV-14). Although fluctuation in data appears after 1974 due to changes in employment definitions, it is still reasonable to point out that there was a transfer of labor force from the traditional agricultural sector to other non-agricultural sectors in the urban area.

TABLE IV-14

PERCENTAGE OF LABOR EMPLOYED IN AGRICULTURAL SECTOR BOTH MUNICIPAL AND NON-MUNICIPAL AREA, 1971-1976

Year	All sector (person)	Agricultural sector (person)	%of Agri.labor force to total
1971	16,618,640	13,157,680	79.2
1972	16,126,490	11,642,150	72.2
1973	17,042,660	12,270,480	72.0
1974*	17,159,740	11,226,280	65.4
1975	17,580,170	13,871,500	78.9
1976	18,410,910	13,948,530	75.7

Source: NSO, Labor Force Survey, Second Round July-Sept., Various Issues.

*From 1974 onward there is reclassification of "unemployed persons" which include unpaid family workers working less than 20 hours per week and person without work not looking for work because of the belief that no work is available.

Finally, farm mechanization led to a further expansion in cultivated area. The effect of farm machinery on area per worker is straight forward since the greater power provided from farm machines, particularly tractors, facilitates heavy land clearance or land tillage in the dry season which permits an increase in cultivated area (A). In fact, the use of farm machines coupled with other yield increasing inputs and more sophisticated pattern of cropping to some extent also enhance the increase in land productivity. Although pertinent time-series data concerning farm

machinery utilization are not available, import data on farm tractors and water pumps are accessible. Information in Table IV-15 reveals that there has been a steady increase in both items. It is also important to also note that after the 1970's there is an increasing number of local small-scale farm machinery production and large tractor assembly plants. About 100 farm machinery firms and three large tractor assembly plants were reported in 1978.[12]

TABLE IV-15

IMPORTS OF FARM TRACTORS AND WATER PUMPS IN SELECTED YEARS

Year*	Farm tractors (unit)	Water pumps (unit)
1953	262[a]	8,828
1958	471	29,671
1963	2,251	21,938
1968	3,018	107,549
1973[b]	3,540	132,568

Source: Calculated from Table A-5.

*Each year is five-year average centerring at the year shown

Note: a) Import number of farm tractor in 1955 is used

b) Import data for this year are averaged value after there was a change in commodity classification in 1970, for more details see Appendix A.

[12] According to a nation-wide survey on the Farm Tractor Industry conducted by the Bank of Thailand in August 1978.

Furthermore, if the expansion of area under farm holding is compared with the number of farm tractors available by agro-economic zones (Table IV-16), there is some implication that expansion in farm holding area since 1950 has been greater in areas with a large number of four-wheel tractors. Information from the same table also reveal that the large expansion in farm land holding has occurred in the more recently developed zones adjacent to the Central Plains, specializing in maize, sugar-cane, and cassava production, (Zone 6, 7, 12 and 15). It is also important to note that farmers often travel with their tractors from one location to another, sometimes across zones, in order to extend the tractors' working season. Therefore, it is possible for zone 4 (Si Sa Ket, Surin and Buri Rum Provinces) to be endowed with a large number of tractors but having small changes in farm holding area since it is closely located to zone 6 and zone 7 in which tractors are widely used for upland crop production.

According to a survey in 1967/1968, there were about 17,500 four-wheel tractors and this rose to 25,000 units in the following year. The potential increase in demand per year was also reported to be about 15-22 per cent.[13] Information from the same survey further reveals that in 1967 tractors were most widely used for land tillage in the Central Region. About 60 per cent of paddy land was tilled by tractors with greater percentages reported for other cash crops.

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[13]Royal Government of Thailand, Thailand Farm Mechanization and Farm Machinery Market, (Bangkok, 1969).

From the above information, one may come to a conclusion that more widespread utilization of farm tractors has taken place. This appears to have been a contributing factor in the rapid expansion of land area per worker in the latter decades.

TABLE IV-16

COMPARISION OF EXPANSION IN FARM LAND HOLDING AND THE NUMBER OF FOUR-WHEEL TRACTORS AVAILABLE BY AGRO-ECONOMIC ZONES

Zones	Total Farm Holding Land in 1950 (1,000 rai) [a/]	Total Farm Holding Land in 1975 (1,000 rai) [b/]	Changes in Farm Holding Land (1,000 rai)	Annual Compound Rate of Growth (per cent)	Number of Four-wheel Tractors
1	4,008	11,488	7,480	4.3	468
2	4,099	6,874	2,775	2.1	299
3	5,338	12,581	7,243	3.5	331
4	9,257	10,088	831	0.3	1,265
5	4,435	8,574	4,139	2.7	1,957
6	4,053	9,080	5,022	3.3	4,373
7	1,300	3,924	2,624	4.5	3,396
8	4,486	7,046	2,560	1.8	1,776
9	1,702	4,864	3,162	4.3	1,908
10	1,570	3,685	2,115	3.5	771
11	6,271	9,793	3,522	1.8	8,177
12	1,738	4,725	2,987	4.1	1,813
13	1,618	4,487	2,869	4.2	1,236
14	752	858	106	0.5	312
15	983	2,438	1,455	3.7	775
16	524	1,268	744	3.6	196
17	4,170	8,768	4,598	3.0	880
18	1,158	3,204	2,046	4.2	87
19	1,192	2,419	1,227	2.9	110

Source: a/DAE/MOAC, Areas of Thailand by Provinces & Region, 1950 (Bangkok, May 1954).

b/DAE/MOAC, "Land Utilization of Thailand, 1975," Agricultural Statistical Bulletin, No. 57.

In summary, the variation in factor combination depends on the corresponding factor price ratios. Generally, it is true that factors in abundance will be priced lower than the scarce ones and this will in turn lead to different patterns of factor use. The new combination should employ a relatively larger amount of the abundant factor and economize on the use of the other scarce factors. New inputs may also be introduced to substitute for the scarce factor. However, there is a time-lag involved in the process of factor adjustment corresponding to changes in factor prices. For the Thai case, time-series data on factor prices are incomplete and inconsistent. It is, therefore, difficult to test this theory. Looking at the significant increases in labor productivity during the last twenty-five years, improvement in farming techniques coupled with application of modern farm inputs should have begun to take place in Thai agriculture

Technological change chiefly involves the use of fertilizer and farm machinery. The rapid increase in planted area per worker in the second subperiod (1963-1973) may seem to imply that land was more of a constraint in the prior period. Some may argue that even in the first subperiod, land areas were left unutilized. However, the available land at that time required high cost in clearing and preparing to make it fit for cultivation. Farm machinery in the form of tractors could enhance the rapid expansion of land in the latter period by providing additional power for land clearance. Furthermore, the use of farm machinery facilitates multiple-cropping and the fuller utilization of the available farm land. This raises the planted area per worker and, to a lesser extent, the labor productivity It is, therefore, possible to verify that in the late

1960s a modest technological revolution in the form of farm machinery began to take root and spread in Thai agriculture.

However, regional variation of farm machinery utilization is also witnessed. Therefore further investigation in the following chapter will be concerned with factors which affect variation in farm machinery adoption among the regions in Thailand.

CHAPTER V

FACTORS INFLUENCING THE ADOPTION AND DIFFUSION OF FARM MECHANIZATION

Farm mechanization has been brought about by various factors in different countries. For example, in the U.S., labor cost was relatively higher than the price of machinery and, hence, it became a dominant explanatory variable in the demand for farm mechines.[1] In India, where labor is relatively abundant, the price of bullocks and buffalo, rose proportionally more than the price of tractors and, therefore, provided an incentive for tractor operation.[2] In the Philippines, farmers' attitude toward tractors revealed that timeliness, ease of killing weeds, and less tedious farm operation were listed as reasons for tractors use.[3] Hence, there are many factors which influence farmers' decision toward farm mechanization. Farmers in general not only make economic decisions but also have to consider other non-economic variables, i.e., socio-cultural, psychological, as well as ecological factors. As Greene has commented in his study:[4]

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[1] Y. Hayami & V. Ruttan, op.cit., Chapter 6.

[2] Narindar S. Randhawa, "Farm Management in Relation to Technology Mechanization, Small Farmer and Rural Employment," (Paper present at the Fifth FAO Meeting, Rome, Italy, 1972).

[3] Stanly S. Johnson, "Performance and Economics of Use of Small Equipment in Tropical Countries: A Case of the Philippines" (Paper presented at the Annual Meeting of the Japanese Society of Agricultural Machinery, Kyoto, Japan, 1968).

[4] Brook A. Greene, op.cit., p. 85.

> "It seems that the farmer's estimate of whether or not to use a new farm practice (farm machinery) involved much more than economic consideration. In fact, the farmer probably does not distinguish between economic and non-economic variables in the adoption process."

Therefore, differences in the pattern of adoption at the regional level are likely to occur because of the underlying physical, economic, and socio-cultural factors.

The purpose of this chapter is to study some major factors which could determine farm machinery adoption and diffusion in Thai agriculture. The following farm machines were studied: four-wheel tractors, two-wheel tractors and water pumps. The main method of analysis utilized is multiple regression using cross-sectional data of the nineteen agro-economic zones in Thailand. Assuming that the economy is operated at general equilibrium, the use of cross-sectional data can therefore be a proxy for long-run phenomena. It is also important to note that factors influencing farmers' adoption of farm machines can only be indicated to a limited extent in this study due to data deficiency.

A. The Adoption Model

Hypothetically, factors influencing farmers' decision to adopt a new farm practice can be classified into three categories; (a) economic, (b) geographic, and (c) socio-cultural.[5] Variables within the first two categories are considered in this study. They are discussed and defined as follows:

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[5]Charles T. Alton, "The Economics of Dry Season Irrigation in Northeast Thailand" (Ph.D. Dissertation, University of Kentucky, 1977), p. 42.

1. Relative Factor Prices

Based on the substitution viewpoint[6] the choice between using animal power, labor, and farm machinery should primarily be guided by their relative prices. In other words, if the opportunity cost of labor and animals becomes sufficiently high relatively to the price of farm machines, it would be more economical to shift to farm mechanization. Therefore, one may expect that in regions where the price of labor and draft animals are relatively higher than the price of machinery a greater degree of mechanization will be witnessed.

Since cross-sectional data of different regions in Thailand are used in this study, the price of farm machinery therefore should not vary much although there may be some regional differences. Furthermore, it is assumed in this study that the contractors' market for farm machines is highly competitive, the farmers therefore face pretty much the same rental cost of using farm machines. If so, then only the price of labor and draft animals are needed to be included in the model.

Under the cost minimizing assumption, in areas where the wage rate and cost of using animals are high, farmers will attempt to reduce farm costs by substituting farm machines for labor and draft animals. Therefore the prices of both labor and draft animals are hypothesized to be positively related to the number of farm machines in each region. In other words, if prices of labor and draft animals are found to be high in certain regions, it is expected that a greater number of farm machines per unit of area will be employed in those regions.

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[6]Hans P. Binswanger, The Economics of Tractors in South Asia: An Analytical Review (New York: Agricultural Development Council, Inc., 1978), pp. 3-5.

2. Proportion of area planted to other non-rice crops

In general, there are two main types of tractors widely used in Thai agriculture, namely four-wheel and two-wheel tractors or power tillers. At present, tractors used in non-rice producing areas are mainly limited to large four-wheel tractors which are primarily used for dry land plowing before the rainy season. In addition, large tractors facilitate land clearance in the upland areas which increases cultivated land for cash crops. Some of these crops include maize, cassava, sugar-cane, cotton, kenaf, etc. The proportion of area cultivated to cash crops or upland crop area to total planted area is therefore expected to be positively related to the demand for four-wheel tractors.

On the other hand, two-wheel tractors are mainly used in rice cultivation since they are small in scale and hence suitable for the submerged rice fields. The opposite relationship to four-wheel tractors is therefore expected for the case of two-wheel tractors. In other words, the relationship between demand for two-wheel tractors and upland crop area should be negative.

3. Proportion of double-cropping area

Additional water during the dry season from various irrigation projects plays an important role on the area that can be double cropped. Together with sufficient water and its effective control, more use of other inputs such as fertilizer, HYVs and farm machinery are found. In areas where multiple-cropping is possible, an acute time constraint on each farm operation may create labor bottlenecks. Generally, such bottlenecks can be reduced if there is sufficient labor migration.

However, if the nearby areas also possess similar cropping schedules, then labor supply may become less flexible. The use of tractor plowing will help solve this problem by allowing sufficient time for planting and reduce the need to hire a large number of supplementary labor.

Double-cropping areas depend on the availability of irrigation facilities. However, effective utilization of irrigation facilities has lagged behind the expansion of irrigation infrastructures in Thai agriculture. This may be due to the fact that there are inadequate ditches and dike networks to carry water on to the fields. Hence, unless the inlet cannals are lined, the water cannot be controlled in each paddy plot. Farmers, then, tend to obtain and control water at the farm level by employing water pumping equipments.

Conclusion drawn for this section is that labor requirements are expected to increase with the double-cropping system which resulted from better water distribution networks. This expectation will most likely encourage farmers to employ labor and time-saving machines such as tractors and water pumps. The demand for farm machinery therefore depends on the level of double-cropping practiced. Hence, the amount of both tractors and water pumps available per rai are expected to be positively related to the percentage of double-cropping area eventhough it is not a direct causal relationship.

4. Average amount of farm income

The success of the introduction of any new farm technique or input depends upon the perceived risk attached to farmers' adoption. It is therefore possible that high income farmers are more capable in

bearing the risk involved. A study by Ronald Ng. reported that farmers who were innovative were generally farmers with higher total incomes. In general, richer farmers are more able to obtain credits and bear the risk. They usually have access to more information since they tend to have higher education and greater contact with ideas outside their villages. Thus, the relationship of average farm income to the amount of farm machinery per unit of planted area is then expected to be positive.

5. Average amount of rainfall

Another variable which should be interesting to investigate concerning the predominantly rain-fed cultivation of Thailand is the frequency of rainfall or the time concentration of rainfall in each region. It is possible for regions with erratic rainfall to require additional power from both tractors and water pumps to carry out speedy land preparation or adjusting water supply at the farm level. Data on average amount of rainfall in each region were used in this study. It is assumed that a higher level of rainfall will result in a higher probability for erratic rainfall to occur. The average amount of rainfall is expected to reveal a positive relationship with the number of tractors and water pumps per unit of planted area. It is also important to note that water pumps in this study refer to low lift pumps which are used for controlling water at the farm level.

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[7] Ronald C.Y. Ng., op.cit., p. 116.

B. Statistical Equations to be tested

In testing the previously-discussed factors, the ordinary least squares method is used. Both linear and log linear forms were experimented with in order to obtain the best possible equations. Three equations were estimated based on three different categories of farm machines, that is, four-wheel tractors, two-wheel tractors and water pumps. It is also important to recognize that it is not necessary for every category of farm machines to display the same relationship with the variables.

In functional form, the equation is as follows:

$$y = f(PL, PMAL, PUP, PDRP, AVGI, RAIN, X)$$

where, Y is composed of three dependent variables defined as follows:

FTP = the number of four-wheel tractors of all sizes per unit of planted area (unit/rai)

PTP = the number of two-wheel tractors per unit of planted area (unit/rai)

WPP = the number of water pumps per unit of planted area (unit/rai)

and where,

PL = the price of labor (baht/man-day)

PMAL = the price of animal service (baht/hour)

PUP = percentage of upland crop area in total planted area (%)

PDRP = percentage of dry season rice crop area in total planted area to rice in a calender year. (It is a proxy for the irrigated area.) (%)

AVGI = the average farm income within the region (baht/household/year)

RAIN = the average level of rainfall in each region (m.m./year)

X = other explanatory variables which are not considered in this study.

C. Sources of Data

Secondary data, both published and unpublished, for each variable were obtained from the Division of Agricultural Economics. Data concerning the number of farm machinery available in each agro-economic zones were compiled from the survey data of the same division for the 1975/1976 crop year.

Data on wage rate and service cost of draft animals were derived from the cost structure of rice production in various zones prepared by the farm production cost section of the Division of Agricultural Economics. Other variables such as the planted area of upland crops, the double cropped area of rice, average farm incomes and average rainfall were obtained from publications of the Division of Agricultural Economics and the Division of Agricultural Extension.

(Details concerning data used are available in Appendix B.)

D. Analysis of the Empirical Results

Regression results of the three equations are presented in Table V-1. Log linear relationships appear to fit well for both four-wheel and two-wheel tractors whereas the ordinary linear relationship performs better in the case of water pumps. This implies that there exists multiplicative effects on tractor adoption and diffusion whereas

an additive effect is implied for water pumps. The time lag in the adoption of farm machinery should support this finding. A study by Greene[8] revealed that water pumps were used before 1950 whereas tractor plowing appeared around the 1960s. As tractorization is a relatively new process as compared to the use of water pumps, only a small change in the explanatory variables is needed to affect significantly the number of tractors available.

TABLE V-1

REGRESSION COEFFICIENT AND STATISTICS OF FIT

Variable Independent / Dependent	Constant	PL	PUP	PDRP	AVGI	RAIN	R^2
FTP	-8.998 (-3.198)	1.246 (1.180)	0.195 (1.471)	0.148 (1.936)	0.600 (1.759)	-	0.698
PTP	-24.338 (-7.292)	6.331 (5.056)	-0.305 (-1.936)	0.180 (1.977)	0.555 (1.371)	-	0.894
WPP*	-16.268 (-2.308)	-	14.593 (2.454)	49.908 (2.268)	-	0.103 (3.364)	0.464

Note: Numbers in parentheses represent "t" statistic values.

*Simple linear relationship.

[8]Brook A. Greene, op.cit., p. 72.

The price of labor is found to be positively related to the number of two-wheel tractors as expected. Although a positive relationship is also found in the case of four-wheel tractors, it is less significant. This may be because four-wheel tractors are larger in scale and require larger amounts of investment capital. Expected returns to such an investment therefore do not depend very much on the price of labor. Given that investment in four-wheel tractors is profitable, its demand probably depends much more on farmers' purchasing power.

A two-wheel tractor is relatively cheaper, more versatile and smaller in its scale of operation. At present, the use of two-wheel tractors has been limited to the rice producing areas in the Central Plains where labor are more of a constraint. Since purchasing two-wheel tractors requires much less capital as compared to large scale four-wheel tractors, they respond more to the price of labor. The greater use of two-wheel tractors in areas where the price of labor is considerably high should imply that two-wheel tractor plowing tends to replace labor.

Information concerning the price of labor and the man-days employed for selected operations in rice production were further used to estimate the price elasticity of demand for labor in Thai agriculture the results presented in Table V-2 reveal that the demand for labor in each farming activity is negatively related to its price. In general, two basic factors which determine the price elasticity of demand for labor are the availability of substitute factors and a number of uses

TABLE V-2

ESTIMATED PRICE ELASTICITY OF DEMAND FOR LABOR IN RICE PRODUCTION SELECTED FARMING ACTIVITIES

Man-days Used in Selected Farming Activity	Constant	Price Elasticity Coefficient	Correlation Coefficient
Planting	4.9056	-1.2027 (-4.2411)	-0.717
Threshing & Winnowing	3.0130	-0.7104 (-1.8857)	-0.41
Harvesting	2.9413	-0.5151 (-2.3695)	-0.50

Source: Table B-2 and B-3.

Note: - equation form for the above simple regressions is
$\log Y = \log a + b \log X$
where Y = number of man-day required
X = wage rate
b = price elasticity of demand for labor
a = constant
- numbers in parentheses represent "t" statistic values.

of which a factor may be put.[9] Although there is no machine to substitute for labor during planting, farmers can usually employ substitute methods. broadcasting or transplanting partially depending on the availability of labor. With respect to threshing, there are various substitute inputs and methods. Instead of flailing method, farmers can use animals

[9] C. E. Ferguson and J. P. Could, Microeconomic Theory, (Homewood, Illinois: Richard D. Irwin, 1975), p. 102.

or tractors or even threshing machines. At present, harvesting still basically depends on labor without any substitute inputs, or methods. Therefore, it reveals a lower price elasticity coefficient as compared to planting and threshing activities.

These findings to some extent support the conclusion that in areas where the price of labor is high, machinery may come to substitute labor in certain farming activities, and hence causing a decline in the demand for labor.

The service price of draft animals was omitted in the course of study due to its "non-significance". This may be because of inaccurate or unreliable data or just simply that there is no substitution between farm machines and animals. In the case of water pumps, it is important to recognize that the service cost of both labor and draft animals were insignificant in explaining the number of water pumps. This may be due to the nature of the pump itself. The use of water pumps in farm operations probably functions as an additional source of power for irrigation instead of as a direct substitute for labor or animal power.

The proportion of area planted to upland crops was found to be positively related to the demand for four-wheel tractor operation as expected. This finding is supported by Chancellor's study[10] of the tractor contractors' services in 1968 where he found that four-wheel tractor contractor services in Thailand were mainly used for upland crop cultivation.

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[10] W.J. Chancellor, op.cit., p.11.

A negative relationship is found for the case of two-wheel tractors and the proportion of upland crop area. This is because two-wheel tractors or power tillers are much smaller in scale, usually 7-12 hp. as compared to 25-70 hp. for the four-wheel tractors. Therefore, they are less suited for upland tillage. Two-wheel tractors are usually operated on soft friable soils of paddy fields which are not suitable for four-wheel tractors because of traction problems.

It is also important to note that where there is sufficient water available in the dry season not only paddy crops can be grown but other field crops such as maize, sugar-cane, tobacco and vegetables can also be cultivated.[11] According to the Royal Irrigation Department, the planted area of a second crop has been increasing following the expansion of irrigation facilities in the mid 1960s. (See Table V-3). Both paddy and upland crop cultivation in the dry-season will be more effective with a stable amount of water provided by pump irrigation which probably compensate for the inadequate inlet canals to provide water to the farms.

A significant and positive relationship was found between average rainfall and the number of water pumps. An explanation may be that in regions where rainfall is high, farmers would tend to possess water pumps for draining out excessive water from their fields in order to maintain a stable level of water. It may also be argued that in areas where there is an inadequate amount of rainfall, farmers in those areas should also employ water pumps in order to supply

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[11] Y. Kaida., "Irrigation and Drainage Present and Future" in Thailand: A Rice Growing Society., ed. by Yaneo Ishii, translated by Peter and Stephanie Hawks (Honolulu: The University Press of Hawaii, 1978), p. 233.

TABLE V-3

ACTUAL EXPANSION OF DRY-SEASON CROPPING IN IRRIGATED AREAS

Unit: 1,000 rai

Year	Second Paddy Crop	Second Upland Crops
1965	28	107
1966	41	140
1967	154	122
1968	219	94
1969	221	89
1970	278	118
1971	398	85
1972	513	112

Source: Y. Kaida., op.cit., p. 234 Table 7.

additional water to their fields. Water pumping equipments can perform the dual tasks of pumping in and draining out water from the fields. However, details on usage of water pumps unfortunately requires further study which is beyond the scope of this study.

Average rainfall was found to be insignificant in the case of tractors, as expected, since there was no explanation on why tractor demand would depend on the average amount of rainfall.

Average farm income was found to have a positive and significant relationship in the case of tractors. On the other hand, it did not perform well in the case of water pumps and was therefore dropped. This may be because water pumps had been adopted much earlier than tractors and their use are now widely accepted by both high and low income farmers. Furthermore, water pumps are less expensive as compared to tractors, therefore average farm income may not be very important in explaining the regional variations in water pumps.

One interesting point to be recognized is that the average farm income and the percentage of double cropping areas are correlated (0.72). Some reasons explaining this finding are as follows:

1) For farmers whose land can be cropped more than once in a year, there is an opportunity for them to earn income from farming in the dry season. Therefore, it tends to increase the average farm income of the farmers who own such type of land.

2) A higher yield of the second paddy crop is often obtained through the use of HYV's.

3) Although the price of dry season crops is affected by the success of wet season production, in general, a higher price is often

obtained for dry-season crops. This is because the products are sold in the "off-season" markets.

To conclude, farmers in different regions respond differently to farm mechanization. Both economic and non-economic variables should be considered together when studying the adoption of farm machinery. However, due to data limitations, the study has only been able to focus on some of the major factors. Both tractor plowing and water pumps were found to be positively related to double-cropping area.

Four-wheel tractors were found to be widely used in upland crop cultivation whereas two-wheel tractor uses were limited to rice cultivation area. With respect to the use of tractor plowing, it is possible that the high farm income regions were more able to afford tractorization. Greater demand for tractor plowing was also found in the area where high cost of labor was withnessed.

The use of water pumps were found to be adopted earlier than other farm machines and their use are better distributed among regions as compared to tractor plowing. In addition, water pumps are applied for irrigation purposes instead of as direct substitutes for labor

E. Some Limitations of the Study

Some of the limitations of this study include:

1. The problem of the direction of causality. For instance, the use of farm machinery does not directly affect the double-cropping system. However, it aids double-cropping by providing timely operations. Therefore, the indirect relationship is reflected. In addition, if the introduction of farm machinery is profitable, then the causality with

respect to average farm income may perform in the opposite direction from what is expected.

2. There are many other variables that should be taken into consideration and yet they have been omitted due to data deficiency. Such variables are, for instance, the availability of farm machine repair services in each zone, area planted to some excluded crops which also require the use of farm machines such as orchards.

3. Since cross-sectional data are used instead of time-series data to study factors which affect farm machinery utilization, conclusions drawn from this analysis may not be comparable to the theory of induced innovation of Hayami and Ruttan, as the author at first hoped.

CHAPTER VI

SUMMARY AND CONCLUSIONS

A. Summary and Conclusions

Within the framework of the theory of induced innovation, technological change in agriculture-both biological and mechanical-is dependent on variations in resource endowments and the growth in demand for products which are reflected in changes in relative factor and product prices. Changes in relative factor prices (land and labor) over time will stimulate the search for new methods of production which will use more of the cheaper and less of the expensive factor. Two main types of technology in agriculture are mechanical and biological innovation. Mechanical innovation is labor saving and its process of diffusion is responsive to changes in the relative prices of labor and capital. Application of mechanical technology to the agricultural sector may induce increases in labor productivity because it leads to a higher proportion of capital to labor.

Between 1951 and 1975, labor productivity (Y/L) in the Thai agricultural sector rose at a substantial rate of growth of 4.5 per cent per year. The land-labor ratio (A/L) and land productivity (Y/A) reveal an equal rate of growth during the same period. However, division of this period of study into two subperiods (from 1951 to the mid 1960s and the mid 1960s to the mid 1970s), reveals a faster rate of growth of the land-labor ratio in the latter period. One of the reasons which could explain this finding is the achievement of a higher level of mechanization in agriculture which may permit the worker to

cultivate a greater amount of land. In addition, with the introduction of tractors for land preparation, expansion in dry-season plowing is achieved and this further enhances the greater amount of cultivated land per year. According to a nation-wide survey of the Division of Agricultural Economics in 1975, it is evident that mechanization has been adopted to a significant level especially in the Central region.

It is unfortunate that statistical analysis of the relationships over time of changes in relative factor prices and their uses cannot be studied because of time-series data deficiency.

It is therefore rather difficult to precisely indicate the reasons for the development of mechanization over time. However, a statistical analysis of some major factors which may influence farm machinery utilization in different regions was tried by using cross-sectional data. Factors influencing the degree of farm machinery utilization differs according to different types of farm machines. The three groups of farm machines studied are four-wheel tractors, two-wheel tractors and water pumps.

The double-cropping area was found to be positively related to all three categories of farm machines. The use of tractors may enhance speedy land preparation and therefore aids double-cropping. A greater demand for water pumps was found in areas with double-cropping since an additional volume of water may be obtained by employing pump irrigation. This implies that the adoption of mechanization is based on such factors as the irrigation system and the use of HYVs which encourage multiple-cropping in Thai agriculture.

The upland crop area was found to be positively related to the number of four-wheel tractors and water pumps whereas negatively related to the number of two-wheel tractors. This is because the early plowing of the sun-baked and heavy texture soils of the upland area before the rainy seasons requires power which cannot be sufficiently provided by draft animals. The power advantage of large four-wheel tractors can solve such a problem and therefore they have been utilized for this purpose in the upland areas. With respect to the scale basis of the machines, two-wheel tractors in general are not suitable for upland cultivation because they possess inadequate power for dry land tillage in the upland areas. On the other hand, they were found to be mostly used for puddling in rice cultivation in the Central region where the submerged land cannot support large tractors. The extensive use of water pumps was found in areas with high upland crop production. This is because water pumps help to provide additional water from nearby sources. Water pumps, as a mean of irrigation, therefore aids upland crop cultivation.

The price of labor was found to be positively related to the number of both two-wheel and four-wheel tractors. Although it was less significant in determining the number of four-wheel tractors in each region, the expectation that regions with higher labor cost tend to mechanize more was partially verified. The variable concerning labor price appeared to be insignificant in explaining the degree of water pumps used. This may be because water pumps were found to be used for functional purpose instead of being a direct substitution for labor. They were found to be utilized earlier than other farm machines and their

use are now widely adopted by both large and small farmers. In addition, its price is relatively lower than tractors. Hence, regional variations in water pump utilization was not so great as compared to tractor uses. With respect to the case of tractor plowing, it is possible that the high income regions were more able to afford tractorization.

B. Tentative Policy Implications

The adoption of farm machinery by farmers will have an effect on other related matters, for instance, income distribution, rural and urban migration of labor, unemployment level, etc. With these considerations in mind, policy implications drawn from the conclusion of the study are;

- Policy makers as well as agricultural researchers should understand that for each type of farm machines, there are different factors affecting adoption and diffusion among regions. For instance, four-wheel tractors were found to be widely used in the upland areas for land tillage. Although labor and draft animals can do the same task as well, they may require a lot of labor time and involve high drudgery in farm task. Farmers may feel that these are quite heavy costs to bear, thus, resulting in the adoption and use of four-wheel tractors. Any policy which promotes upland cultivation may therefore result in a higher demand for four-wheel tractors.

- Since tractor plowing was found to be positively related to the cost of labor, policies which attract labor toward urban areas and raise rural wage rate can encourage the use of tractors by Thai farmers.

- Since one important factor influencing farm machinery adoption is the greater intensification of farming through multiple-cropping which

in turn depends upon the irrigation system, policies toward the improvement of irrigation facilities will further enhance adoption and diffusion of farm machinery.

- The progress of mechanization shows regional differences which may be based on various factors including the level of farm incomes. Given that the adoption of farm machinery is profitable, there will be growing inequalities of income distribution among regions. Policies to promote farm mechanization should therefore take this into consideration. In addition, it is necessary for policy makers to understand the limitations from environmental and socio-economic conditions at the regional level which may obstruct the progress of farm mechanization.

- Labor migration out of the agricultural sector into the urban industrial sector has been recognized in the Thai economy. Since the use of farm machines can reduce drudgery of farm tasks which may encourage the new generation of farmers to maintain farming occupations rather than abandon them for urban industrial jobs. Therefore any policies which enhance farmers to employ farm machinery may indirectly reduce the number farmers migrating out of the agricultural sector.

C. Data Deficiency

Farm mechanization is starting to take root in Thai agriculture. Since it may have important repercussions on employment, income distribution, and the future pattern of agricultural development, research on farm mechanization development is therefore quite important. At present, the major obstacle to any study is the deficiency in time-series data concerning factor prices in the agricultural sector. These data include prices of labor, draft animals, farm machinery and land.

Labor mobility and migration data or studies in Thai agriculture are also still lacking. They would help provide useful insights into the existence of possible labor bottlenecks impinging upon the adoption and diffusion of farm mechanization. Compilation of the mentioned data will be very useful to future studies concerning technological development in Thai agriculture.

APPENDICES

APPENDIX A

Major time-series data of resource endowment in Thai agriculture for 1951-1975 are presented in this appendix.

A-1. Agricultural Labor Force

Census data of the National Statistical Office (NSO) are only available every ten years. After 1970, Labor Force Surveys (LFS) have been conducted by the NSO twice annually. However, data from the LFS are not comparable with the censuses due to different techniques of sampling. Therefore, time-series data on agricultural labor force were obtained from the closest estimation of the Division of Agricultural Economics. The estimation is based on censuses of the NSO in 1960 and 1970. Both male and female workers are taken into account. Man-hour data are not used primarily due to lack of availability.

Source: DAE/MOAC, Selected Economic Indicators Relating to Agriculture, No. 84, 1975, p. 11.

A-2. Land

Two sets of land area are compiled. Arable land consist of paddy land, field crops, and tree crops and are used as available supply of land. Planted area for all crops are presented as the amount of land under utilization.

Source: DAE/MOAC, Selected Economic Indicators Relating to Agriculture, No. 84 (3), 1978, p. 12.

A-3. Animal Power

The number of buffalo and cattle are included as working animals. It is assumed that the proportion of buffalo and cattle available for farm work is constant over time. Working animals of all ages are included mainly due to lack of data on number of animal under working ages.

Source: Data for 1952-1961 from DAE/MOAC, Agricultural Statistics of Thailand, No. 24/1974
Data for 1962-1975 from DAE/MOAC, Agricultural Statistics of Thailand, No. 100/1978 based on annual survey at the 1st of April every years.

A-4. Fertilizer

Data concerning fertilizer consumption in Thai agriculture are obtained as the simple sum of their physical weights including all nutrients available.

Source: Data for 1951-1955 are obtained from DAE/MOAC, Agricultural Statistics of Thailand, 1966 Table 100 Data for 1956-1975 are cited from UN: ESCAP/ARCAP; Marketing and Distribution of Fertilizer in Thailand, 1976 Annex-Table 6.

A-5. Farm Machinery

Two series of import data of tractors and water pumps are compiled because time-series data on number of farm machinery inventory in Thai agriculture are not available.

Source: Customs Department, Ministry of Finance, Annual Statement of Foreign Trade Statistics, Various issues.

Note: From 1970 onward, commodity classification has been changed from SITC to BTN classification. According to the Bank of Thailand, farm tractors under the new classification are commodity number BTN 870122, BTN 870123, and BTN 870124 which are conincided with the item under SITC 713-01, See also: UN. Statistical Office, Standard International Trade Classification Revised, p. 36.

A-6. Agricultural Output

Data for agricultural output are in terms of gross value of output originating from crops net of intermediate products. Gross Domestic Products originating from various crops are compiled for supplementary purposes. Data are presented at 1962 price.

Source: All of these data are obtained from NESDB, National Income of Thailand, 1964, 1965, 1968-1969, 1970-1971, 1972-1973, and 1976 edition.

The real value of Gross Domestic Product originating from agricultural crops for 1952-1956 are not available; therefore, real values of GDP for these years were calculated from current prices by using the implicit deflator for GDP originating from crops cited from Jamlong Artikul, A Planning Model for Thailand, (Ph.D Dissertation Cornell University, Itheca, N.Y., 1976), Appendix A-1. Deflator index for the year 1951 was calculated from data series of 1952-1956 wholesale price index (1962 based year) as the joining calculator.

Wholesale price index with 1962 as based year was calculated from the series of wholesale price index presented in NESDB, National Income of Thailand, 1964 edition p. 140.

Wholesale price index in 1952 = 81.68 whereas the GDP deflator from the study of Jamlong (See the above information) in the corresponding year was = 0.9143. Therefore, if wholesale price index for 1951 was 77.38, GDP deflator for the same year was calculated to be 0.8662. We then deflated the current value of 1951 GDP by the calculated implicit deflator and using the results as its real value.

A-7. Planted Area to Rice

Two series of wet-season and dry-season rice are compiled.

Source: Division of Agricultural Economics, Ministry of Agriculture Agricultural Co-operatives.

TABLE A-1

AGRICULTURAL LABOR FROCE

Year	(Thousand)	Index 1951 = 100
1951	9,066.8	100
1952	9,207.5	102
1953	9,350.2	103
1954	9,495.2	105
1955	9,642.5	106
1956	9,792.0	108
1957	9,943.9	110
1958	10,098.1	112
1959	11,159.2	123
1960	11,332.2	125
1961	11,507.9	127
1962	11,686.4	129
1963	11,867.6	131
1964	12,051.7	133
1965	12,238.6	135
1966	12,428.4	137
1967	12,621.1	139
1968	12,816.8	141
1969	13,015.6	144
1970	13,217.4	146
1971	13,422.4	148
1972	13,630.5	150
1973	13,841.9	153
1974	14,056.6	155
1975	14,274.6	157

Source: DAE/MOAC, Selected Economic Indicators Relating to Agriculture, No. 84, 1975, p. 11

TABLE A-2

ARABLE LAND AREA AND PLANTED AREA

In Thousand

Year	Field Crops Vegetable	Tree Crops	Total	Index 1951=100	Planted Area to all Crops (1,000 rai)	Index 1951=100
1951	4,878.0	5,448.0	47,478.1	100	42,429	100
1952	4,766.6	5,268.7	47,027.5	99	38,870	92
1953	4,710.9	5,188.3	46,788.4	98	44,137	104
1954	4,695.8	5,176.5	46,729.8	98	40,649	96
1955	4,745.2	5,238.2	46,864.9	99	42,177	99
1956	4,856.0	5,261.2	50,083.3	105	44,333	104
1957	5,043.2	5,542.4	47,697.7	101	40,055	94
1958	5,321.6	5,751.8	48,393.7	102	44,673	105
1959	5,709.5	6,081.7	49,583.6	104	47,704	112
1960	6,905.6	6,144.9	50,177.7	106	48,844	151
1961	8,825.6	6,209.3	53,681.3	113	51,543	121
1962	9,596.7	6,720.4	55,319.9	117	53,461	126
1963	10,592.3	7,513.2	57,527.5	121	55,806	131
1964	11,864.2	8,689.1	60,467.4	127	57,207	135
1965	13,495.2	10,432.3	64,420.8	136	58,718	138
1966	13,410.3	10,121.6	66,522.9	140	66,669	157
1967	13,424.3	9,862.7	69,523.9	146	62,903	148
1968	13,507.7	9,663.7	73,141.4	154	67,126	158
1969	13,693.6	9,519.1	77,456.8	163	69,238	163
1970	13,977.6	9,430.3	82,579.1	174	70,512	166
1971	14,368.3	9,351.2	88,595.6	187	72,016	170
1972	16,470.8	9,915.1	93,483.1	197	72,739	171
1973	19,970.8	10,919.5	101,449.2	214	81,469	192
1974	20,538.4	10,974.5	103,253.9	217	80,434	189
1975	20,938.7	11,401.0	105,600.4	222	86,139	203

Source: DAE/MOAC, Selected Economic Indicators Relating to Agriculture, No. 84 (3), 1978, p. 12.

TABLE A-3

ANIMAL POWER

in Thousand

Year	Buffalo	Cattle	Total	Index 1951 = 100
1951	-	-	-	
1952	3,894.7	3,162	7,056.7	100
1953	3,999.8	3,197.1	7,196.9	102
1954	4,108.1	4,244.9	7,342.0	104
1955	4,219.7	3,272.4	7,492.1	106
1956	4,334.6	3,312.6	7,647.2	108
1957	4,453.0	3,354.7	7,807.7	111
1958	4,575.0	3,398.6	7,973.6	113
1959	4,700.7	3,444.5	8,145.2	115
1960	4,830.2	3,492.4	8,322.6	118
1961	4,963.6	3,542.4	8,506.0	121
1962	5,101.1	3,594.6	8,695.6	123
1963	5,147.0	3,624.4	8,771.4	124
1964	5,220.2	3,752.9	8,973.2	127
1965	5,297.0	3,887.5	9,184.6	130
1966	5,377.5	4,028.6	9,406.1	133
1967	5,461.8	4,176.3	9,638.1	136
1968	5,459.9	4,290.3	9,840.2	139
1969	5,642.1	4,451.6	10,093.6	143
1970	5,734.5	4,667.0	10,401.5	147
1971	5,574.2	4,460.2	10,034.4	142
1972	5,361.7	4,485.0	9,846.3	140
1973	5,941.7	4,335.2	10,276.9	146
1974	5,946.7	4,432.4	10,379.1	147
1975	5,441.7	4,310.7	9,752.4	138

Source: DAE/MOAC, Agricultural Statistics of Thailand, Bangkok, Various Issues.

TABLE A-4

FERTILIZER CONSUMPTION IN THAILAND

In Metric Tons

Year	Import (1)	Domestic Production (2)	Non Agricultural Use (3)	Agricultural Use (1)+(2)-(3)
1951	377	-	-	377
1952	2,207	-	-	2,207
1953	3,255	-	-	3,255
1954	4,925	-	-	4,925
1955	20,591	-	-	20,591
1956	23,429	-	-	23,429
1957	40,020	-	-	40,020
1958	29,170	-	-	29,170
1959	47,639	-	-	47,639
1960	51,955	-	251	51,704
1961	54,768	-	465	54,303
1962	66,465	-	181	66,284
1963	97,378	-	400	96,978
1964	108,977	-	2,538	106,439
1965	88,943	-	1,973	86,970
1966	141,428	4,315	1,759	143,984
1967	218,244	34,344	3,221	249,367
1968	265,686	26,881	6,457	286,110
1969	265,830	17,040	5,006	277,864
1970	249,641	39,763	3,608	285,796
1971	226,544	37,975	3,140	261,379
1972	383,303	31,000	8,105	406,198
1973	388,410	22,800	9,051	462,159
1974	335,325	29,000	10,107	354,218
1975	430,970	18,400	11,286	438,084

Source: DAE/MOAC, Agricultural Statistics of Thailand, 1966, Table 100 and UN: ESCAP/ARCAP, Marketing and Distribution of Fertilizer in Thailand, (Bangkok, 1976) Annex-Table 6.

TABLE A-5

IMPORTED NUMBER OF SELECTED FARM MACHINERY

Year	Tractors (Unit)	Water Pumps (Unit)
1951	-	2,598
1952	-	4,466
1953	-	14,319
1954	-	9,464
1955	262	11,294
1956	404	93,485
1957	267	20,811
1958	384	13,482
1959	445	9,409
1960	855	11,166
1961	1,487	12,059
1962	1,353	11,861
1963	1,922	19,741
1964	3,446	26,931
1965	3,047	39,099
1966	3,872	60,923
1967	4,305	82,125
1968	3,610	151,343
1969	2,614	106,666
1970	1,763	136,686
1971	2,414	105,109
1972	1,612	90,092
1973	1,715	150,095
1974	3,318	168,524
1975	6,877	149,021

Source: Customs Department, Ministry of Finance, Annual Statement of Foreign Trade Statistics, Various Issues.

TABLE A-6

GROSS DOMESTIC PRODUCTS ORIGINATING FROM CROPS AT 1962 PRICES

(In Million of Baht)

Year	GDP Originating From Rice	GDP Originating From Maize	GDP Originating From Sugar-Cane	GDP Originating From Cassava	GDP Originating From Kenaf	GDP Originating From Rubber	GDP Originating From Other Crops	Total GDP Originating From Total Crops	Index 1951=100
1951	5,962	41	148	30	40	2,565	3,771	12,557	100
1952	5,565	36	160	28	36	1,483	3,280	10,588	84
1953	6,548	76	213	34	32	1,073	4,370	12,363	98
1954	4,529	69	295	34	35	1,307	4,768	11,037	88
1955	5,657	85	243	27	29	1,943	4,667	12,651	101
1956	6,466	144	267	24	58	1,644	5,133	13,736	109
1957	6,219	116	430	157	72	970	3,655	11,619	93
1958	7,954	158	447	183	103	1,003	3,715	13,563	108
1959	7,559	270	517	406	146	1,241	3,731	13,870	110
1960	8,072	360	558	367	390	1,096	5,030	15,873	126
1961	8,433	396	413	519	498	1,206	4,852	16,317	130
1962	9,586	441	327	624	287	1,268	5,141	17,673	141
1963	10,345	568	490	634	439	1,285	5,541	19,311	154
1964	9,891	632	526	468	608	1,368	5,653	19,146	153
1965	9,508	725	363	443	1,026	1,413	6,103	19,509	155

TABLE A-6 --continued

Year	GDP Originating From Rice	GDP Originating From Maize	GDP Originating From Sugar-Cane	GDP Originating From Cassava	GDP Originating From Kenaf	GDP Originating From Rubber	GDP Originating From Other Crops	Total GDP Oritinating From Total Crops	Index 1951=100
1966	11,578	819	333	568	1,262	1,398	7,098	23,056	100
1967	9,594	887	339	541	974	1,406	6,997	21,033	167
1968	10,659	934	390	551	387	1,652	7,261	22,856	182
1969	11,314	1,167	636	811	848	1,968	7,798	24,542	195
1970	11,575	1,348	691	901	765	2,006	7,928	25,214	200
1971	11,646	1,631	579	1,085	746	2,173	8,431	26,291	209
1972	10,116	922	945	1,306	886	2,316	9,005	25,496	203
1973	11,763	1,640	1,264	1,935	1,082	2,630	9,100	29,414	234
1974	11,355	1,862	1,366	1,832	749	2,606	10,232	30,002	239
1975	12,129	2,108	1,638	1,988	493	2,393	10,435	31,184	248

Source: National Economic & Social Development Broad, National Income of Thailand, Various Issues.

TABLE A-7

PLANTED AREA TO RICE

Unit: 1,000 rai

Year	Planted Area		Total Planted Area	% or Dry-Season Rice to total Planted Area
	Wet-Season	Dry-Season		
1956	37,578	70	37,650	0.2
1957	31,644	73	31,716	0.2
1958	35,921	66	35,986	0.2
1959	37,864	44	37,908	0.1
1960	36,944	64	37,008	0.2
1961	38,479	69	38,549	0.2
1962	41,546	72	41,618	0.2
1963	41,173	83	41,257	0.2
1964	40,751	120	40,871	0.3
1965	40,820	141	40,962	0.3
1966	46,214	219	46,434	0.5
1967	41,288	324	41,612	0.8
1968	44,483	385	44,867	0.9
1969	48,189	543	48,734	1.1
1970	48,763	825	49,453	1.7
1971	50,020	1,341	50,730	2.6
1972	44,621	1,883	45,931	4.1
1973	47,640	1,308	48,948	2.7
1974	45,803	2,047	47,850	4.3
1975	52,582	2,563	55,145	4.6
1976	52,747	2,736	55,483	4.9

Source: Division of Agricultural Economics, Ministry of Agriculture & Agricultural Co-operatives.

APPENDIX B

Lists of all variables used in the regression analysis and their sources are presented in this appendix. All variables are complied in terms of agroeconomic zones. There are 19 zones in Thailand. Division of these zones i based on various factors such as soil type, rainfall, temperature, cropping pattern, and production efficiency. Provinces comprised within each zone are presented as follows;

Zone	Provinces
1	Nong Khai, Udon Thani, Sakon Nakhon, and Nakhon Phanom.
2	Ubon Ratchathani, and Yasothon.
3	Khon Kaen, Kalasin, Maha Sarakham, and Roi Et.
4	Surin, Buri Rum, and Si Sa Ket.
5	Nakhon Ratchasima and Chaiyaphum.
6	Loei, Phetchabun, Nakhon Sawan and Uthai Thani.
7	Lop Buri and Sarabui.
8	Tak, Phisanulok, Khamphaeng Phet, and Phichit.
9	Nan, Lampang, Phrae, Sukhothai, and Uttaradit.
10	Chieng Rai, Chieng Mai, Mae Hong Sorn, and Lamphun.
11	Chainat, Sing Buri, Suphan Buri, Nonthaburi, Ang Thong, Ayuttaya, Nakhon Pathom, Pathum Thani, Thon Buri, Nakhon Nayok, and Bangkok.
12	Kanchanaburi, Ratcha Buri, Phetcha Buri, and Prachuap Khiri Khan.
13	Prachin Buri, and Chachoengsao.
14	Samut Prakan, Samut Sakhon, and Samut Songkhram.
15	Chon Buri, and Rayong.

Zone	Provinces
16	Chanthaburi, and Trat.
17	Chumphon, Surat Thani, Nakhon Si Thammarat, Phattalung and Songkla
18	Ranong, Phuket, Satun, Trang, Phangnga, and Krabi
19	Pattani, Yala, and Narathiwat.

Information on the number of farm machines in each zones is derived from a nation-wide survey of the Division of Agricultural Economics in 1975. Three main catagories of farm machines are taken into consideration. There are four-wheel tractor (FT), two-wheel tractor (PT), and water pump (WP). Number of these farm machines endowed in each zones are presented in Table B-1.

Pertinent data concerning labor wage rate and service cost of draft animal in each zone are not available. Wage rate in this study therefore is derived from cost of planting one rai of rice in 1977 and the number of man-day required to finish this task. Since planting process is absolutely manual, calculated wage rate from a piece work should therefore represent an appropriate proxy for service cost of labor. By the same token, data for the cost of animal were obtained from a piece work rate and its physical units required to complete land preparation of one rai of rice, Table B-2.

Planted area data comprised of area planted to rice and area planted to eigth major cash crops; maize, cassava, sugar-cane, mung-bean, soy-bean, ground-nuts, cotton and kenaf. Area planted to these crops for 1975/1976 crop year were obtained from the DAE/MOAC, Agricultural Statistics of Thailand No. 100, (Bangkok, 1978). Area planted to dry season rice for the corresponding crop year were obtained from the Division of Agricultural Extension. These data are presented in Table B-3.

Average farm incomes in each zone were obtained from the summary report of the Agro-economic Zones for Agricultural Extension & Development prepared by the Division of Agricultural Economics. It is based on the general farmer's economic condition survey data taken in 1970 by the same division.

Average rainfall by zone were obtained from the summary report of the Agro-economic Zones for Agricultural Extension & Development. These data were originally collected by the Rainfall Measurement Station of the Meteorological Department and based on the average of twelve months for each province during 1966 to 1970.

Data concerning average farm income and average rainfall by zones are presented in Table B-5.

TABLE B-1

DISTRIBUTION OF SELECTED FARM MACHINES BY ZONES, IN 1975/1976 CROP YEAR

Zone	Four-Wheel Tractor (<45 H.P.)	Four-Wheel Tractor (>45 H.P.)	Total Four-Wheel Tractor (FT)	Two-Wheel Tractor (PT)	Water Pump (WP)
1	177	291	468	115	11,674
2	181	118	299	113	1,697
3	199	132	331	891	12,575
4	67	1,198	1,265	251	3,590
5	682	1,275	1,957	1,633	15,539
6	1,909	2,464	4,373	2,382	17,094
7	1,970	1,426	3,396	5,544	12,694
8	935	841	1,776	4,195	15,759
9	968	940	1,908	2,868	12,504
10	392	379	771	1,830	14,122
11	6,265	1,912	8,177	38,374	67,867
12	1,040	773	1,813	3,410	16,743
13	750	486	1,236	11,772	10,924
14	208	104	312	5,979	5,802
15	519	256	775	1,882	8,601
16	50	146	196	1,310	14,778
17	356	524	880	6,512	6,487
18	56	31	87	771	1,518
19	68	42	110	169	1,380

Source: DAE/MOAC, Selected Economic Indicators Relating to Agriculture, No. 84 (3) 1978.

TABLE R-2

COST OF LABOR DURING PLANTING AND THRESHING BY ZONES

Zone	Cost of Labor During Planting (Baht/rai)	No. of Man-day Required (Man-day)	Price of Labor (Baht/Man-day)	Cost of Labor During Threshing (Baht/rai)	No. of Man-day Required (Man-day)	Price of Labor (Baht/Man-day)
1	67.50	4.50	15.00	34.35	2.29	15.00
2	65.28	4.08	16.00	33.28	2.08	16.00
3	95.58	5.31	18.00	71.28	3.96	18.00
4	70.42	4.24	16.61	56.10	2.87	19.55
5	73.96	3.70	19.99	51.97	2.60	19.98
6	97.51	4.51	21.62	46.72	2.25	20.76
7	91.85	3.65	25.00	62.50	2.50	25.00
8	84.20	4.21	20.00	57.00	2.85	20.00
9	94.65	4.35	21.76	51.13	2.35	21.76
10	58.13	2.91	19.98	57.70	2.89	19.96
11	55.00	2.20	25.00	28.50	1.14	25.00
12	92.47	3.70	24.99	51.35	2.05	25.05

TABLE B-2 --continued

Zone	Cost of Labor During Planting (Baht/rai)	No. of Man-day Required (Man-day)	Price of Labor (Baht/Man-day)	Cost of Labor During Threshing (Baht/rai)	No. of Man-day Required (Man-day)	Price of Labor (Baht/Man-day)
13	51.25	2.05	25.00	31.50	1.26	25.00
14	54.78	2.19	25.00	65.00	2.60	25.00
15	67.17	2.69	24.97	41.67	1.67	24.95
16	53.70	1.79	30.00	51.30	1.71	30.00
17	75.92	3.04	24.97	50.18	2.01	24.96
18	93.50	3.74	25.00	59.50	2.38	25.00
19	62.00	2.48	25.00	81.25	3.25	25.00

Source: DAE/MOAC, "Cost of Production, 1977/1978 Crop Year," Agricultural Bulletin No. 71, 1978 and the Unpublished Working Sheets of the Corresponding Division.

TABLE B-3

COST OF LABOR DURING HARVESTING AND SERVICE COST OF ANIMAL BY ZONES

Zone	Cost of Labor During Harvesting (Baht/rai)	No. of Man-day Required (Man-day)	Price of Labor (Baht/Man-day)	Cost of Animal During Land Prenaration (Baht/rai)	No. of Hour Required (hour)	Cost of Animal (Baht/hour) (PMAL)
1	63.90	4.26	15.00	18.06	0.42	43.00
2	75.04	4.69	16.00	11.20	0.24	46.67
3	106.38	5.91	18.00	-	-	54.40[e]
4	61.15	3.69	16.57	-	-	46.67[e]
5	96.65	4.83	20.01	186.08	3.08	60.41
6	79.91	3.90	20.49	62.90	0.70	89.86
7	75.00	3.00	25.00	88.00	0.80	110.00
8	99.00	4.95	20.00	155.96	4.61	12.14
9	102.97	4.38	23.51	112.77	1.53	73.70
10	58.65	3.96	14.81	56.95	0.54	105.40
11	89.95	3.57	25.20	78.84	1.87	42.16

TABLE B-3 --continued

Zone	Cost of Labor During Harvesting (Baht/rai)	No. of Man-day Required (Man-day)	Price of Labor (Baht/Man-day)	Cost of Animal During Land Preparation (Baht/rai)	No. of Hour Required (hour)	Cost of Animal (Baht/hour) (PMAL
12	85.38	3.41	25.04	110.04	1.54	71.45
13	89.00	3.56	25.00	95.90	2.86	33.53
14	78.50	3.14	25.00	46.56	0.45	103.47
15	74.16	2.97	24.97	98.32	0.83	11.46
16	77.10	2.57	30.00	69.98	2.91	24.05
17	131.20	5.25	24.99	89.59	2.62	34.19
18	106.50	4.26	25.00	50.00	0.90	55.55
19	105.75	4.23	25.00	42.63	1.31	32.54

Source: DAE/MOAC, "Cost of Rice Production, 1977/1978 Crop Year," Agricultural Bulletin No. 71, 1978 and the Unpublished Working Sheets of the Corresponding Division.

TABLE B-4

TOTAL PLANTED AREA, PLANTED AREA TO RICE AND UPLAND CROPS BY ZONES

Zone	Rice Planted Area (1,000 rai) (RP)	Dry-Season Rice Planted Area (1,000 rai) (DRP)	% of Dry-Season Rice to Total Rice Planted Area (PDRP)	Planted Area to Upland Crop (1,000 rai) (UP)	Total Planted Area P=RP+UP (1,000 rai) (P)	% of Upland Crop to Total Planted Area (PUP)
1	6,139.49	10.76	0.001752	1,398.76	7,538.25	0.185555
2	3,264.35	1.51	0.000462	411.40	3,675.75	0.111923
3	6,705.88	6.64	0.000990	1,036.29	7,742.16	0.133850
4	5,445.44	2.90	0.000532	997.30	6,442.73	0.154794
5	3,435.40	25.22	0.007341	2,402.95	5,838.35	0.411580
6	3,440.58	45.41	0.013198	3,368.97	6,809.55	0.494742
7	1,591.67	24.38	0.015317	1,957.39	3,549.06	0.551524
8	3,984.95	98.06	0.024607	1,094.09	5,079.04	0.215413
9	2,084.49	14.23	0.006826	1,316.15	3,400.64	0.387039
10	2,138.47	215.01	0.100544	450.52	2,588.99	0.174014
11	6,580.77	1,891.61	0.287445	635.78	7,216.54	0.088100

TABLE B-4 --continued

Zone	Rice Planted Area (1,000 rai) (RP)	Dry-Season Rice Planted Area (1,000 rai) (DRP)	% of Dry-Season Rice to Total Rice Planted Area (PDRP)	Planted Area to Upland Crop (1,000 rai) (UP)	Total Planted Area P=RP+UP (1,000 rai) (P)	% of Upland Crop to Total Planted Area (PUP)
12	1,423.98	50.95	0.035780	1,370.66	2,794.64	0.490460
13	2,496.32	247.65	0.099206	573.00	3,069.32	0.186686
14	317.80	106.36	0.334676	2.30	320.10	0.007185
15	512.23	12.96	0.025296	1,701.94	2,214.27	0.768624
16	232.93	0.05	0.000214	143.91	376.84	0.381886
17	2,429.46	90.25	0.037148	116.65	2,546.11	0.045815
18	543.60	1.26	0.002318	48.00	591.60	0.081135
19	476.05	21.82	0.045835	60.40	536.45	0.112592

Source: DAE/MOAC, Agricultural Statistics of Thailand 100 (Bangkok, 1978).

TABLE B-5

AVERAGE RAINFALL AND AVERAGE FARM INCOME BY ZONES

Zone	(RAIN) Average Rainfall (m.m./year)	(AVGI) Average Farm Income (baht/family)
1	1,656.00	1,705.08
2	1,560.60	2,678.19
3	1,341.30	2,354.53
4	1,388.50	1,665.75
5	1,111.90	2,046.03
6	1,171.60	5,611.34
7	1,368.00	9,040.48
8	1,326.80	5,681.18
9	1,172.60	3,008.09
10	1,288.00	2,205.22
11	1,348.90	8,599.50
12	1,195.30	6,022.50
13	1,541.20	4,980.94
14	1,235.20	15,271.70
15	1,465.30	7,234.66
16	3,669.50	5,966.84
17	2,119.40	3,231.74
18	2,675.30	4,074.61
19	2,203.40	3,503.04

Source: DAE/MOAC, Agro-Economic Zones for Agricultural Extension Development, (Bangkok, 1972).

TABLE B-6

SELECTED FARM MACHINES PER UNIT OF AREA BY ZONES

Zone	Four-Wheel Tractor Per Rai	Two-Wheel Tractor Per Rai	Water Pump Per Rai
1	0.062083	0.01525	1.54068
2	0.081344	0.03074	0.46167
3	0.042753	0.11508	1.62422
4	0.196345	0.03895	0.55721
5	0.335198	0.27970	2.66154
6	0.642189	0.34980	2.51030
7	0.956873	1.56210	3.57672
8	0.349672	0.82594	22.79150
9	0.561071	0.84337	3.67696
10	0.297800	0.70684	5.45464
11	1.133090	5.31750	9.40436
12	0.648742	1.22019	5.99111
13	0.402695	3.83538	3.55909
14	0.974697	18.67860	18.12560
15	0.350003	0.84994	3.88435
16	0.520115	3.47628	39.21560
17	0.345625	2.55763	2.54781
18	0.147059	1.30325	2.56592
19	0.205052	0.31503	2.57247

BIBLIOGRAPHY

Ames, Edward, and Nathan Rosenberg. "Enfield Arsenal in Theory and History." Economic Journal. Vol. VII, No. 312 (December 1968), pp. 413-439.

Andrews, James M. Siam: 2nd. Rural Economic Survey 1934-1935. Hong Kong: Bangkok Time Press, 1935.

Arsawai, Sunthari. The Role of Government and Private Individual in Developing: A Study in the History of Rangsit Project (1988-1904) Bangkok: Thai Khadi Suksa, Thammasat University, 1978. (in Thai)

Artikul, Jamlong. "A Planning Model for Thailand." Unpublished Ph.D. Dissertation, Cornell University, N.Y., 1976.

Bank of Thailand. "Report on Power Tiller and Tractor for Rice Farming." Unpublished Preliminary Report, 1978. (in Thai)

Barnett, J.C. Report of the First Annual Exhibition of Agricultural and Commerce Held in Bangkok. Bangkok: Ministry of Agriculture, 1910.

Bartsh, William H. "Employment Effects of Alternative Technologies and Techniques in Asian Crop Production: A Survey Evidence." Provisional draft. Geneva: International Labor Office, 1973.

Behrman, J.R. Supply Response in Underdeveloped Agriculture, A Case Study of Four Major Annual Crops in Thailand, 1937-1963. Amsterdam: North-Holland Publishing Co., 1974.

Binswanger, H.P. The Economics of Tractors in South Asia New York: ADC Inc., 1978.

Binswanger, H.P., and Vernon W. Ruttan and others. Induced Innovation. Baltimore: The Johns Hopkins University Press, 1978.

Chakkaphak, Chak and Ben R. Jackson. "Farm Mechanization in Thailand." Report to the International Symposium on Farm Mechanization in Asia. Tokyo, July 1978.

Chancellor, W.J. "Survey of Indigeneous Farm Implement." Report of Initial Phrase of Program for Evaluation and Improvement of Small Tools in Thai Agriculture. Submitted to Asia Foundation: San Francisco, July 1961.

_____. Survey of Tractor, Contractor Operations in Thailand and Malaysia. David, California: Agricultural Engineering Department University of California, 1970.

Day, Richard H. and Inderjit Singh. Economic Development as an Adaptive Process: The Green Revolutions in the Indian Punjab. London: cambridge University Press, 1977.

Department of Cultivation, Thailand. "Farm Machinery Experiment in Rangsit." Kasikorn Journal Vol. 19, No. 3, 1947, pp. 291-303. (in Thai)

Feeny, David. "Technical and Institutional Change in Thai Agriculture 1880-1940." Unpublished Ph.D. Dissertation, University of Wisconsin, Madison, 1976.

Ferguson, C.E. and J.P. Gould. Microeconomic Theory Homewood, Ill.: Richard D. Irwin Inc., 1975.

Greene, Brook A. "Rate of Adoption of New Farm Practices in the Central Plains, Thailand." Occasional Paper, No. 41. Itheca, New York: Department of Agricultural Economics, Cornell University, 1970.

Hagen, Everett E. The Economic of Development. Illinois: Richard D. Irwin Inc., 1975.

Hayami Y. and V. Ruttan. Agricultural Development: An International Perspective. Baltimore: Johns Hopkins Press, 1971.

Hepfen, H.J. and E. Bicsalski. Small Farm Implements. Rome: FAO 1953

Hicks, J.R. The Theory of Wages. New York: St. Martin Press, 1963.

Increny, John P. and Graham F. Donaldson. "The Consequences of Farm Tractor in Pakistan." Staff working paper No. 210. Washington: International Bank for Reconstruction and Development, Feb. 1975.

Ingram, James C. Economic Change in Thailand 1850-1970. Stanford: California, Stanford University Press, 1971.

Ishii, Yaneo. ed. Thailand: A Rice-Growing Society. Translated by Peter and Stephanie Hawks. (Mimeographs of the Center for Southeast Asia Studies, Kyoto University), Honolulu: University Press of Hawaii, 1978.

Johnston, David B. "Rural Society and the Rice Economy in Thailand 1880-1930." Unpublished Ph.D. Dissertation Yale University, 1975.

Komate, Somchart. "Labor Problems of Double-Cropping in Channasutr Land Consolidation Project." Unpublished M.A. Thesis: Faculty of Economics, Thammasat University, 1976.

Krachangyao, Sukti. "Irrigation in Thailand." Bangkok Bank pamphlet Jan.-June, 1978. (in Thai)

Moreman, Michael. Agricultural Change and Peasant Choice in Thai Village. Berkeley and Los Angeles: University of California Press, 1968.

Ng, Ronald C.Y. "Supplementary Report on the Development Attitude Survey: Chao Phya Irrigation Improvement Project Stage II." Report to the International Bank for Reconstruction and Development, Jan., 1977.

Rajadhon, Anumarn. Life and Ritual in Old Siam: Three Studies of Thai Life and Customs. Translated and edited by W.J. Gedney. New Haven: HRAF Press, 1961.

Rasanood, Sriaroon and others. "A Survey of the IRRI Axial Flow Threshing Efficiency Compared with the Traditional Methods of Threshing." Bangkok: Faculty of Economics and Business Administration, Kasetsart University, 1977.

Rosenberg, Nathan, ed. The Economics of Technical Change. Baltimore: Penguin Books, Inc., 1971.

Schultz, T.W. Transformation of Traditional Agriculture. New Haven: Yale University Press, 1968.

Singh, Gajendra., and J.H. De Golde ed. Rural Development Technology on Integrated Approach. Bangkok: Asian Institute of Technology, 1977.

Subwattana, Thaveesilp. "Rice Production and Trade in Central Thailand from the Reign of King Rama V to King Rama VII (1868-1932)." Unpublished M.A. Thesis, Department of History Chulalongkorn University, 1976. (in Thai)

Songsak, Sriboonchittra. "The Private Cost of Using Tractors Versus Buffaloes: A Case Study of Farmers in Chachoeng Sao Province." Unpublished M.A. Thesis, Faculty of Economics, Thammasat University, 1975.

Southworth, Herman. Farm Mechanization in East Asia. Singapore: Agricultural Development Council, 1972.

Tin, U. Hla. "Status of Agricultural Mechanization in Burma." in International Agricultural Machinery Workshop, proceeding the International Rice Research Institute, Sept., 1978.

Thailand, Ministry of Agriculture and Cooperatives, Department of Agricultural Economics. Agricultural Statistics Yearbook, Bangkok (Various Issues).

_____. Selected Economic Indicators Relating to Agriculture No. 84, Bangkok, 1978.

_____. Selected Economic Indicators Relating to Agriculture No. 84 (3), Bangkok, 1978.

_____. Areas of Thailand by Provinces & Regions., Bangkok, May 1954.

_____. Agro-Economic Zones for Agricultural Extension & Development. Bangkok, 1972.

Thailand, Ministry of Agriculture and Cooperatives, Department of Agricultural Economics. "Land Utilization of Thailand, 1975." Agricultural Bulletin No. 57, 1975.

_____. "Cost of Rice Production 1977/1978 Crop Year." Agricultural Bulletin No. 71, 1978.

Thailand, National Archives. R.5 Ks 13/319. File #17 (Memorandum on "How to Improve Farming").

_____. R.5 Ks 1/10, Letter from Chao Phya Pravet to King Rama V.

_____. R.5 Ks 3.1/2, Letter from Chao Phya Wongsanuprapat to King Rama V.

Thailand, National Economic and Social Development Broad, National Income, Bangkok. (Various Issues).

Thevakul, M.R. Debaridhi. "Agriculture with the Nation's Economic Securities." Unpublished Personal Research Paper, Division of Agricultural Engineering, Ministry of Agriculture and Agricultural Cooperation, Dec., 1966.

Thummong, Singkamwanich. "Farming by Machine." Kasikorn Journal Vol. 21, No. 2 (March, 1948), pp. 109-114. (in Thai).

World Bank: East Asia and Pacific Office. "Thailand: Toward a Development Strategy of Full Participation." Unpublished Report, May 1978.

Zimmerman, Carle C. Siam: Rural Economic Survey 1930-31. Bangkok: Bangkok Time Press, 1931.