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THE CONSEQUENCES OF SMALL RICE FARM MECHANIZATION PROJECT

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AN EX ANTE EVALUATION OF SMALL FARM MECHANIZATION POLICIES IN THAILAND

by

T. Pongsrikul
The International Rice Research Institute

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Introduction

Rice is the most important subsector in Thai agriculture as a major source of staple food, income, employment, and foreign exchange earnings. Rice generates more foreign exchange than any other crop. Even though Thailand has been one of the major rice exporters of the world for several decades (Pongsrikul, 1983), rice yields have been lower than yields in many countries of Asia. Table 1 shows that Thailand's yield in 1981 was only 312 kg/rai, lower than yields of all selected countries except Cambodia, Laos, and Sri Lanka. The low yield implies low farm incomes to Thai farmers. Efforts to increase total rice output has been primarily a result of expansion in cultivated land through deforestation. The forest area declined from 25,572 thousand hectares in 1967 to 16,093 thousand hectares in 1981, or from 49.8 percent of the total land in 1967 to 31.3 percent in 1981 (Table 2). That is, 9506 thousand hectares of forest land (representing 37 percent of the 1967 forest area) has been cleared in just 14 years. This deforestation resulted from both illegal logging and landless farmers who cut down trees. The former destroyed more forest area than the

latter, since farm land increased only 4,700 thousand hectares in the period from 1967-1981. The government realizes that the potential for further expansion in cultivated land has reached its frontier and existing paddy land is not fully utilized, e.g., only 78.6 percent of the paddy land in 1981 was actively used for rice. As a result, high priority has been given to agricultural development since the Second Social and Economic Development Plan. Many agricultural policies, particularly intensification programs, were adopted to assist rice farmers in improving yields, cropping intensity and incomes. The introduction of new HYVs and double cropping increased use of farm machines because the HYVs require precise timing in transplantation and the times for land preparation between crops is very short. Without farm mechanization, these activities become impossible to complete in a timely fashion. Use of large tractors increased from 13,338 units in 1975 to 50,044 units in 1981 or 275.2 percent. The high growth rate of tractorization was partially due to a boom in the domestic tractor industry during the 1970s which substantially lowered the tractor prices.

Despite adoption of intensification programs, rice yields still fluctuated over the 1975-1981 period. These fluctuations may be due to the fact that Thai agriculture primarily depends on rainfall. For instance, only 22.3 percent of the paddy land in 1981/82 was irrigated. Furthermore, most irrigation in Thailand is multi-purpose being used

for hydroelectric power generation and flood protection. Only 68.4 percent of the total irrigated land in 1981 was directly devoted to improvements in agricultural productions and only 18.1 percent of the paddy area was directly assisted by irrigation projects. The low yields may also result from low fertilizer application rates and lack of pesticide use. Fertilizer use in Thailand is relatively low comparable to other Asian countries. For example, the fertilizer use in Thailand in 1980 was 16.2 kg. NPK/ha while use in Indonesia and Japan during the same year were 63.0 and 372.1 kg. NPK/ha, respectively (Table 4). Furthermore, the growth of fertilizer use in Thailand over the either 1970-19809 period was only 10.6 percent.

The purpose of this paper is to elaborate the present status and problems of farm mechanization in Thai agriculture and also to examine the effects of alternative combinations of agricultural policies on Thai agricultural performances. Target policy variables of interest are use of fertilizer, irrigation, and farm mechanization. Different combinations of farm mechanization and other agricultural inputs, under a given target rate of population increase, will be used to evaluate policy impacts on yield and total output, foreign trade, income and income distribution, employment, and government expenditures. A theoretical analysis will be presented as a guide to analyze the simulated results. Policy recommendations are given at the end of the study.

Background of Thai Economy

This section describes the structure of the Thai economy to serve as an initial benchmark for the simulation analyses.

(1) Population

Total population in Thailand has consistently increased from 37 million in 1971 to 48 million in 1981, or averaging 2.5 percent a year during the 1971-1981 period. Table 4 indicates that population growth rates prior to 1977 were relatively high, but fell subsequently. The lower population growth after 1977 was due to successful birth control programs, especially in the northern region of Thailand. Various economic factors also played a vital role, including the high cost of raising children which forces married couples to have smaller families, and the high cost of living which puts more house-wives on the labor market. In this study, a two percent growth rate is use.

Population is classified as following categories; urban, rural non-farm, small farmer, large farm, and landless farmers. Table 4 reveals that the agricultural sector has the highest share in total population. Approximately 61.4 percent of the total population in 1981 were envolved in agricultural population. The non-agricultural population, which consists of urban and rural non-farm groups, has 38.6 percent of the total population. Approximately 60 percent of non-agricultural population lives in urban area. The population of

urban and rural non-farm groups increased faster than other groups because the economy expanded in the 1970's, creating more job opportunities in the non-agricultural sector for both male and female workers. The landless farmers account for 23 percent of the agricultural population. Farmers whose farm area is larger than 4.8 hectares (the average farm size of Thailand in the period 1971-1981 (see Table 5)) are classified as large farmers; otherwise they fall into the small farmer category. Given this criteria, the 1978 Agricultural Census Report showed that approximately 72 percent of total farms were small, while large farms accounted for 28 percent.

(2) Land

Total land area in Thailand is 51.4 million hectares of which approximately 38 percent are used for agricultural production (1981/82 crop year). Approximately 63 percent of total agricultural land is devoted to rice production and 77.7 percent of total paddy land is rainfed. Only 22.3 percent of rice land is irrigated.

Theoretically, irrigation systems may consist of one or all of the following components.

(a) Sources of water such as dams and reservoir

(b) Main distribution systems such as canals and drainage channels

(c) Farm distribution systems such as ditch

Many irrigation works have been constructed by the department of Royal Irrigation for several decades. In the earlier period, the government advocated large, highly technical irrigation projects. Now the emphasis is shifting towards small irrigation systems. Irrigation systems in this study are divided into the following categories:

(a) The complete irrigation system consists of water sources, main distribution systems, and on farm distribution systems with measurement and control in farm ditches. Rice land under this type of irrigation is the best quality and has the highest yield.

(b) Partial irrigation system consist of a water source, the main distribution system, and an on farm distribution system with a farm ditch system (low farm ditch intensity) but has no provisions for measurement. Rice land under this type of irrigation system is the second best quality.

(c) Basic provisions for water supply, flood protection, etc. This type of irrigation system provides only a source of water and no distribution systems. Land under this system is the third-best quality.

The quality of land therefore depends on the degree of water sufficiency. A high degree of water sufficiency is associated with high yields. Rainfed paddy area is classified as fourth quality land in this study. Using these criteria, the amount of each land quality

is shown in Table 6. The coefficients of fertilizer yield response functions for fertilizer by land quality and season are also shown in Table 4.

(3) Labor requirements

A national-wide survey of the Office of Agricultural Economics indicated that labor requirements in rice production during the wet season (1980/81) averaged 75 man-days per hectare. A study by S. Sukharomana showed that labor requirements per hectare in the dry season were about 45 percent higher than for the wet season. The labor requirements by group, land quality, and season are shown in Table 8.

In agricultural sectorlabor comes from family and hired sources. Hired labor may be obtained from either the landless or the small farmer groups. The family labor may come from small or larger farmer group. Rice production employs more family more than hired labor because the majority of Thai farms are family units rather than commercial farms. Approximately 86 percent of total labor requirements in the wet season (1980/81),or 58.53 man-days per hectare, were from family units. Hired labor accounted for only 22.1 percent, or 16.6 man-days per hectare. Normally, the percentage of hired compared to total labor on large farms is 10 percent higher than the average figure. That is, if the percentage of hired to total labor use of

small farms is 22.1, the percentage of large farms will be 32.1 percent.

(4) Costs of Thai Rice Production

A report by the Office of Agricultural Economics indicates that variable costs consistently increased in the period of 1977/78 - 1980/81. In 1980/81, variable costs accounted for 80.8 percent of the total cost of rice production. Among inputs, human labor constituted about 41 percent of total cost, which was the largest single share. From table 10, labor cost per rai in the wet season increased from 235 baht in 1977/78 to 345 baht in 1980/81, while land cost per rai increased from 120.23 baht in in the wet season in 1977/78 to 150 baht in 1980/81. Other costs of rice production per rai are relatively low but increased rapidly in recent years, e.g., from 20.23 baht per rai in 1977/78 to 44.46 baht per rai in 1980/81.

The costs of kind payments can be obtained by dividing the costs in Table 10 by the farmgate paddy prices. For instance, if human labor cost are divided by the farmgate price of paddy in the same year, the wage expressed in paddy will be 6.64 kg/rai a day or equivalent to 42 kg palay per day in the wet season. Normally, wages paid by large farms are higher than those paid by small farms. If large farms paid 43 kg palay a day, small farms would pay 41 kg/day.

Theoretically, land rent will be paid in accordance with marginal productivity of land. Higher rents will be paid to better land quality. Large farms have a tendency to pay higher rents than small farms. The average rent in the 1981/82 wet season was about 610 kg/hectare, while in the dry season it was about 958 kg/hectare. Rents payable by group, land quality, and season are shown in Table 11.

Farm Mechanization in Thailand

(1) Historical background

The first tractor in Thai agriculture was imported from Australia for governmental experiments in Rangsit area in 1907. However, tractors were introduced to farmers for the first time in 1910, but did not gain popularity because the machines were too heavy and large for Thai conditions. At the same time, a lot of attention was called to improve rice production technology. To accommodate this goal, the government established an Agricultural Experimental Station under the Department of Agriculture, Ministry of Agriculture and Cooperatives in 1919 to improve rice varieties, fertilizer, soil testing, and farm machinery. The station experimented with both individual machines and different combinations of machines. The results recommended use of tractor plowing along with water pumps, since the latter had control over water levels on rice fields. Early 1950s, the experimental station also rented out imported tractors to nearby farmers at a service charge of 15-18

baht/rai. The service was stopped, however, shortly after initiation due to budgetary difficulties.

In 1953, the Rice Department was established to stimulate rice production. Research and testing farm machinery were done by a Research and Testing Section of the Engineering Division. Primary responsibilities of this division were to modify imported machines and to invent farm machines to suit Thai cultivation systems. The Division, under the leadership of M. R. Debaridhi Thevakul, successfully developed the "Debaridhi Pump" in 1955 and the well-known "Iron Buffalo" in 1958 (Wattanutchariya, 1981). The former, a modification of the traditional wooden water wheel, used a 4-5 horsepower engine. This machine was first adopted in 1957 and is very widely used today (Jongsuwat, 1980). The Iron Buffalo was modified from the design of a small walking tractor, developed by M.R. Debaridhi in 1953. Several models of the Iron Buffalo were developed during the early 1960s. The early model used a 12.75 horsepower diesel engine, while the later models used larger 25 horsepower water cooled 25 horsepower engines. The design of the Iron Buffalo was later released to private producers. Unfortunately, production of this design ceased in 1967 due to inefficient production and keen competition from other machines. In addition to the Engineering Division, the Department of Agricultural Extension also carries out research, testing and evaluation of harvesting machines, threshers and storage methods. This Department recently reorganized and adopted new

systems and procedures for extension. As a result, a Farm Mechanization Section has been established in the Crop Promotion Division of the Department of Agricultural Extension. Responsibilities of the new section are to carry out farm mechanization surveys, establish pilot projects, improve machinery, promote farmer's ownership of farm machinery, and develop both mobile and regional Farm Mechanization Training Centres to train extension agents and farmers.

In 1979, the National Committee on Agricultural Machinery was established to advise the government on policy matters such as promotion of appropriate farm mechanization, development and maintenance of agricultural machines, credit and training. The committee also established a sub-committee, consisting of persons from the National Social and Economic Development Board, economist and representatives from manufacturers, to carry out actual day to day work.

Furthermore, international organizations such as UNDP/FAO and IRRI also provide technical assistance to governmental agencies. For instance, the Engineering Division has collaborated, with IRRI since 1971, on research on small-scale farm machinery. This effort makes available additional designs to manufacturers in Thailand. The most successful machine is the axial flow thresher, first introduced in Thailand in 1975.

In addition to the government, a number of private firms have designed and produced both two- and four wheel tractors. The two-wheel tractor or power tiller was first produced by Kamnan Prung Takkeaw in 1963 and his two-wheel tractors were marketed in 1965. At the same time, a group of firms in Ayuttaya designed a simple four-wheel tractor and modified it to include a hydraulic system. However, power tillers were the most popular among Thai farmers, especially in the Central Plains, because they are cheaper and perform better than four-wheel tractors. Furthermore, introduction to this area of high yield varieties in 1969 has stimulated demand for small four- and two-wheel tractors.

(2) Farm machines in use

The utilization of farm machines in Thailand has expanded rapidly over the past 15 years. Domestic supply consists of locally manufactured and imported macnines. The production scale of domestic firms ranges from less than 100 to more than 1,000 tractors per year. Most large and medium-scale firms are situated in the central region, particularly near Bangkok. Small-scale firms are scattered in outer provinces and adjust their production in accordance with the seasonal orders of local customers. In addition to tractors, these firms produce other types of farm machinery, e.g., irrigation pumps and threshers.

Domestic manufacturers do not produce every part of these farm machines. Most engines of domestically manufactured tractors are

imported. Presently, only two out of more than 400 domestic manufacturers of farm machines produce diesel engines in Thailand (Wattanutchariya, 1981). The annual production of all domestic firms is approximately 40,000-45,000 units and the average power of domestic-manufactured engines is around 6-9 horsepower.

Table 13 shows the commonly used farm machines in Thailand. Tractors are the most important machine in modern Thai agriculture. Among tractors, two-wheel walking tractors or power tillers are most popular because they are cheap and compatible with Thai conditions and farm size, which is relatively small. Use of power tillers increased from 90,000 units in 1975 to 284,351 units in 1981, or 277.9 percent in the period of 1975-1981. The machine density of two-wheel tractors in 1981 was 29.6 per thousand hectares. Imported power tillers have the highest share in the total, for example, only 49,500 units out of 284,351 units of power tiller in 1981 were domestically manufactured. Both small and large 4-wheel tractors are widely used, but the latter are more popular than the former. The popularity of large tractors in the last ten years was due to the expansion of cultivated areas, e.g., the utilization increased from 13,338 units in 1975 to 50,044 units in 1981, or an increase of 275.2 percent in the period. All large tractors are imported. In contrast, approximately 12 percent small tractors in uses of 1981 was domestically produced.

Two other important widely adopted farm machines are hand sprayers and irrigation pump units. The former are totally produced domestically. Hand sprayers numbered 1,310,500 units in 1975 and the numbers became 1,138,504 units in 1981, or decreased by 86.8 percent. On the other hand, there were 251,288 irrigation pumps in 1975 which increased to 603,548 units in 1981. The number of r remained more or less unchanged during 1975-1981.

(3) Marketing and The Price of Farm Machinery

Farm machinery in Thailand is distributed through one or a combination of the following channels: wholesalers, retailers, farmer groups and agricultural cooperatives. According to the 1983 study of Intachaisri, farm machinery suppliers, which consist of domestic manufacturers and importers, sold 3 percent and 7 percent of their products directly to individual farmer and agricultural cooperatives (including farmer groups), respectively. In contrast, they sold 70 percent of their products to 388 wholesalers, and the remaining 20 percent were sold to 800 retailers. The wholesalers, in turn, sold 50 percent of total supply to retailers and the remaining 20 percent directly to individual farmers. Therefore, retailers took care of 70 percent of the total supply. In 1979, retailers sold farm machines worth 3,765.8 million baht, while the wholesalers' sale was 3,012.7 million baht. In general, the former will deal with small farmers and the latter will do business with large farmers.

In fact, the distribution patterns depend on the size of manufacturers and type of machine. Consider the marketing channels for tractors. Competition among power-tiller suppliers is very keen because of a low degree of product differentiation. Large manufacturers generally sell their products through wholesalers, and the wholesalers sell these machines to retailers or individual farmers for either cash or on a credit basis. In addition to being sales agencies, the wholesaler also provides repair services to customers and gathers information on customers' needs at different location. In contrast, small manufacturers sell their products directly to customers and provide repair services directly. Unlike large firms, their customers are generally small farmers. Small firms maintain market shares by focusing their products on local demand and having close contact with customers. Regular customers usually obtain privileges from manufacturers such as long-term and flexible credits terms.

Competition among suppliers of small four-wheel tractors is not as keen as two-wheel tractors because of excess demand and moderate product differentiation. Most four-wheel tractors are sold directly to rice farmers for credit, and the manufacturer alsoacts as the financiers. Small four-wheel tractors are most popular among farmers who employ broadcast seeding techniques in rice production because they do not perform well in wet rice fields. Large four-wheel tractors are all imported and used primarily for custom work in upland conditions.

The marketing channels of locally manufactured and imported tractors are shown in Figure 1.

From Figure 1, tractor suppliers sell 35 percent of their total product directly to farmers and 5 percent are sold to agricultural cooperatives and farmer groups. They also sell 20 percent and 40 percent of their products to the respective wholesalers and retailers. The wholesaler sells only 2 percent directly to farmers and the remaining 18 percent to retailers. Retailers handled 58 percent of the tractors at the final stage.

In general, tractors are purchased through credit arrangements available from sales agencies. Down payments average about one third of the purchase price, and payment periods for the balance average 18 months with an annual interest rate of 15 percent. Financial sources usually come from savings, relatives, or private money lenders. Financial institutions play a very limited role.

Table 15 shows the retail prices of selected farm machinery and implements, fuel and power, and draft animals for the period 1965-1979. According to this data, the prices of locally manufactured machinery are generally lower than imported equipment, but the former changes faster than the latter. For instance, the retail price of a locally produced 8 hp power tiller in 1979 averaged about 21,151 baht while an imported power tillers was 23,920 baht. The percentage change in price of the former over the period was 66.7 percent while that of the latter

was only 20.8 percent. The same patterns are true for small four-wheel tractors and other farm machines (see Table 15).

(4) Utilization Patterns and Ownership

Farm machines can perform different functions in rice farming. This study will focus only on the utilization of tractors and rice threshers. In Thai agriculture, tractors are often used 18 hours a day for about 5 months a year except in the multiple cropping areas (Chakkaphak, 1978). Presently, the main tasks of tractors are land preparation and cultivation. About 86 percent of the tractor's working time is engaged in tilling. The main implements used are disc plows, disc harrows, rotary tillers and trailers.

Large tractors are primarily used for land preparation on large farms growing upland crops and in preparing fields for broadcast rice. Small tractors, in contrast, are suitable for paddy cultivation and land preparation on small wetland rice farms. In general, two-wheel tractors can perform in the wetland better than small four-wheel tractors. Small four-wheel tractors, however, are suitable for small upland farms where broadcast rice is grown. Sometimes a combination of different tractor sizes is necessary. A study in 1973 by the Agricultural Engineering Division concluded that the optimum tractor size for a transplanted rice fields of 12.5 hectares was 10 hp. However, the ideal of tractor system for farm sizes of 20 to 40 hectares is hiring large tractors for plowing dryland to be broadcast

seeded followed by either two- or small four-wheel tractors. After seeding, small tractors are used to cover the seeds. In addition to land preparation and cultivation, tractors are also used for water pumping, threshing and transportation. The rice thresher was first introduced to Thai agriculture in 1975. The most popular version is the IRRI-type "Axial Flow" machine. The major benefits of mechanical threshing are the net cost and time savings. The rice thresher also does not require preparation of a threshing floor and winnowing, releases the time pressure in double cropping systems.

There are two major types of ownership patterns: individual and joint. Nearly all farm machines are owned by individual farmers and only 0.5 percent are owned by farmer groups on a joint ownership basis (Intachaisri, 1983). Patterns of ownerships of different farm machinery by farm size are shown in Table 16. Ownership depends upon farm income and the prices of machine. Large farmers have larger machine complements because they have higher incomes than small farmers. For the low-price machine the difference is less evident. For instance, all large four-wheel tractors are owned by large farmers. The proportion of two-wheel tractor owned by large and small farmers are .55 and .45, respectively. For rice threshers, 50 % are owned by large farmers and 50% by small farmers.

Farmers buy tractors for their own operations, but approximately 95 percent of the large tractors are also employed for custom services.

To achieve full utilization, owners hire out their tractors after finishing their own work. Most tractors in Thai agriculture are busy only 5 months a year except in multiple cropping areas. Tractor contractor services are used mainly for cultivation of upland crops and is broadcast rice areas where land is cultivated dry and the full-size tractor becomes a necessity. The custom rate is determined by soil conditions and the crops. For example, the rate for plowing upland in 1980 was about 500-550 baht per hectare compared to 240-272 baht per hectare for paddy land. The tractor contractor system, established 15 years ago, plays a significant role in the tractorization of Thai agriculture because it provides small farmers, who wish to use tractors but cannot afford to buy them, access to tractors. In the past tractor contractors serviced only nearby neighbours and the contract was a direct agreement between farmers. Competition is now very keen because of more tractor owners. The contract agreement is sometimes made through agents, who contact customers and get a commission for the effort. Some contractors travel more than 100 km to arrange custom services.

(5) Appraisal of Farm Mechanization

There are pros and cons in the introduction of farm mechanization. Farm mechanization stimulates the of Thai agriculture from subsistence to commercialized farming. Farm machines save time

and labor which solves the problem of labor shortage for harvesting the first crop and land preparation for the second and also releases labor in threshing the first crop. For example, the plowing rate for buffalo is 0.08 - 0.16 hectare/day, while the two-wheel and four-wheel tractors are 0.48 - 0.8 and 1.25 - 1.6 hectare/day, respectively. Land preparation by tractors is much faster than by animal power. The development of the local farm machinery industry has enhanced the use of tractors and power threshers. There are however, several other reasons for adopting machines (Table 18).

The effect of tractors and threshers on yield, employment, and income are important issues. Most studies have concluded that tractors do not affect yields. An exception is the power thresher which increased yields by reducing losses (Table 19). It is widely accepted that tractors and power thresher decrease total employment (Table 19). However, they displace family more than hired labor. More than 70 percent of the labor used in rice production in Thailand comes from family sources. In most instances, the evidence shows that mechanization increase farmers' income.

(6) The Role of Thai Government in Farm Mechanization

While a National Committee on Agricultural Machinery was established as a policy making body in 1979, there is not yet a specific policy to directly assist farmers in purchasing farm machines

in Thailand. There are however, several international trade and agricultural development policies that indirectly stimulate use of farm mechanization. For example, imports of tractors with implements and accessories for tractors are exempted from import tariffs. Two implications drawn from this policy are that the domestic market for tractors is highly competitive and the domestic manufacture of tractors is indirectly promoted. Policies promoting small-scale industry also encourage farmers to adopt farm mechanization because it results in reduces domestic machinery prices. Since the Fourth Social and Economic Development Plan in 1976, the Thai government has given high priority to low-cost loans available for farmers. To accommodate this objective, the Bank of Thailand has adopted a policy requiring all commercial banks and the Bank of Agriculture and Agricultural Cooperatives to give agricultural loans amounting to not less than 20 percent of total outstanding deposits. This has resulted in approximately 300 to 400 million baht being made available available as low-cost loans to farmers in 1978 alone.

Another Thai government assist to farm mechanization is establishment of institutions and agencies to carry out research, and to test and to develop quality controls and standards for machines. The most outstanding research efforts have come from the Agricultural Engineering Division that developed the famous Iron Buffalo, Debaridhi irrigation pump, and axial flow threshers. In 1974 the government

established the Industrial Services Institute with UNDP support to assist farm machinery manufacturers in extension, training, and technical and managerial services.

Bachelor Degrees in Agricultural Engineering are offered at three universities: Kasetsart, Khon Kaen, and Chieng-mai universities. In addition to Kasetsart and Khoen Kaen, graduate study in agricultural engineering is also offered by the Division of Agricultural and Food Engineering at the Asian Institute of Technology (AIT), an institution sponsored by various countries and international organizations. AIT offers both Master and Doctorate programs. Besides degree levels training, a number of vocational agricultural training institutions also provide general agricultural education on farm machinery. The Thai-German Agricultural Engineering Center in Khon Kaen, established under German bilateral assistance, gives informal education in farm machinery and its development, in soil and land improvement, and in irrigation science. Over the past five years, the center has trained more than 4,000 enrollees including extension workers, cooperative members, land consolidation staff, and farmers (Intachaisri, 1983).

Examining data in Table 20, it is clear that budget for farm mechanization has increased. Funds increased from 4.2 million baht in 1965 to 70.1 million baht in 1978. The budget for this purpose is however relatively low, amounting to only 10% of the total budget for agriculture.

(7) Issues and Problems of Mechanization

The existence of farm mechanization in Thai agriculture leads to many controversial issues and problems as follows.

a. Imports of used farm equipment

The market for farm equipment is a sellers' market. The high rate of inflation, partially resulting from increased costs of oil, raised prices for imported farm equipment. In the period of 1965-1979, prices increased more than two-fold (Table 15). The high price of new machines lead to an increase in the import of second hand tractors from developed countries (specifically Japan), particularly small four-wheel tractors. These machine were imported for reconditioning and resale at prices 60 to 80 percent the cost of new units. This makes the price of second-hand imported tractors competitive with locally manufactured units but embodying higher efficiency and more functions. As a result, imported second hand tractors gained in popularity among Thai farmers and lead to higher imports. The over-import of used tractors is presently the hottest issue in farm mechanization in Thailand, primarily because it hurts domestic manufacturers. To remain in the business, domestic producers automotive parts and their units sell for 50 to 70 percent price of new imported models (Chancellor, 1983). The quality of these units is, however, lower than the imported machines.

This development leads to two distinctive perspectives. Some economists prefer a free-trade policy compared to a protection policy because farmers can purchase tractors at lower prices which consequently leads to a higher income for farmers. In contrast, others advocate a higher tariff protection for domestic producers, because without the protection many local producers will be forced out of business. The nation would also face with higher unemployment. The negative view is that farmers have to pay higher prices for the tractors. Theoretically, the government should grant high tariff protection only to the industries with high value-added or with extensive forward and backward linkages. However, a combination of moderate import-tariff protection and direct subsidies for the purchase of farm machines may be the compromise solution.

b. Employment and income

This lively controversy revolves around the argument that farm mechanization has an adverse influence on agricultural employment, since tractorization displaces farm labor and leads to higher unemployment in the countryside. This hypothesis implies a downward shift in the demand for farm labor. A fall in labor demand leads to lower wage rates as the supply of farm labor remains unchanged or increased. Lower wage rates in the agricultural sector implies lower income for hired farm labor, which consists of small and landless

farmers. The further implication is that income distribution becomes worse. The effect of income distribution won't be so serious if non-farm jobs are available in rural areas. If the labor released has to look for jobs in urban areas, outward migration may stimulate higher unemployment in these areas.

Many past and current studies show that farm mechanization can solve the problem of labor shortages in the peak seasons and also increase land use intensity through multicropping. Normally, labor shortages occur during the harvest period for the first crop and land preparation for the second crop (also during the first crop threshing period and the planting of the second crop). The use of HYV's requires precise, short duration timing of transplantation.

From the preceeding paragraph, we may be lead to believe that modern agriculture and multiple cropping are almost impossible without using farm machinery. The question is whether we really need them? With an increase in population and limited cultivated land, we need to intensify cropping and increase yields to ensure sufficient food in the future. Tractorization enables farmers to clear and prepare more land for cultivation using less time. Furthermore, the use of an appropriate combination of farm machines may lead to higher total employment and wage rates. If this is the case, the income of hired agricultural labor will increase. It also implies an improvement in income distribution. We must be bear in mind that sufficient agricultural infrastructure, such as

irrigation and purchased inputs such as fertilizer are required. Farm mechanization alone cannot lead to success.

c. Ownership and economies of scale

In general, the majority of Thailand's farmers cannot afford their own machines. They must utilize tractor services obtained through either contractors or joint ownership arrangements. Both systems face difficulties in servicing their clients when monsoon rains do not arrive on schedule.

The average farm size in Thai agriculture is about 4 hectares, which is relatively small for tractorization. A feasibility study done by the Agricultural Engineering Division in 1973 concluded that the optimum size of tractor for the transplanted rice field of 12.5 ha was 10 hp (Chakkaphak, 1978). Therefore, an increase in farm size is desirable to obtain economies of scale from utilization of farm machinery.

An increase in farm size through land purchase or leasing in land generally difficult because most farmers have very low incomes. The government may use land reform policy to enlarge farm sizes and have agricultural zoning to prevent the agricultural land from being converted for other purposes. Alternatively, the government might encourage farmers to establish cooperatives or encourage investors to form large commercial farms. The government could also provide low-cost loans to small farmers to purchase farm machinery. Promotion of ownership would

improve the income of small farmers and income distribution, since small farmers comprise the bulk of farms in the country.

d. Credit availability

Farmers generally have to rely for credit on one or more institutions: commercial banks, Bank of Agriculture and Agricultural Cooperatives (BAAC), machinery dealers, village or local money-lenders, and relatives or friends. Even though the government presently adopts many policies to provide more low-cost credit to the agricultural sector through the of BAAC, institutional credit has not expanded as fast as planned. This is due to the banks collateral requirements which prevent small farmers access to agricultural credit. Credit schemes are often more beneficial to large than small farmers, because only large farmers are eligible. Credit schemes are not usually specifically designed to accelerate purchase of farm equipment. These circumstance leave machinery dealers and local money-lenders as the major sources of credit for farm mechanization. Their interest rates are normally higher than those of financial institutions. Tractor dealers face the problem, however, that farmers often cannot make payments on time. Overdue payments are difficult to collect and many have to repossess the machines. High risk and uncertainty make dealers charge higher interest rates than formal financial institutions.

As far as credit is concerned, expansion of low-cost funding for small farmers to purchase machines is a key element to accelerate farm mechanization. There are several alternative means to achieve this objective. The government should encourage farmers to establish their own cooperatives to obtain low-cost loans. For remote and isolated farmers, the BAAC should encourage farmers to form their own joint liability groups and to be responsible for each other in applying for low-cost loan. If one member cannot on schedule, the remainder of the group must make the payment and collect from that member later. The initial deposit and subsequent payments should also be small so farmers can afford them. small payments can be realized by advocating purchase of small, inexpensive farm equipment with long term pay-off periods.

e. Technical issues

These issues revolve around the development and modification of farm machines to suit conditions in Thailand.

Dissemination of research development results to farmers is limited because most, R & D work on farm mechanization is conducted in Bangkok. In additon, many of the agricultural extension staff at the field level have no training in farm mechanization. To compound the problem, most research units do not receive direct feed-back from farmers, since most machines are tested at Kasetsart University (Kanazawa, 1983).

To be compatible with farm conditions in Thailand, R & D must focus on small low cost equipment.

Regional centers should be established in four regions of Thailand to conduct research on farm mechanization, to create pilot projects to improve use of mechanization by training agricultural extension workers and farmers, and to disseminate information on farm mechanization technology to farmers. The centers should have mobile training units to serve remote farmers. To implement these ideas, the government would need to allocate more budget for mechanization development.

f. Issues on farm machinery industry

The Thai government provides little or no protection for domestic producer of farm equipment (Appendix 2 of Sukharomana, 1983). For example, imports of tractors with implements are exempted from import tariffs, while imports of engines are subject to a 5 percent import tariff. This policy makes it difficult for domestic tractor producers to compete with foreign producers, because local manufacturers must import engines. Furthermore, the farm machinery industry in Thailand is only at the adolescent stage, since most firms are small and operate with simple fabrication technology. Small firms do not enjoy economies-of-scale. The also lack skilled labor. They must train their own workers and have difficulty retaining them. Because the demand for farm machinery is derived from the demand of agricultural products, the uncertainty of commodity prices forces domestic manufacturers of farm machinery to set

production plans. These involve extra cost. Most small firms also lack adequate financial means to develop their own research capacity to design better farm machines. Also many cannot handle their own imports of inputs and parts due to the lack of funds.

The domestic farm machinery industry needs both financial and technological help. The government should establish low-cost credit specifically for domestic producers of farm equipment. Producers of small tractors and irrigation pumps should have high priority. Trade policies on farm mechanization should be reconsidered. Perhaps moderate import tariff protection on second hand tractors and low duties on engines and components used in agricultural machinery should be considered in detail.

8. Energy issues

Rising oil and gas prices affects use of farm inputs. Higher prices lead to higher prices for fertilizer which consequently leads to lower fertilizer use, lowering crop yield responses. The adverse impact on crop production reduce the demand for farm equipment. Alternatively, rising fuel prices increase the operational costs of machines, and raise the rates for custom hiring. The burden of rising prices is passed on to the farmers if the elasticity of demand for contractor services is inelastic. Conversely, tractor contractors would bear all or part of the burden if the elasticity of demand is elastic.

With the rising price of petroleum, the government develop cheaper sources of energy for agricultural production, i.e., windmill power to operate irrigation pumps, solar energy, biomass and biogas. Luckily, Thailand has a sizable natural gas reserve, sufficient for approximately 25 years use, in the Gulf of Thailand. Methanol, derived from natural gas, may provide some uses as a motor fuel.

Analytical Framework

Present Thai international trade policies conflict with agricultural development policies. The former has an adverse influence on the agricultural sector, while the latter assists farmers. In general, a policy will affect domestic production and consumption, foreign trade, and social welfare. These relationships are shown in Figure 2. The horizontal axis represents quantities of rice. The vertical axis in panel (a), (b) and (c) represents the price of rice, while the vertical axis represents other commodities. The world price of rice is determined by the intersection of world supply S^a and world demand D^a in the world market, at point E^a in panel (a). For simplicity, a small country assumption will be used. The world price of rice facing Thailand is the horizontal line OP_o. Without government intervention, the domestic price of rice will equal its world price, or $OP_w = OP_o$. The corresponding quantities of domestic production and consumption are OP_e and OP_o in panel (b), respectively. In this

case, the level of social welfare is determined at point E_o, the tangency between the price line P_oP_o and the community indifference curve IC_o in panel (d). Thailand will export Q_oP_o units of rice (or R_oR_3 units) in exchange for E_oQ_o units of other commodities. The domestic price will fall from OP_o to OP_t, when Thai government imposes high export taxes on rice exports. Domestic consumption will rise to OR units, but domestic production declines to OR_2 units in panel (a). Under these circumstances, Thailand will export Q_1P_1 units of rice in exchange for E_1Q_1 units of other goods. These results imply trade contraction since triangle $E_1Q_1P_i$ is smaller than triangle $E_oQ_oP_o$ in panel (d). Social welfare is also lower, since the tangency point from E_o on indifference curve IC_o to E_1 on IC_o which lowers welfare. The welfare cost resulting from this policy is the sum of the areas of triangles ABC and DGF.

Suppose the government adopts the agricultural development policies. The domestic supply curve will shift from S^d to $S^{d'}$. Without export tax policies, Thailand will produce OR_4 units of rice and consume OR_o units as depicted in panel (c). The production possibility curve will shift from $Y'R'R''$. Thailand will export P_1Q_1 units of rice in exchange for E_2Q_1 units of other commodities. The agricultural development policies will lead to trade expansion since the triangle $P_1Q_1E_2$ is greater than triangle $E_oQ_oP_o$. If government imposes export taxes on rice, the domestic

price of rice becomes OP_t in panel (c) or price line changes from P_oP_o to P_tP_t in panel (E). Under this situation, domestic production will be only OR_3 units as in panel (c). Thailand will export Q_1P_2 units of rice in exchange for E_3Q_1 units of other commodities. This will be the case of trade contraction, because triangle $E_eQ_1P_2$ is smaller than triangle $E_2Q_1P_1$ (see panel E). Social welfare will fall from point E_2 to E_3, since IC_2 represents a higher satisfaction level than IC_1. The social cost in this case is sum of the areas of triangle ABC and HJK in panel (c). That is, a high export tax leads to a smaller trade volume and higher social costs or excess burden to society.

IRRI Rice Policy Model

The conceptual framework of this model is based on a quantitative accounting technique embodying provisions for rice policies employed in many Southeast Asian countries; i.e. buffer stocks and international trade regulations, fertilizer demand and supply policies, irrigation investment and productivity policies, and demand and consumption analysis (Herdt and Webster, 1982). It is a partial equilibrium analysis determined by the adjustment of supply and demand.

1. Supply side

The model begins with a rice production module covering techniques used on large and small farms. The sum of output from these farms are total rice production in a given year. Output depends on the sum of land areas representing differing degrees of quality, fertilizer uses and response levels, level of farm mechanization and labor requirements fpr each technique.

Rice land consists of eight levels of quality each differentiated by the degree of water control. Total land is fixed, but the proportion of various qualities of land depends upon government's investments in irrigation. More investment will increase the quality of land and yield. In addition, use of HYVs and fertilizer also increase rice yields. The fertilizer response function, together with the relative prices and availability of fertilizer, determines the rice yield and fertilizer uses for on each land class. The response functions take the form:

$$Y_{ij} = a_i + b_i \, FERT_{ij} + c_i \, (FERT_{ij})^2 \quad . . . . . (1)$$

where:

a_i, b_i and c_i are parameters, while i, and j are subscripts denoting land quality and farm class, respectively.

The values of these parameters are shown in Table 7 and were estimated using regression techniques. The supply of fertilizer is determined by the government. Fertilizer is distributed among different land classes using the profit maximization allocation process. When the

amount of fertilizer used for each land class is known, yield can be obtained from expression (1). Total output from each land class is the product of yield and planted area:

$$q_{ijl} = A_{ijl} \cdot Y_{ijl} \quad \ldots\ldots\ldots\ldots (2)$$

where:

q_{ijl} = rice output of the ith land class produced by the jth farm class in the lth season.

Y_{ijl} = rice yield of the ith land class produced by the jth farm class in the lth season.

A_{ijl} = total planted area by land class, farm class, and season, respectively.

For the economy as a whole, total rice output without farm mechanization is determined by the expression (3) as below:

$$Q_1 = \sum_{i=1}^{4} \sum_{j=1}^{2} \sum_{l=1}^{2} q_{ijl} \quad \ldots\ldots\ldots\ldots (3)$$

where: Q_1 = total rice output without mechanization.

The model treats farm machinery as having possible impacts on yield and total output. The total area under mechanization is the product of the number of machines available and the machine's seasonal capacity; or

$$A_{kl} = N_{kl} \cdot C_{kl} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where:

A_{kl} is total area under k machine operation in l^{th} season.

N_{kl} and C_{kl} are the number of the kth machine and its capacity in the lth season.

The total change in rice output resulting from mechanization is the product of total area under the kth mechanization class and the additional yield resulting from use pf the kth machine:

$$q_{kl} = A_{kl} \cdot Y_{kl} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

where:

q_{kl} and Y_{kl} are the incremental rice output and yield resulting from the use of machine k in the l season.

The effects of farm mechanization on total rice output for each farm class are determined as:

$$q_{kjl} = q_{kl} \cdot R_{kjl} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

where:

q_{kjl} is the change in rice output resulting from use of the kth machine by the jth farm class in the lth season.

The effects of farm mechanization on total change in rice output resulting from mechanization can be obtained from expression (7).

$$Q_2 = \sum_{k=1}^{m} \sum_{j=1}^{2} \sum_{l=1}^{2} q_{kjl} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

where:

Q_2 is the change in total output resulting from use of the kth machine.

q_{kjl} is the change in output resulting from use of the kth machine by the jth farm class in the lth season.

Total rice output is defined as:

$$Q = Q_1 + Q_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

where:

Q is the total output.

Labor used in the model consists of family and hired labor. Total labor used without the existence of farm mechanization is defined as:

$$Tl_1 = \sum_{i=1}^{4} \sum_{j=1}^{2} \sum_{l=1}^{2} (A_{ijl} \cdot L_{ijl})(h_{ijl} + f_{ijl}) \quad \ldots \quad (9)$$

where:

Tl_1 = total labor used.

A_{ijl} = total area of the ith land class used by the jth farm class in the lth season.

L_{ijl} = labor requirements per hectare in the ith land class used by the jth farm class in the lth season.

h_{ijl} and f_{ijl} are the percentages of total labor represented by hired and family labor employed on the ith land quality by j^{th} farm class in the lth season.

In addition to yield, farm mechanization also has impacts on labor use, which is defined as:

$$Tl_2 = \sum_{k=1}^{m} \sum_{j=1}^{2} \sum_{l=1}^{2} (N_{kjl} \cdot C_{kjl}) (h_{kjl} + f_{kjl}) \quad . . (10)$$

where:

Tl_2 = the change in total labor use resulting from farm mechanization.

Ag, Eg, and Nq are parameters.

Total employment is defined as:

$$TL = Tl_1 + Tl_2 \quad . . . . . (11)$$

where:

TL is total labor use during a given year.

2. Demand side

Demand for rice is a function of rice price and per capita income. The demand function is of the Cobb-Douglas form which takes the form:

$$DMRICE = A_g . PRICE^{Eg} . INCOME_g^{Ng} \quad . . . . . (12)$$

where:

$DMRICE_g$ is the quantity of demand by the gth economic class.

A_g is the intercept.

PRICE is the domestic market price of rice.

E_g is the price elasticity of demand for rice of the gth class.

$INCOME_g$ is the per capita income of the gth class.

N_g is the income elasticity of demand for the gth class.

Labor income results from the wage paid. For each population group, YL_g, is defined as:

$$YL_g = \sum_{i=1}^{4} \sum_{j=1}^{2} (A_{ij}.L_{ij}.h_{ij})W_j + \sum_{k=1}^{m} \sum_{j=1}^{2} (N_{kj}.C_{kj}.h_{kj})W_j \quad . . . (13)$$

where:

W_j is the wages paid by the jth farm class.

N_{kjl} is the number of k machines used by the jth farm in the lth season.

C_{kjl} is the capacity of the kth machine used by the jth farm in the lth season.

h_{kjl} and f_{kjl} are percent hired and family labor affected by the kth machine in the jth farm class in the lth season.

In general, rice prices are determined by demand and supply within the model through an iterative procedure which searches for that price which clears the domestic market. There is no foreign trade explicitly

accounted for in this case. However, if the time element is taken into account and if the world market has perfect information and responds, the foreign trade is possible. Alternatively, prices may be assumed to be fixed, which is the small country assumption. Excess demand and supply in this case will be offset by imports and exports of rice, respectively. The consequence leaves the market price of rice invariably affected. The assumption of fixed price is not too unrealistic to the case of Thailand, since the government has policies to stabilize the domestic rice price.

The model assumes that incomes flow to the owners of resources and of rice output. There are four types of income in the model: labor income, rental income, farm income, and non-farm income. Five population classes are also assumed, landless farmers, small farmers, large farmers, urban, and non-farm rural, each of which may receive income from one or more sources.

Rental income is derived from ownership of land. It is the product of rent paid to each land class and the area of each class. The rental income for each population group, YR_g, is described as follows:

$$YR_g = \sum_{i=1}^{4} \sum_{j=1}^{2} (A_{ij} . P_{ij} . R_{ij}) \quad . . . . . (14)$$

where:

P_{ij} is the proportion of ith land class used by the jth farm class.

R_{ij} is rent paid for land of quality i by the jth farm class.

Farm income is the income from rice production. The farm income of population group g, YF_g, is defined as:

$$YF_g = P_d . Q_g - TC_g \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

where:

P_d is palay price

Q_g is total production of the gth group.

TC_g is total cost of production of the gth group, which consists of fertilizer, machine, rent, wages and other cost.

Non-rice income is exogenously determined. The total income of each population group, Y_g, is

$$Y_g = YL_g + YR_g + YF_g + YO_g \quad \ldots\ldots\ldots\ldots \quad (16)$$

where:

YO_g is the non-rice income of the gth group.

3. Policy instrument and costs

The current version of the model includes policy instruments in four areas; fertilizer, irrigation, farm mechanization, and population control. Each policy instrument has a cost associated with it.

The fertilizer policy consists of two instruments. The first is fertilizer price. The cost of the policy, the difference between world

and local prices of fertilizer, is calculated by the model. The second instrument is the rate of growth in fertilizer availability, which is determined by governmental action.

Two irrigation policy instruments are included: development of new irrigation and rehabilitation of old systems. New irrigation investment upgrades land from rainfed to different qualities of irrigated land, while the rehabilitation investment on the other hand improves the dry season irrigated land.

The policy instrument in the population program is control of the population growth rate. To reduce the current rate to the target rate involves costs the greater the difference between the two rates the greater the cost of population control.

The mechanization policies involve two policy variables: a direct subsidy on farm machinery and the rate of increase in the machinery stocks. Direct subsidies include subsidies on capital costs and fuel prices. It is easy to measure the policy costs of the first instrument, since it is a direct cost to the government.

The flowchart in Figure 3 illustrates the prototype rice policy model, and provides a better understanding of how the model works. The equilibrium may be determined by a shift in demand or supply. An increase in income or population or a combination of both, will raise domestic demand and price of rice. In the short-run, the excess demand will be offset by imports or the buffer stock of rice. In the

medium-run, the equilibrium can be restored by encouraging intensive use of fertilizer, provided irrigation and mechanization are well developed. In the long-run, rice output can be increased by implementing the fertilizer, irrigation, and farm mechanization policies to accommodate high domestic demand. Higher output implies higher rice incomes. Higher income will result in an increase in domestic demand and supply in the second round. The adjustment will continue until the equilibrium is achieved.

Suppose the government implements the agricultural policies to improve the use of fertilizer, irrigation, and machinery to increase domestic output. Exports of the rice surplus, however, will restore the equilibrium price. The incidence of higher output also leads to higher rice income and higher domestic demand for rice. Again, higher demand will signal higher price and output in the second round, and so on. The adjustment will stop when the equilibrium price is regained.

Empirical Analysis

The algorithm for simulating the IRRI model was initially written by Dr. J. P. G. Webster in a Microsoft Basic (Webster, 1982). Another version, modified by Dr. Herdt and Ms. Linda Castillo, is available at the Agricultural Economics Department of IRRI. The model is run with and without policy instruments, and the difference between the two simulations is the policy impact on the economic variables. Many

policies are incorporated in the model: namely, population, fertilizer, irrigation, construction and rehabilitation, and farm mechanization. The following impacts will be investigated:

(1) Impacts of Farm Mechanization

To examine the effects of farm mechanization, policies on population, irrigation and rehabilitation, and fertilizer are held constant (see Table 21 and 22). According to Table 21, with existing agricultural conditions and policies, total rice output increases over the ten years of the simulation. Rice surpluses also have increasing trends because domestic production increases faster than domestic consumption. For instance, Thailand had approximately 9.35 million tons of rice surpluses in the first year of the base run, which corresponds to 1982. Per capita incomes of all economic classes increase, but that of the landless farmers have the slowest upward trend. This is because they own neither rice land or farm machinery. In contrast, the per capita incomes of small and large farmers increase the most, since they own the major share of the rice land and farm machines. The per capita income of the urban class, after increasing from the base run, has a decreasing trend. This is due to the fact that migration of the population from rural to urban areas is incorporated into the model. Both total labor use and hired labor have rising trends, because the increase in cultivated land resulting from other agricultural policies outraces labor substitution resulting from implementation of farm mechanization. Since

hired labor increases at a higher rate than the total labor, this implies that Thai agriculture has tended to use more hired than family labor. Finally, policy costs to government also increase because of subsidies on fertilizer.

From Table 22, we see the simulated values of all economic variables have increasing trends. The impact of farm mechanization can be traced from the results presented in Tables 21 and 22. Total output and surplus of rice in Table 22 is lower than that in Table 21. It implies that, under given agricultural conditions and policies, lower levels of mechanization lead to lower total rice output because less rice land is cultivated. Lower total production causes a decline in the rice surplus for export, since domestic consumption remains unchanged. The per capita incomes of all farm classes increases when farm mechanization is removed from the model. Farm mechanization leads to a pattern of income distribution against the farmer classes. It also implies that tractorization is not profitable to Thai farmers. Farmers use tractors for non-economic reasons, such as convenience or solving labor shortages at the peak season. On the other hand, the per capita incomes of urban and rural non-farm classes remain unchanged because they own no farm machinery. The policy costs to government are not affected because there is neither a direct subsidy nor promotion of farm mechanization in Thailand. Tractorization also replaces both family and hired labor,

since total labor and hired labor uses in Table 22 are higher than that in Table 21.

(2) Impacts of Irrigation Investment

In this case, the population, fertilizer, and farm mechanization policies are held constant. Suppose the area from rehabilitated systems and irrigation investment increased only 3,000 and 30,000 hectares (equivalent to a 10% increase from the existing irrigated area) instead of 100,000 and 200,000 hectares, respectively. Given these conditions, Table 23 shows that total rice output increases slightly over the ten year period. Since population increases faster than total output, rice surpluses have a decreasing trend. Per capita income of all economic classes except the rural non-farm class also have decreasing trends, because population increases faster than farm income over the years of simulation. Per capita income of the rural non-farm class has an increasing trend, because income is derived from non-farm income sources. Less investment in irrigation and rehabilitation means lower land qualities and less total cropped land. The decline in cropped land causes use of both family and hired labor to fall, which implies higher unemployment in the agricultural sector. The decreasing trends for both total labor and hired labor indicate that a ten percent increase in investment in both irrigated and rehabilitated land are not sufficient to offset land depreciation. From a series of computer runs, we find that

the irrigated and rehabilitated areas have to increase at least 200,000 and 50,000 hectares, respectively, in order to affect an increasing trend in both total and hired labor use (see table 24). From table 21 and 23, it can be concluded that investments in new irrigation and rehabilitation have positive relationships with rice output, surplus, employment, and income and income distribution and overall policy costs.

(3) Impact of Fertilizer Use

Policies on population, irrigation, and farm mechanization are held constant. Even when the fertilizer application rates increase only one percent, the values of all economic variables have increasing trends. From Table 21 and 25, we see that the change in fertilizer use rate has very little or no effect on per capita income and employment, but has positive effects on total output and policy costs to the government.

Summary, Conclusions and Policy Recommendations

The study employs the IRRI Rice Policy model, a partial equilibrium analysis, to simulate the effects of population and agricultural development policies on total production, employment, rice surplus, policy costs, incomes and income distribution in the agricultural sector. Agricultural policies of interest in this study are farm mechanization, irrigation, and fertilizer policies. The initial portion of the paper describes the structure and status of Thai agriculture to serve as the baseline for simulating the model. The farm mechanization aspect

proceeds in the following sequences: historical background, status, marketing distribution and prices, utilization and ownership, appraisal, roles of government, and issues and problems of farm mechanization in Thailand.

Empirical results indicate that implementation of farm mechanization leads to higher total production and rice surpluses but worsens the income of farmers which implies that equity in income distribution is moving against the agricultural sector. It further implies that farm mechanization, particularly tractorization, is not profitable to Thai farmers. This result is partly due to government policy which keeps domestic rice prices at a low level to assist domestic consumers and encourage exports. Furthermore, farm machinery displace both family and hired labor, but displace the former more than the latter. With the existing level of farm mechanization and a 5 percent rate of growth, farm mechanization did not worsen employment appreciably that much, since the population has increased a little over one million persons a year and total employment increases about 8 million mandays or one million jobs annually. In contrast, investments in irrigation and rehabilitation of old system has positive relationship with total output and the rice surplus, per capita incomes, and employment. Table 23 indicates that under the present agricultural conditions, a ten percent increase in investment in irrigation and rehabilitation is insufficient. The level of investment should be adequate for at least 200,000 and

50,000 hectares, respectively. Unlike irrigation investment, a one percent increase in fertilizer use has little or no effect on per capita income and employment, but has positive effects on total rice output and policy costs to the government.

An individual policy cannot improve farm mechanization in Thailand. Therefore, policy recommendations should concern policies on agricultural and industrial development, international trade, and energy.

(1) Agricultural and industrial development policies

The availability of adequate infrastructure and modern technology are prerequisites for effective use of farm mechanization. The government should give high priority to the provision of irrigation facilities, and the uses of HYV and fertilizer. Sufficient irrigation and adoption of modern agricultural technologies lead to multiple cropping which requires tractor services for land preparation and amelioration of labor shortages in peak periods. To improve efficient use of water, a minimum irrigation fee should be imposed. A good transportation system will also improve the flow of commodities from farm to market.

Centers for small farm mechanization should be established in all four regions to train agricultural extension workers. These persons can train and advise farmers in the areas of their stations. The training courses should focus on operation and proper care their farm machines, because the useful life of machine is a function of proper operation and

maintenance. Mobile units should be formed to advise and check farm machine in remote areas.

Low-cost loans should be directed to small farmers who need farm machines. The down payment should be sufficiently small so that farmers can afford to pay. This credit scheme would enable small farmers to own their farm machinery and avoid conflicts in schedules for hired machines. Furthermore, they may also earn extra income by hiring out their tractors during the off season. The same type of loans should be available to small manufacturers of farm machines in the outer provinces. Special loans with moderate interest rates may be made available for small manufacturers in the provinces to expand production. The BAAC may take over their credit given to farmers by a charging minimum financial fee to enable the small manufacturers to have money for circulation.

(2) International trade policies

The government should impose moderate tariffs on imports of large tractors and small, used tractors to protect domestic tractor producers. Conversely small tractors, water pumps, and rice threshers should be exempted from import tariffs. By doing so, the relative prices of large and used tractors compared to small locally built farm machinery are higher. Consequently, demand for tractors will shift from larger to small tractors, which are compatible with Thai farming conditions. To enable domestic producers of small farm machineries to compete with

foreign producers, imports of accessory inputs and engines for farm machines should be exempted from import tariffs. This measure and the credit scheme will lower and domestic cost of production. However, import tariff protection should not be permanent.

A phasing out of high export tax rates on rice export is probably the most desirable measure to improve farmers and income distribution, because the foreign demand for Thai exports is elastic. Therefore, the high export tax rates on rice exports depress domestic rice prices and consequently paddy prices. This preposition, however, is hard for the government to accept because of budgetary and political difficulties. The abolition of high export taxes is political in nature as rice has always been a political commodity. In the past, pressure resulting from high domestic prices of rice forced the government to dissolve the Parliament. On this ground, the phasing out of export taxes seems implausible. However, some burdens may be relieved from rice exporters by giving them the option to meet the rice reserve requirement either by surrending rice or by paying money in equivalent values. This option enables them to take advantage of price differential (Pongsrikul, 1983).

(3) Energy policies

The government should provide fuel gasoline to small farmers, who own farm machines and tractor contractors who is renting their tractor services to small farmers. The government also must develop alternative sources of energy for agricultural production, such as solar energy, biomass and biogas, or even windmill power to operate irrigation pumps.

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Table 1. Rice yields in Thailand and selected country, 1975-1981.

Country \ Year	1975	1976	1977	1978	1979	1980	1981
Thailand	293	295	255	312	291	305	312
Burma	291	288	311	335	376	423	426
Malaysia	420	437	421	411	442	432	451
Phillipines	278	291	314	332	343	345	353
China	526	563	559	655	680	666	678
Japan	990	880	987	1027	958	820	901
India	299	262	314	331	261	328	328
Pakistan	367	376	373	388	379	384	410
Bangladesh	297	285	310	310	291	325	317
Indonesia	412	445	447	462	478	510	586
Cambodia	223	206	192	171	159	133	155
Laos	214	202	196	192	215	232	250
Nepal	332	302	289	296	261	308	303
Sri Lanka	309	316	343	360	388	382	404
Vietnam	362	361	322	293	314	279	358
South Korea	852	955	1098	1086	1023	787	919
North Korea	811	950	946	923	985	960	980
U. S. A.	819	836	791	804	825	790	874
World	393	392	409	439	428	440	457

Sources: Center for Agricultural Statistics, Ministry of Agriculture and Cooperatives, Agricultural Statistics of Thailand Crop Year 1981/82, 1982.

Note: One rai = 0.16 hectare.

Table 2. Land utilization of Thailand, 1967/68 - 1981/82.

Year	Forest land		Agricultural land		Paddy land			Paddy planted area	
	Area 10^3 ha	% to total land	Area 10^3 ha	% to total land	Area 10^3 ha	% of total land	% to agric. land	Area 10^3 ha	% to total paddy land
1967/68	25,574	49.8	13,530	26.3	7,494	14.6	55.4	6,658	88.8
1968/69	24,784	48.2	13,980	27.2	8,045	15.7	57.5	7,179	89.2
1969/70	24,684	48.0	14,491	28.2	8,678	16.9	59.9	7,797	89.8
1970/71	23,343	45.4	15,068	29.3	9,389	18.3	62.3	7,594	80.9
1971/72	22,198	43.2	15,902	30.9	10,209	19.9	64.2	7,527	73.7
1972/73	21,999	42.7	16,568	32.2	10,478	20.4	63.2	7,349	70.1
1973/74	21,552	41.9	17,496	34.0	10,746	20.9	61.4	8,363	77.8
1974/75	21,109	41.1	17,671	34.4	10,888	21.2	61.7	7,982	73.3
1975/76	20,921	40.7	17,954	34.9	11,043	21.5	61.5	8,896	80.6
1976/77	19,841	38.6	18,207	35.4	11,397	22.2	62.0	9,575	79.2
1977/78	18,651	36.2	18,207	35.4	11,723	23.2	62.6	9,031	83.5
1978/79	17,522	34.0	18,630	36.2	12,050	23.4	62.9	9,998	78.4
1979/80	17,022	33.1	18,816	36.6	12,050	23.4	64.0	9,435	79.2
1980/81	16,547	32.1	19,040	37.0	12,151	23.6	63.8	9,618	79.2
1981/82	16,093	31.3	19,407	37.8	12,201	23.7	62.9	9,595	78.6

Table 3. Fertilizer use on rice (NPK), selected Asian countries, 1965-81.

Country	Kg NPK/ha			% growth in NPK/ha/yr
	1970	1975	1980	1979-1980
Afghanistan	2.4	4.3	6.3	10.1
Bangladesh	15.7	22.6	46.3	11.4
Burma	2.1	4.1	10.0	16.9
China	33.5	48.1	154.6	16.5
India	13.2	16.5	30.9	8.9
Indonesia	13.1	26.0	63.0	17.0
Japan	372.6	319.3	372.1	-0.1
Cambodia	1.1	0.6	2.7	9.4
Korea, North	154.7	201.8	325.5	7.7
Korea, South	241.6	357.9	375.7	4.5
Laos	0.2	0.4	7.8	44.2
Malaysia	25.7	30.1	105.1	15.1
Nepal	2.7	6.1	9.7	13.6
Pakistan	14.6	28.0	49.5	13.0
Philippines	28.8	28.1	33.7	1.6
Sri Lanka	47.3	32.5	77.0	5.0
Thailand	5.9	10.9	16.2	10.6
Vietnam	61.7	61.0	40.7	-4.1
Europe	169.2	199.1	221.3	2.7
Oceania	31.2	25.8	37.2	1.8
U. S. A.	80.9	90.0	111.6	3.3

Source: Department of Agricultural Economics, IRRI, World Rice: Facts and Trends, 1983.

Table 4. Total population and population by economic classification, 1971-81.

	Total population		Agr. population		Population by economic classification[a]				
	1000 persons	% growth	1000 persons	% to total	Urban 1000 persons	Small F 1000 persons	Large F 1000 persons	Rural non-farm 1000 persons	Landess 1000 persons
1971	37,348	2.7	28,285	75.7	5,438	15,792	5,987	3,625	6,506
1972	38,389	2.5	28,461	74.14	5,957	15,900	6,015	3,971	6,546
1973	39,350	2.6	28,664	72.8	6,411	16,020	6,051	4,274	6,593
1974	40,418	2.9	28,792	71.2	6,976	16,106	6,064	4,650	6,622
1975	41,602	2.8	28,968	69.6	7,580	16,211	6,094	5,054	6,663
1976	42,772	3.0	29,080	68.0	8,215	16,287	6,105	5,477	6,688
1977	44,062	2.3	29,252	66.4	8,886	16,386	6,138	5,924	6,728
1978	45,081	2.2	29,324	65.0	9,454	16,438	6,141	6,303	6,745
1979	46,085	2.0	29,405	63.8	10,008	16,490	6,152	6,672	6,763
1980	46,960	2.0	29,454	63.0	10,504	16,523	6,157	7,002	6,774
1981	47,910	2.5	29,450	61.4	11,076	16,528	6,148	7,384	6,774
Average of 1971-81		2.5							

Sources: Center for Agricultural Statistics, Ministry of Agriculture and Cooperatives, Selected Economic Indicators Relating to Agriculture, 1979 and other issues.

Economic Office, Asian Development Bank, Key Indicators of Developing Member Countries of ADB, 1981 and 1982.

Note: [a] Computed from above sources.

Table 5. Rice field, yields, and areas of crop failure, 1967/68 - 1981/82.

Year	Planted areas		Yields		Irrigated rice land			Rainfed rice land		Area of crop failure	
	Wet season	Dry season	Wet season	Dry season	Average (W & S)	Area 10^3 ha	% to paddy land	Area 10^3 ha	% to paddy land	Irrigated area	Rainfed area
	(10^3 ha)		(kg./ha)							(10^3 ha)	
1967/68	na	na	na	na	na	1,763	26.5	4,894	73.5	19	832
1968/69	na	na	na	na	na	1,768	24.5	5,459	75.5	32	859
1969/70	na	na	na	na	na	1,802	23.6	5,835	76.4	38	354
1970/71	na	na	na	na	na	1,838	23.6	5,963	76.4	80	590
1971/72	na	na	na	na	na	1,872	23.4	6,131	76.6	19	458
1972/73	7,139	210	1,638	3,544	1,688	1,808	25.3	5,331	74.7	18	550
1973/74	8,037	326	1,725	3,106	1,781	1,822	23.9	5,789	76.1	14	403
1974/75	7,651	331	1,625	2,838	1,675	1,856	25.3	5,472	74.7	27	522
1975/76	8,519	377	1,656	3,200	1,719	1,882	22.4	6,530	77.6	37	552
1976/77	8,137	438	1,681	3,181	1,756	1,914	22.7	6,526	77.3	5	304
1977/78	8,554	477	1,444	3,325	1,538	1,941	23.1	6,458	76.9	19	1,830
1978/79	9,346	681	1,625	3,325	1,750	2,035	21.9	7,242	78.1	75	971
1979/80	9,099	336	1,613	3,300	1,675	2,056	22.3	7,166	77.7	34	1,046
1980/81	9,101	516	1,694	3,800	1,806	2,061	21.0	7,742	79.0	54	758
1981/82	9,023	572	1,744	3,525	1,850	2,123	22.3	7,402	77.7	22	720

Source: Center for Agricultural Statistics, Ministry of Agriculture and Cooperatives, Agricultural Statistics of Thailand, Crop Year 1981/82, 1982.

Note: 1 rai = .16 hectare.

Table 6. Total land endowment by group, land quality, and season, 1981.

Season \ Farm sizes	Small farms				Large farms			
	1st quality	2nd quality	3rd quality	4th quality	1st quality	2nd quality	3rd quality	4th quality
	(10^3 hectares)							
Wet seson	136	292	1,088	2,098	166	334	1,329	2,565
Dry season	107	221	121	234	133	271	148	284

Source: Computation.

Table 7. Coefficients of yield response functions for fertilizer by land quality and season, 1981. ($Y = {}_o + {}_1 + {}_1F + {}_2F^2$)

Season \ Land quality												
	o	1	2	o	1	2	o	1	2	o	1	2
Wet season	572.5	22.4	-0.04	421.5	19.8	-0.06	389.3	15.7	-0.07	254.5	9.05	-0.08
Dry season	810.6	30.1	-0.01	556.7	25.4	-0.03	479.8	20.5	-0.09	0	0	0

Source: Estimation

Notes: The experiment was performed on Alluvial Soil and the RD7 variety.

Table 8. Labor requirements by group, land quality, and season, 1981.

Farm sizes / Season	Small farms				Large farms			
	1st quality	2nd quality	3rd quality	4th quality	1st quality	2nd quality	3rd quality	4th quality
	(mandays/ha)							
Wet season	75	77	78	70	76	78	79	72
Dry season	136	138	140	150	137	138	140	160

Sources: Computation

Note: 1 manday = 8 manhours.

Table 9. Average human power use in Thai rice production, wet season, 1981.

	Human labor (hrs/ha)		
	family	hired	total
Land preparation	5.00	0.35	5.35 (0.89)
Planting	136.50	55.00	191.50 (31.86)
Crop caring	55.75	0.95	56.70 (9.43)
- fertilizer application	10.75	0.15	10.90
- weed control	21.00	0.50	21.50
- pest control	8.50	0.30	8.80
- irrigation	15.50	-	15.50
Harvesting	137.00	65.00	202.00 (33.61)
Threshing and others	134.00	11.50	145.50 (24.21)
Total	468.25 (77.91)	132.80 (22.09)	601.05 (100.00)

Source: The Office of Agricultural Economics, Ministry of Agriculture and Cooperatives. (Unpublished data).

Note: Figures in parentheses are in percentage.

1 rai = 16 ha.

Table 10. Cost of Thai rice production in wet season, 1977/78-1980/81.*

Items	Cost			
	1977/78	1978/79	1979/80	1980/81
	(baht per rai)			
Variable costs	425.09 (77.21)	510.98 (79.82)	591.83 (80.08)	676.24 (80.80)
- human labor (wages)	234.81 (42.65)	277.72 (43.38)	317.42 (42.95)	345.07 (41.23)
- animal power	42.55 (7.73)	92.80 (14.50)	99.97 (13.53)	123.87 (14.81)
- mechanical power	79.78 (14.49)	60.69 (9.48)	81.33 (11.00)	101.00 (12.07)
- seed	23.77 (4.32)	20.45 (3.19)	23.59 (3.19)	29.31 (3.50)
- fertilizers	20.23 (3.67)	33.45 (5.23)	37.48 (5.07)	29.06 (3.47)
- pesticides	3.10 (0.56)	2.55 (0.40)	3.35 (0.45)	3.47 (0.41)
- others	20.85 (3.79)	23.32 (3.64)	28.69 (3.88)	44.46 (5.31)
Fixed costs	125.48 (22.79)	129.17 (20.18)	147.24 (19.92)	160.67 (19.20)
.and (rent)	120.23 (20.84)	115.02 (17.97)	134.29 (18.17)	149.72 (17.89)
- depreciation of farm equipment	5.25 (0.95)	14.15 (2.21)	12.95 (1.75)	10.95 (1.31)
Total	550.57 (100.00)	640.15 (100.00)	739.09 (100.00)	836.91 (100.00)

Source: The Office of Agricultural Economics, Ministry of Agriculture and Cooperatives. (Unpublished data).

Note: Figures in parentheses are in percentage.

* From Sakurat Montreevat, 1983.

Table 11. Rents payable by group, land quality and season, 1981.

Farm sizes / Seasons	Small farmers				Large farmers			
	1st quality	2nd quality	3rd quality	4th quality	1st quality	2nd quality	3rd quality	4th quality
	(mandays/ha)							
Wet season	635	620	610	590	650	630	610	600
Dry season	958	850	500	20	1057	890	502	25

Source: Calculation.

Table 12. Other costs of rice production by group, land quality, and season, 1981.

Farm sizes / Season	Small farms				Large farms			
	1st quality	2nd quality	3rd quality	4th quality	1st quality	2nd quality	3rd quality	4th quality
	(kg. palay/ha)							
Wet season	50	50	50	50	61	61	61	61
Dry season	53	53	53	53	63	63	63	63

Table 13. Number of farm machines in use in Thailand by origins, 1975-1981.

	1975		1976		1977		1978		1979		1980		1981		Growth, 1975-1981		Density of of 1981 (10^3 ha)
	Total	Domestic	Total	Domestic	Total	Domestic	Total	Domestic	Total	Domestic	Total	Domestic	Total	Domestic	Import %	Domestic %	
Power tillers	62,141[a]	27,860	81,520[a]	31,766	101,782[a]	49,722[a]	139,723[a]	52,281	176,467[a]	54,124	229,591[a]	51,000	234,851[a]	49,500	277.9	77.7	29.6
Small 4-wheel tractors	11,993[a]	2,582	13,513[a]	2,914	19,374[a]	4,568	21,953[a]	5,031	26,238[a]	4,920	31,258[a]	4,900	34,308[a]	4,850	186.1	87.8	4.1
65-80 hp tractors	13,338	-	17,569	-	22,826	-	28,987	-	33,285	-	37,177	-	50,044	-	275.2	-	5.2
Motor rollers	9,882	-	9,000	-	8,700	-	8,200	-	8,000	-	-	-	-	-	-	-	-
Hand sprayers	-	1,310,464	-	1,379,436	-	1,452,038	-	1,528,461	-	970,000	-	1,131,645	-	1,138,504	-	86.8	118.6
Water wheel engine	56,891	-	68,219	-	81,923	-	89,775	-	107,730	-	125,811	-	146,927	-	158.3	-	15.3
Irrigation pump	251,288	-	277,084	-	317,328	-	359,308	-	473,975	-	517,975	-	603,548	-	140.2	-	62.9
Cleaning machine	42,342	-	47,423	-	53,114	-	59,486	-	66,806	-	74,782	-	83,801	-	97.9	-	8.7
Shelling equipment	5,721	-	6,407	-	7,175	-	8,036	-	9,000	-	10,079	-	11,287	-	97.3	-	1.2
Threshing	3,955	-	4,430	-	4,962	-	5,557	-	6,224	-	18,394	-	20,601	-	420.9	-	2.1
Feed miller	374	-	419	-	469	-	525	-	588	-	-	-	-	-	-	-	-
Wind miller	1,937	-	2,169	-	2,429	-	2,721	-	3,047	-	-	-	-	-	-	-	-
Sugar-cane cutter	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-
Rice mill	24,658	-	24,914	-	25,170	-	25,426	-	25,682	-	25,947	-	26,212	-	6.3	-	2.7

Sources: Center for Agricultural Statistics, Ministry of Agriculture and Cooperative, Agricultural Statistics of Thailand Crop Year, 1980/81 and 1981/82.

Note: [a] Imported figures only.

Table 14 Number of domestic producers, retailers, and wholesalers of farm machinery in Thailand.

Items / Year	1965	1970	1975	1979
Domestic producers				
a. Number of manufacturers or establishements: Total	90	310	340	420
of which: Those producing power-driven machinery implements	80	294	310	388
b. Value of production: Total[a]	32,300	216,500	1,115,500	2,015,500
of which: Power-driven machinery and implementent[a]	27,300	175,700	777,500	1,380,400
c. Total number of persons employed by manufacturers	2,500	3,750	5,750	12,705
Retailers				
Number of retailers	300	650	730	800
Number of employee	1,500	3,250	3,650	4,000
Value of annual sales of farm machinery and implements[a]	n.a.	502,381	2,134,109	3,765,838
Average value of sales per retailer[a]	n.a.	773	2,923	4,707
Wholesalers				
Number of wholesalers	80	294	310	388
Number of employees	2,000	7,362	7,760	9,700
Value of annual sales of machinery and implements[a]	n.a.	401,904	1,707,287	3,012,670
Average value of sales per whole saler[a]	n.a.	1,367	5,507	7,765

Source: Office of Agricultural Economics, Ministry of Agriculture and Cooperative, also from J. Intachaisri, Thailand, in Mechanization in Asia, Published by Asian Productivity Organization.

Notes: [a] unit = 10^3 baht.

Table 15. Retail prices of farm machinery and implements, fuel and powers and draft animals, 1965-1979.

Products	Specification	1965		1970		1975		1979		% change, 1975-79	
		Domestic	Imported	Domestic	Imported	Domestic	Imported	Domestic	Imported	Domestic	Imported
Machinery											
Diesel engines	12 hp	-	9,400	-	12,600	-	18,120	-	25,150	-	38.8
Power tillers	8 hp	9,169	-	10,787	-	12,690	19,800	21,150	23,920	66.67	20.8
Small wheel tractor	15-30 hp	20,000	34,180	23,520	47,459	29,400	49,548	49,000	54,590	66.67	10.2
Large tractor	60 hp	-	89,856	-	112,320	-	187,200	-	272,000	-	45.3
Manual sprayers		-	-	364	-	-	-	405	-	-	-
Power sprayers	2.8 hp	2,731	-	3,103	-	3,695	-	4,680	5,149	26.6	-
Pump/simple water-lift machines	4.5 hp	5,195	-	6,335	-	9,050	-	13,900	-	53.6	-
Power threshers	12 hp	n.a.	n.a.	n.a.	n.a.	17,000	-	23,000	-	35.3	-
Implements											
Wooden plough	per unit	75	-	80	-	100	-	180	-	80.0	-
Steel plough	"	85	-	100	-	150	-	250	-	66.7	-
Hoe	"	22	-	25	-	40	-	70	-	75.0	-
Sickle	"	12	-	15	-	25	-	50	-	100.0	-
Fuel and power											
Gasoline	per liter	1.86	-	1.86	-	3.43	-	9.26	-	170	-
Diesel fuel	"	1.90	-	1.90	-	2.33	-	6.54	-	181	-
Lubricating oil	"	12.00	-	12.00	-	15.00	-	21.00	-	40.0	-
Electricity	per kwh	0.50	-	0.50	-	0.90	-	1.10	-	22.2	-
Draft animals											
Cattle	per head	1,500	-	1,500	-	3,000	-	5,000	-	66.7	-
Buffalo	"	3,000	-	3,000	-	5,000	-	8,000	-	60.0	-

Source: Office of Agricultural Economics, Ministry of Agriculture and Cooperatives, also in Intachaisri's paper.

Table 16. Proportions of ownerships on selected farm machines by farm sizes, 1981.

Types of farm machines	Farm sizes	
	Large farms	Small farms
Locally manufactured machines		
a. Two-wheel tractors	0.55	0.45
b. Small four-wheel tractors	0.60	0.40
c. Power threshers	0.5	0.5
Imported machines		
a. Two-wheel tractors	0.65	0.35
b. Small four-wheel tractors	0.70	0.30
c. Large four-wheel tractors	1.00	0

Source: Estimation.

Table 17. Useful life of farm machinery and repair: cost ratio.

Farm machinery		Service life (hours)	Annual use (hours)	Repair: cost Ratio[a]
Diesel engines		4,200	600	2:1
Power tiller (5-10 hp)		2,400	300	0.8:1
Wheel tractors:	15-30 hp	5,000	500	1:1
	30-60 hp	8,000	800	1:2:1
	60 hp and over	8,000	800	1:2:1
Manual sprayers		1,200	200	1:2:1
Power sprayers		1,200	200	1:2:1
Pumps/simple water-life machines		3,600	600	0:8:1
Tractor-attached combines		2,400	400	1:2:1

Source: Office of Agricultural Economics, Ministry of Agriculture and Cooperatives, and also in J. Intachaisri, 1983.

Note: [a] Repair - Cost ratio = total expected repair expenses during the useful life divided by initial purchase cost.

Table 18. Ranges of reasons for adopting tractors and threshers in irrigated areas, Suphanburi and Chachoengsao Princes, wet season.

Reasons for adopting mechanization	Tractors[a] (percent)	Rice threshers[b] (percent)
1. Save time in farm work	22.78	52
2. Can plant on time	20.78	n.a.
3. Easy and reduce drudgery	18.56	8
4. Butter ploughing/job	12.32	9
5. Increase output	5.62	n. a.
6. No animal and human labor available	4.21	8
7. Reduced weed	3.74	n. a.
8. Lower costs	n. a.	7
9. Other season	3.42	16
Total samples	196	222

Source: Field survey, the Consequences of Small Rice Farm Mechanization in Thailand, IRRI.

Note: [a] Only Suphanburi, 1981/82 wet season.

[b] 1978/1979 season.

n.a. not available or not applicable.

Table 19. Effects of tractors and power threshers on employment and yields.

Types of machine	Employment (manday/ha)				Yield (kg/ha)	
	Wet season		Dry season		Wet season	Dry season
	Family Labor	Hired Labor	Family Labor	Hired Labor		
Two-wheel tractor[a]	-12.4	+4.2	-12.4	+4.2	0	0
Small four-wheel tractor[a]	-14.7	+1.9	-14.9	+1.9	0	0
Large four-wheel tractor[a]	-15.6	+1.1	-15.6	+1.1	0	0
Power thresher[b]	- 5.0	-5.0	-5.0	-5.0	+50	+50

Sources: Estimated from Table 2.13 and 2.14 of Power Input Utilization and Substitution in Thai Rice Production, 1983, by Sukurat Montreevat.

Table 20. Annual government outlay for farm mechanization, 1965-1978.

Item	1965	1970	1975	1978
Total national goverment budget	12,870	27,300	48,000	81,000
Of which: outlay for agricutlure	413.8	636.6	4,175.8	6,938.9
Of which: outlay for farm mechanization	4.2	6.4	42.2	70.1

Source: Office of Agricultural Economics, Ministry of Agriculture and Cooperatives, also in the study by J. Intachaisri, 1983.

Table 21 Existence of Farm Mechanization

I.R.R.I. Rice Policy Model
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Policy summary:

-Population: present growth rate = 2.30%; growth rate in 10 years = 2.00%;
government cost = 0.01 million baht per annum

-Fertilizer: starting supplies =300.00 thou. tonnes; growth rate = 5.00% pa;
government subsidy per tonne of urea = -64350.00 baht

-Land: depreciation rate = 5.00% pa;
rehabilitation rate =100000 ha pa, costing 4842 baht per ha.
new irrigated land =200000 ha pa, costing 25250 baht per ha.

-Mechanisation policies:

FPower tiller
numbers in use =234,851 projected rate of increase = 5 %, subsidy per machine = 0 baht.

DPower tiller
numbers in use = 49,500 projected rate of increase = 5 %, subsidy per machine = 0 baht.

D.small tractor
numbers in use = 4,850 projected rate of increase = 5 %, subsidy per machine = 0 baht.

F.small tractor
numbers in use = 34,308 projected rate of increase = 5 %, subsidy per machine = 0 baht.

Large tractor
numbers in use = 50,044 projected rate of increase = 5 %, subsidy per machine = 0 baht.

Power Thresher
numbers in use = 20,601 projected rate of increase = 5 %, subsidy per machine = 0 baht.

Results summary:

Yr	Popln	Fert	Yield	Export	- Per Capita incomes -					Totlab	HireLab	GovtCost
	m.	'000t	mt	mt	L/L	S.f.	L.f.	Urb	Rn-f	million	mandays	m.baht
0	-	-	-	-	6805	7238	11231	13347	8680	-	-	-
1	47.90	300.00	19.64	9.35	6866	8572	12642	13647	8811	712.4	408.97	-13770.80
2	48.99	315.00	20.26	9.65	6867	8601	12655	13634	8814	720.0	414.79	-14736.00
3	50.08	330.75	20.90	10.10	6867	8619	12668	13622	8818	727.5	420.72	-15749.60
4	51.19	347.29	21.55	10.57	6867	8638	12683	13612	8821	734.8	426.71	-16813.70
5	52.31	364.65	22.21	11.05	6867	8656	12698	13602	8825	742.0	432.76	-17931.10
6	53.43	382.88	22.90	11.56	6867	8674	12713	13592	8829	749.0	438.83	-19104.40
7	54.56	402.03	23.60	12.08	6867	8693	12730	13584	8834	755.6	444.90	-20336.30
8	55.71	422.13	24.32	12.62	6867	8711	12747	13576	8839	761.9	450.94	-21629.90
9	56.85	443.24	25.06	13.18	6868	8730	12764	13568	8844	767.7	456.93	-22988.10
10	58.01	465.40	25.82	13.76	6868	8749	12783	13561	8849	773.1	462.84	-24414.20

Table 22 Absence of Farm Mechanization

I.R.R.I. Rice Policy Model
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Policy summary:

-Population: present growth rate = 2.30%; growth rate in 10 years = 2.00%;
government cost = 0.01 million baht per annum

-Fertilizer: starting supplies =300.00 thou. tonnes; growth rate = 5.00% pa;
government subsidy per tonne of urea = -64350.00 baht

-Land: depreciation rate = 5.00% pa;
rehabilitation rate =100000 ha pa, costing 4842 baht per ha.
new irrigated land =200000 ha pa, costing 25250 baht per ha.

-Mechanisation policies:

FPower tiller
numbers in use = 0 projected rate of increase = 0 %, subsidy per machine = 0 baht.

DPower tiller
numbers in use = 0 projected rate of increase = 0 %, subsidy per machine = 0 baht.

D.small tractor
numbers in use = 0 projected rate of increase = 0 %, subsidy per machine = 0 baht.

F.small tractor
numbers in use = 0 projected rate of increase = 0 %, subsidy per machine = 0 baht.

Large tractor
numbers in use = 0 projected rate of increase = 0 %, subsidy per machine = 0 baht.

Power Thresher
numbers in use = 0 projected rate of increase = 0 %, subsidy per machine = 0 baht.

Results summary:

Yr	Popln m.	Fert '000t	Yield mt	Export mt	- Per Capita incomes - L/L	S.f.	L.f.	Urb	Rn-f	Totlab million mandays	HireLab	GovtCost m.baht
0	-	-	-	-	6805	7238	11231	13347	8680	-	-	-
1	47.90	300.00	17.87	7.58	6896	8683	13003	13647	8811	1119.7	568.69	-13770.80
2	48.99	315.00	18.40	7.77	6898	8715	13029	13634	8814	1147.6	582.50	-14736.00
3	50.08	330.75	18.94	8.13	6899	8737	13081	13622	8818	1176.4	596.81	-15749.60
4	51.19	347.29	19.50	8.50	6901	8760	13135	13612	8821	1206.3	611.61	-16813.70
5	52.31	364.65	20.06	8.88	6902	8782	13189	13602	8825	1237.0	626.91	-17931.10
6	53.43	382.88	20.64	9.28	6904	8805	13244	13592	8829	1268.7	642.68	-19104.40
7	54.56	402.03	21.23	9.69	6906	8828	13301	13584	8834	1301.4	658.94	-20336.30
8	55.71	422.13	21.83	10.11	6908	8851	13358	13576	8839	1334.9	675.69	-21629.90
9	56.85	443.24	22.45	10.55	6910	8875	13418	13568	8844	1369.4	692.91	-22988.10
10	58.01	465.40	23.07	11.00	6912	8898	13479	13561	8849	1404.9	710.62	-24414.20

Table 23 A 10% increase in irrigation investment

I.R.R.I. Rice Policy Model
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Policy summary:

-Population: present growth rate = 2.30%; growth rate in 10 years = 2.00%;
government cost = 0.01 million baht per annum

-Fertilizer: starting supplies =300.00 thou. tonnes; growth rate = 5.00% pa;
government subsidy per tonne of urea = -64350.00 baht

-Land: depreciation rate = 5.00% pa;
rehabilitation rate = 3000 ha pa, costing 4842 baht per ha.
new irrigated land = 30000 ha pa, costing 25250 baht per ha.

-Mechanisation policies:

FPower tiller
numbers in use =234,851 projected rate of increase = 5 %, subsidy per machine = 0 baht.

DPower tiller
numbers in use = 49,500 projected rate of increase = 5 %, subsidy per machine = 0 baht.

D.small tractor
numbers in use = 4,850 projected rate of increase = 5 %, subsidy per machine = 0 baht.

F.small tractor
numbers in use = 34,308 projected rate of increase = 5 %, subsidy per machine = 0 baht.

Large tractor
numbers in use = 50,044 projected rate of increase = 5 %, subsidy per machine = 0 baht.

Power Thresher
numbers in use = 20,601 projected rate of increase = 5 %, subsidy per machine = 0 baht.

Results summary:

Yr	Popln m.	Fert '000t	Yield mt	Export mt	- Per Capita incomes - L/L	S.f.	L.f.	Urb	Rn-f	Totlab million	HireLab mandays	GovtCost m.baht
0	-	-	-	-	6805	7238	11231	13347	8680	-	-	-
1	47.90	300.00	19.64	9.35	6866	8572	12642	13647	8811	712.4	408.97	-18533.00
2	48.99	315.00	19.74	9.12	6864	8562	12634	13628	8811	692.4	400.95	-19498.20
3	50.08	330.75	19.84	9.04	6863	8543	12627	13610	8811	671.5	392.61	-20511.70
4	51.19	347.29	19.94	8.97	6861	8524	12620	13594	8812	649.6	383.91	-21575.90
5	52.31	364.65	20.05	8.90	6859	8506	12614	13580	8813	626.7	374.84	-22693.30
6	53.43	382.88	20.17	8.85	6857	8489	12608	13566	8813	602.8	365.37	-23866.60
7	54.56	402.03	20.30	8.79	6855	8471	12603	13554	8814	577.7	355.47	-25098.50
8	55.71	422.13	20.43	8.75	6853	8454	12599	13542	8815	551.4	345.13	-26392.00
9	56.85	443.24	20.56	8.71	6851	8437	12595	13532	8817	523.9	334.31	-27750.20
10	58.01	465.40	20.70	8.68	6848	8420	12591	13522	8818	495.0	322.97	-29176.30

Table 24 Irrigation Investment leading to increasing trends of employment

I.R.R.I. Rice Policy Model
****

Policy summary:

-Population: present growth rate = 2.30%; growth rate in 10 years = 2.00%;
government cost = 0.01 million baht per annum

-Fertilizer: starting supplies =300.00 thou. tonnes; growth rate = 5.00% pa;
government subsidy per tonne of urea = -64350.00 baht

-Land: depreciation rate = 5.00% pa;
rehabilitation rate = 75000 ha pa, costing 4842 baht per ha.
new irrigated land =200000 ha pa, costing 25250 baht per ha.

-Mechanisation policies:

FPower tiller
numbers in use =234,851 projected rate of increase = 5 %, subsidy per machine = 0 baht.

DPower tiller
numbers in use = 49,500 projected rate of increase = 5 %, subsidy per machine = 0 baht.

D.small tractor
numbers in use = 4,850 projected rate of increase = 5 %, subsidy per machine = 0 baht.

F.small tractor
numbers in use = 34,308 projected rate of increase = 5 %, subsidy per machine = 0 baht.

Large tractor
numbers in use = 50,044 projected rate of increase = 5 %, subsidy per machine = 0 baht.

Power Thresher
numbers in use = 20,601 projected rate of increase = 5 %, subsidy per machine = 0 baht.

Results summary:

Yr	Popln	Fert	Yield	Export	- Per Capita incomes -					Totlab	HireLab	GovtCost
	m.	'000t	mt	mt	L/L	S.f.	L.f.	Urb	Rn-f	million mandays		m.baht
0	-	-	-	-	6805	7238	11231	13347	8680	-	-	-
1	47.90	300.00	19.64	9.35	6866	8572	12642	13647	8811	712.4	408.97	-13891.80
2	48.99	315.00	20.20	9.58	6866	8596	12652	13633	8814	716.5	413.09	-14857.10
3	50.08	330.75	20.77	9.97	6866	8611	12662	13621	8817	720.2	417.21	-15870.60
4	51.19	347.29	21.36	10.38	6866	8625	12673	13609	8820	723.7	421.30	-16934.80
5	52.31	364.65	21.96	10.80	6866	8640	12685	13598	8823	726.8	425.33	-18052.20
6	53.43	382.88	22.57	11.23	6866	8654	12697	13588	8827	729.4	429.29	-19225.50
7	54.56	402.03	23.20	11.68	6866	8668	12710	13579	8831	731.6	433.14	-20457.40
8	55.71	422.13	23.85	12.15	6865	8683	12723	13570	8835	733.1	436.86	-21750.90
9	56.85	443.24	24.51	12.63	6865	8697	12737	13562	8840	734.1	440.43	-23109.10
10	58.01	465.40	25.19	13.13	6865	8711	12752	13555	8844	734.4	443.82	-24535.20

Table 25 A 1% increase in fertilizer application

I.R.R.I. Rice Policy Model
****

Policy summary:

-Population: present growth rate = 2.30%; growth rate in 10 years = 2.00%;
government cost = 0.01 million baht per annum

-Fertilizer: starting supplies =300.00 thou. tonnes; growth rate = 1.00% pa;
government subsidy per tonne of urea = -64350.00 baht

-Land: depreciation rate = 5.00% pa;
rehabilitation rate =100000 ha pa, costing 4842 baht per ha.
new irrigated land =200000 ha pa, costing 25250 baht per ha.

-Mechanisation policies:

FPower tiller
numbers in use =234,851 projected rate of increase = 5 %, subsidy per machine = 0 baht.

DPower tiller
numbers in use = 49,500 projected rate of increase = 5 %, subsidy per machine = 0 baht.

D.small tractor
numbers in use = 4,850 projected rate of increase = 5 %, subsidy per machine = 0 baht.

F.small tractor
numbers in use = 34,308 projected rate of increase = 5 %, subsidy per machine = 0 baht.

Large tractor
numbers in use = 50,044 projected rate of increase = 5 %, subsidy per machine = 0 baht.

Power Thresher
numbers in use = 20,601 projected rate of increase = 5 %, subsidy per machine = 0 baht.

Results summary:

Yr	Popln m.	Fert '000t	Yield mt	Export mt	- Per Capita incomes - L/L	S.t.	L.f.	Urb	Rn-f	Totlab million	HireLab mandays	GovtCost m.baht
0	-	-	-	-	6805	7238	11231	13347	8680	-	-	-
1	47.90	300.00	19.64	9.35	6866	8572	12642	13647	8811	712.4	408.97	-13770.80
2	48.99	303.00	20.20	9.58	6867	8594	12655	13634	8814	720.0	414.79	-13963.80
3	50.08	306.03	20.77	9.97	6867	8605	12668	13622	8818	727.5	420.72	-14158.80
4	51.19	309.09	21.35	10.37	6867	8616	12683	13612	8821	734.8	426.71	-14355.80
5	52.31	312.18	21.94	10.78	6867	8627	12698	13602	8825	742.0	432.76	-14554.70
6	53.43	315.30	22.54	11.20	6867	8637	12713	13592	8829	749.0	438.83	-14755.50
7	54.56	318.46	23.16	11.64	6867	8647	12730	13584	8834	755.6	444.90	-14958.40
8	55.71	321.64	23.78	12.08	6867	8657	12747	13576	8839	761.9	450.94	-15163.40
9	56.85	324.86	24.42	12.55	6868	8666	12764	13568	8844	767.7	456.93	-15370.30
10	58.01	328.11	25.08	13.02	6868	8675	12783	13561	8849	773.1	462.84	-15579.40

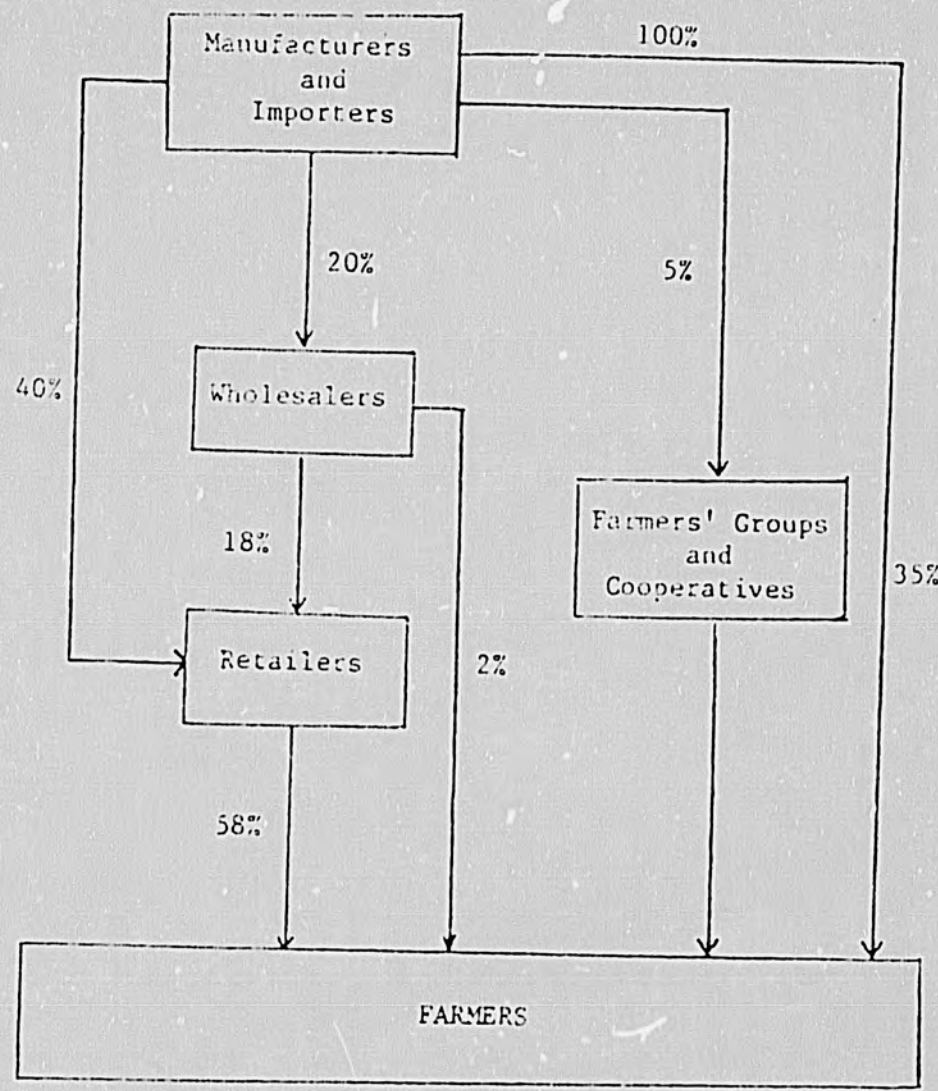

FIGURE 1 MARKETING CHANNELS OF TRACTORS

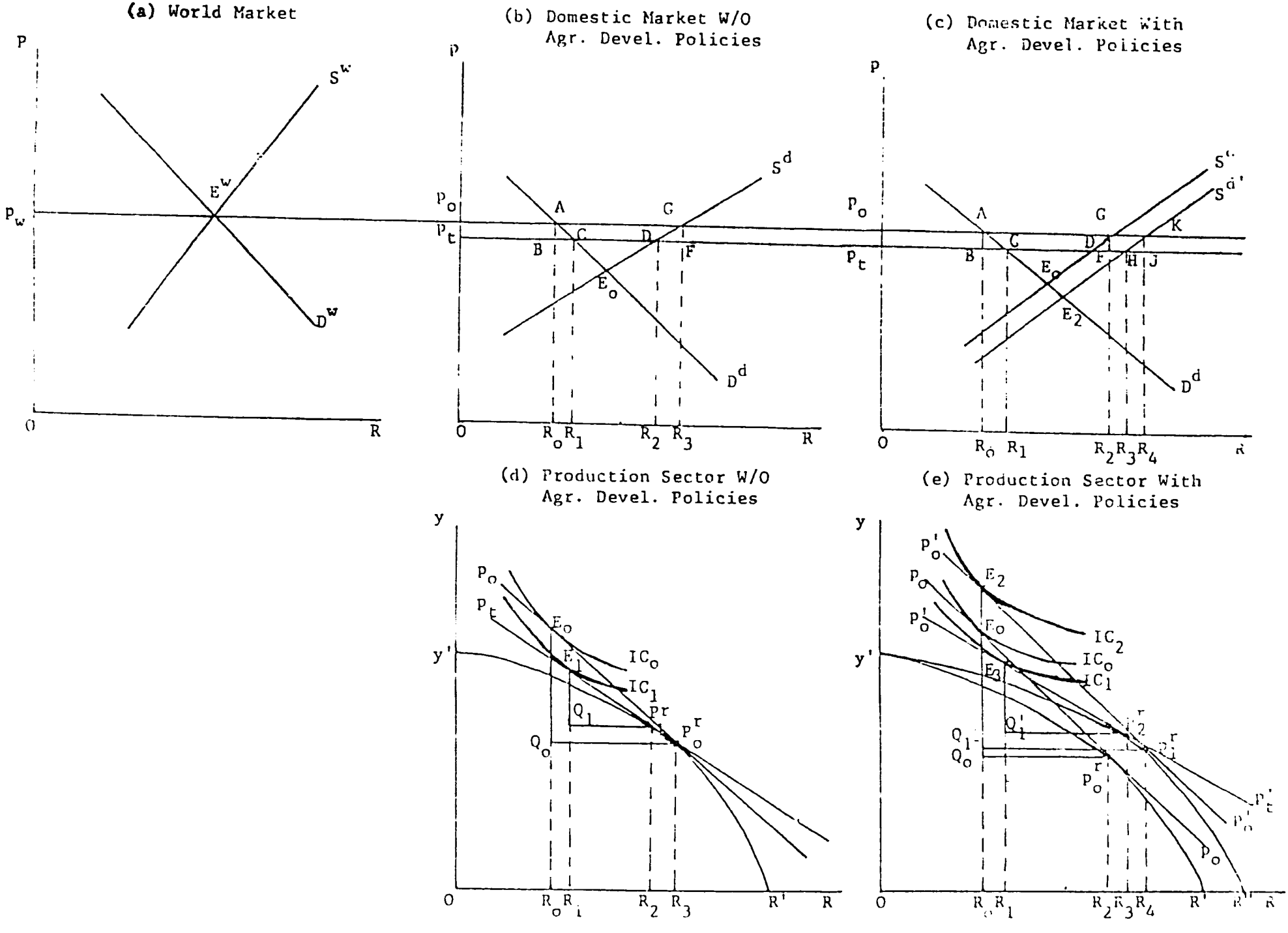

FIGURE 2 IMPACTS OF TRADE AND AGRICULTURAL DEVELOPMENT POLICIES

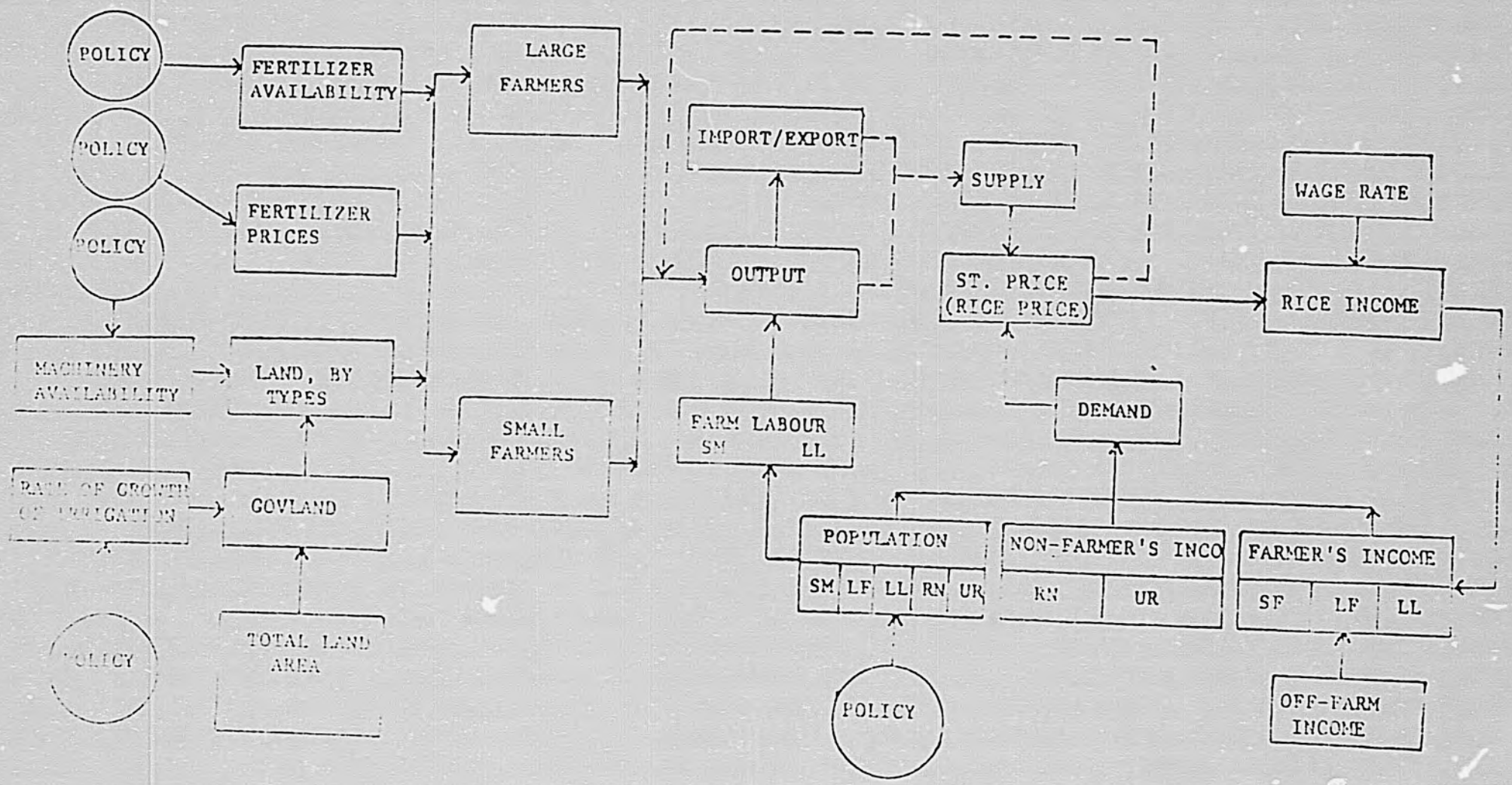

FIGURE 3 PROTOTYPE RICE POLICY MODEL

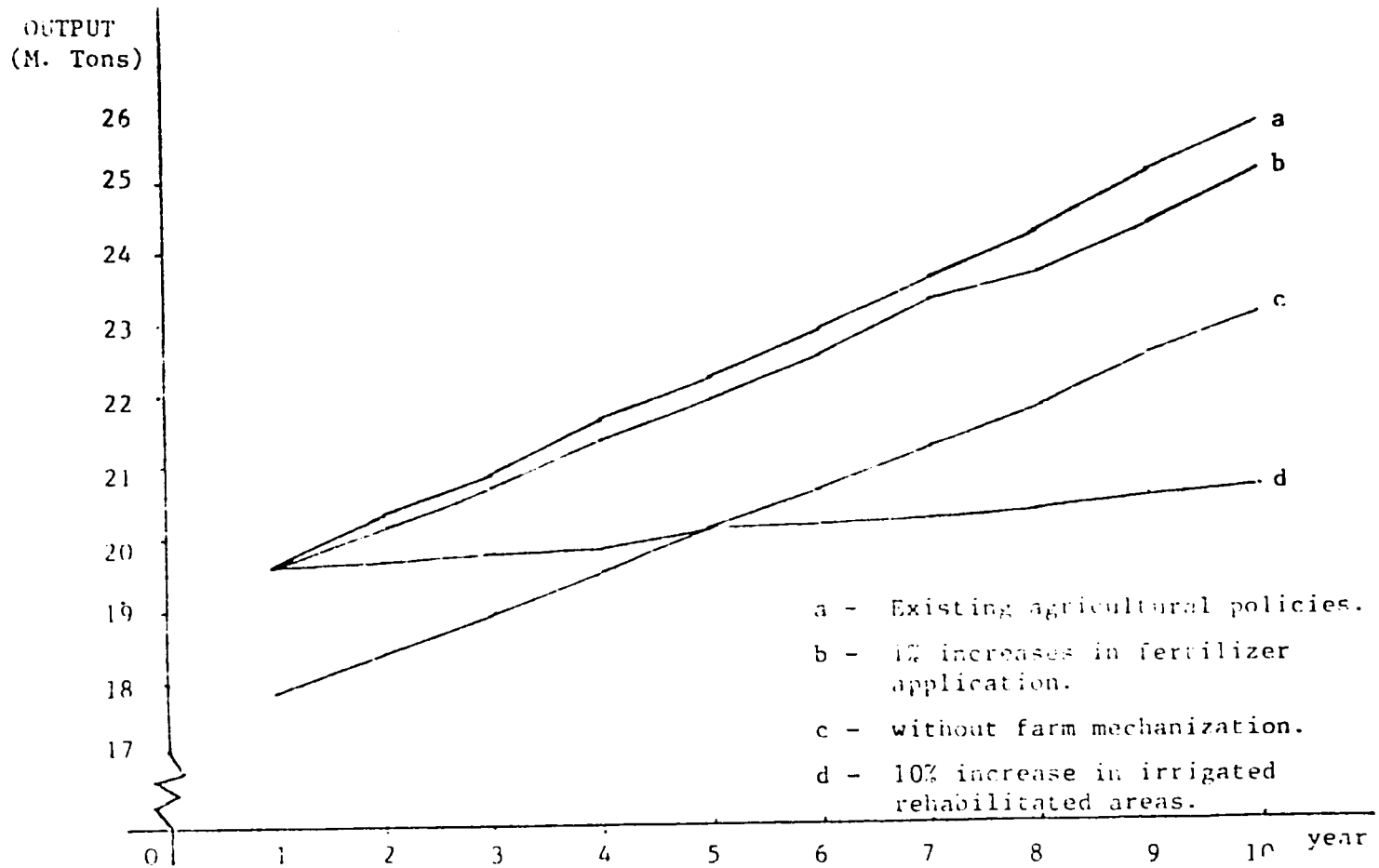

FIGURE 4: IMPACTS OF AGRICULTURAL POLICIES ON TOTAL OUTPUT, THAILAND.

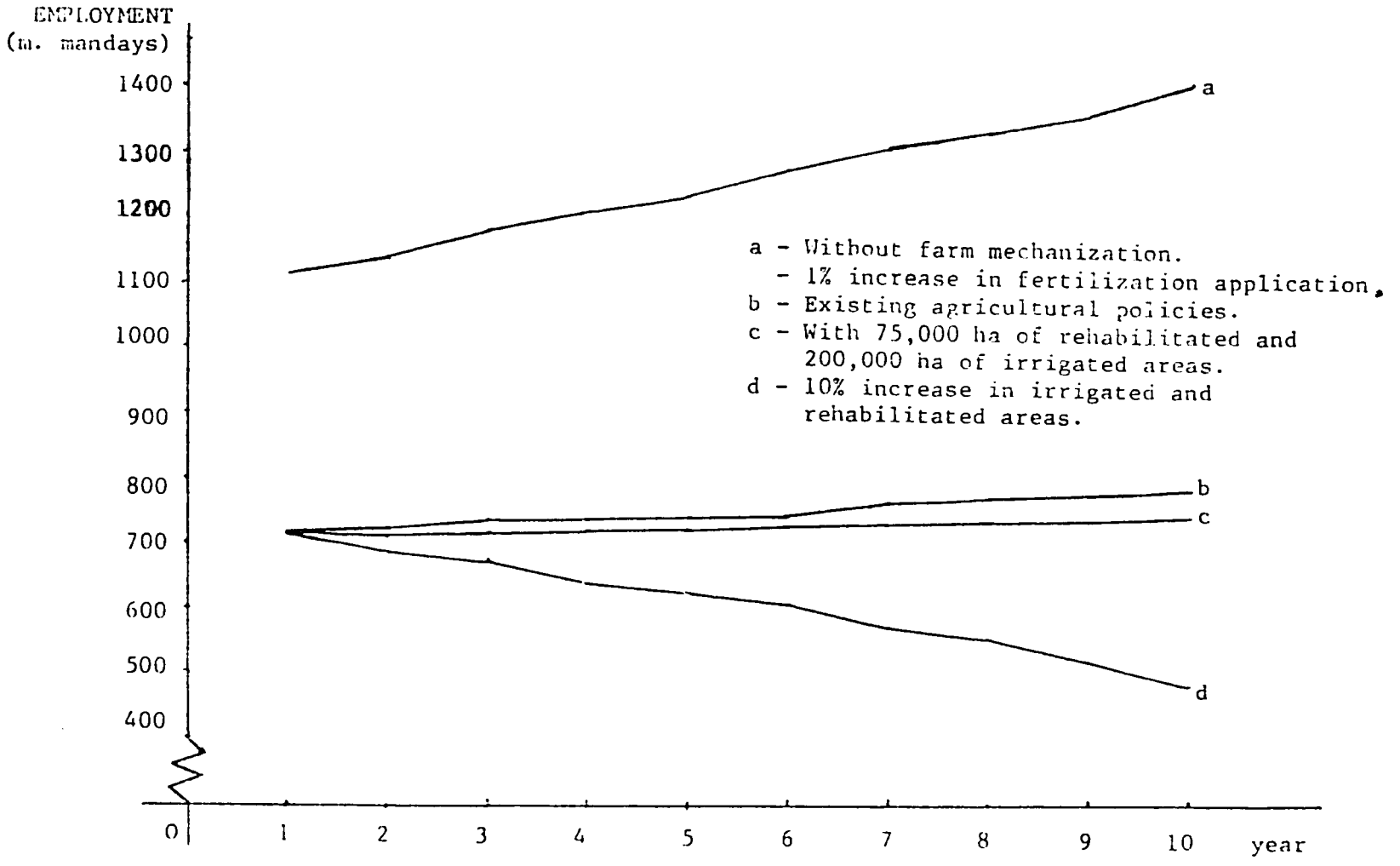

FIGURE 5: IMPACTS OF AGRICULTURAL POLICIES ON TOTAL EMPLOYMENT, THAILAND.

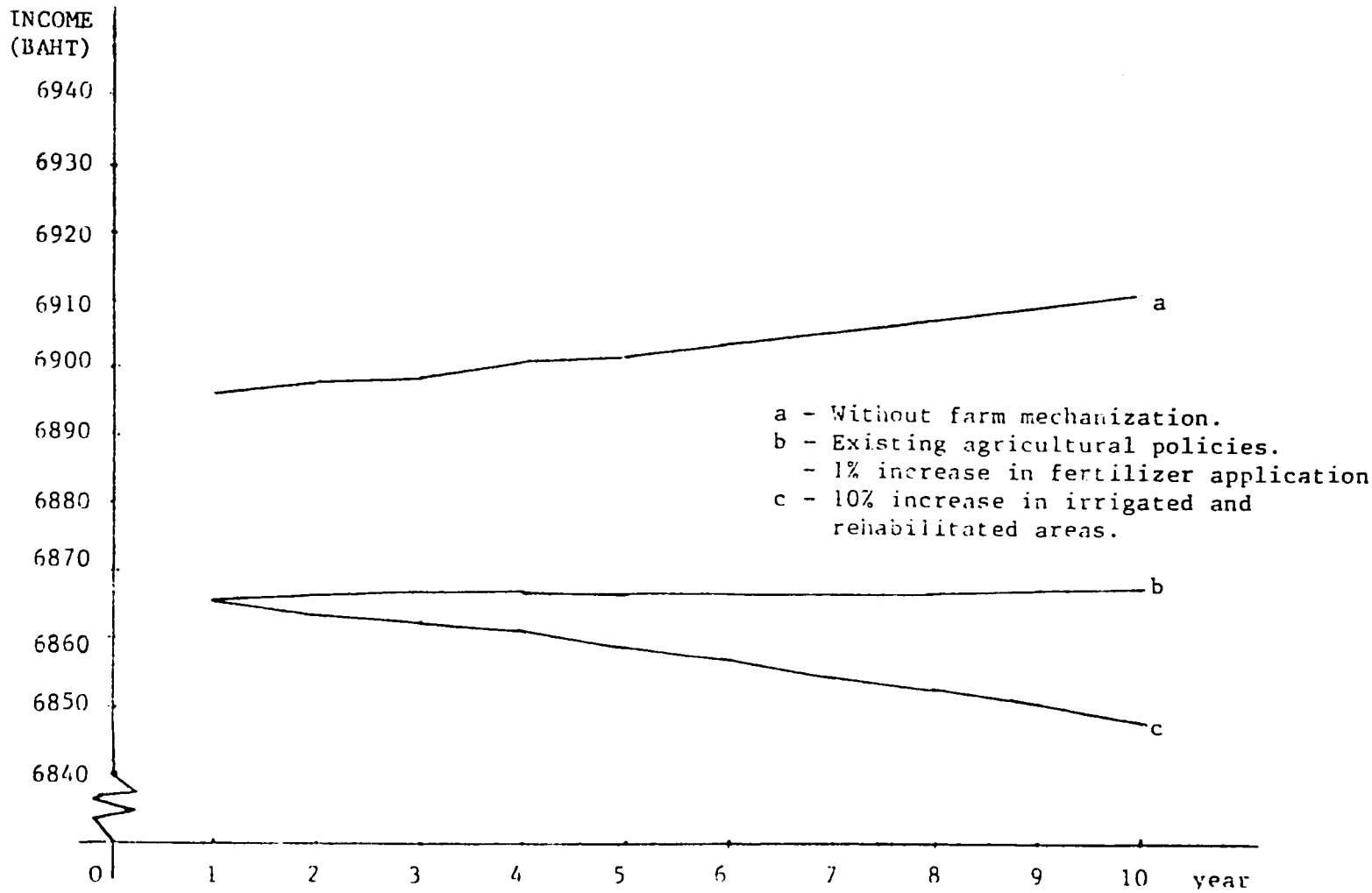

FIGURE 6: IMPACTS OF AGRICULTURAL POLICIES ON PER CAPITA INCOME OF LANDLESS FARMERS, THAILAND.

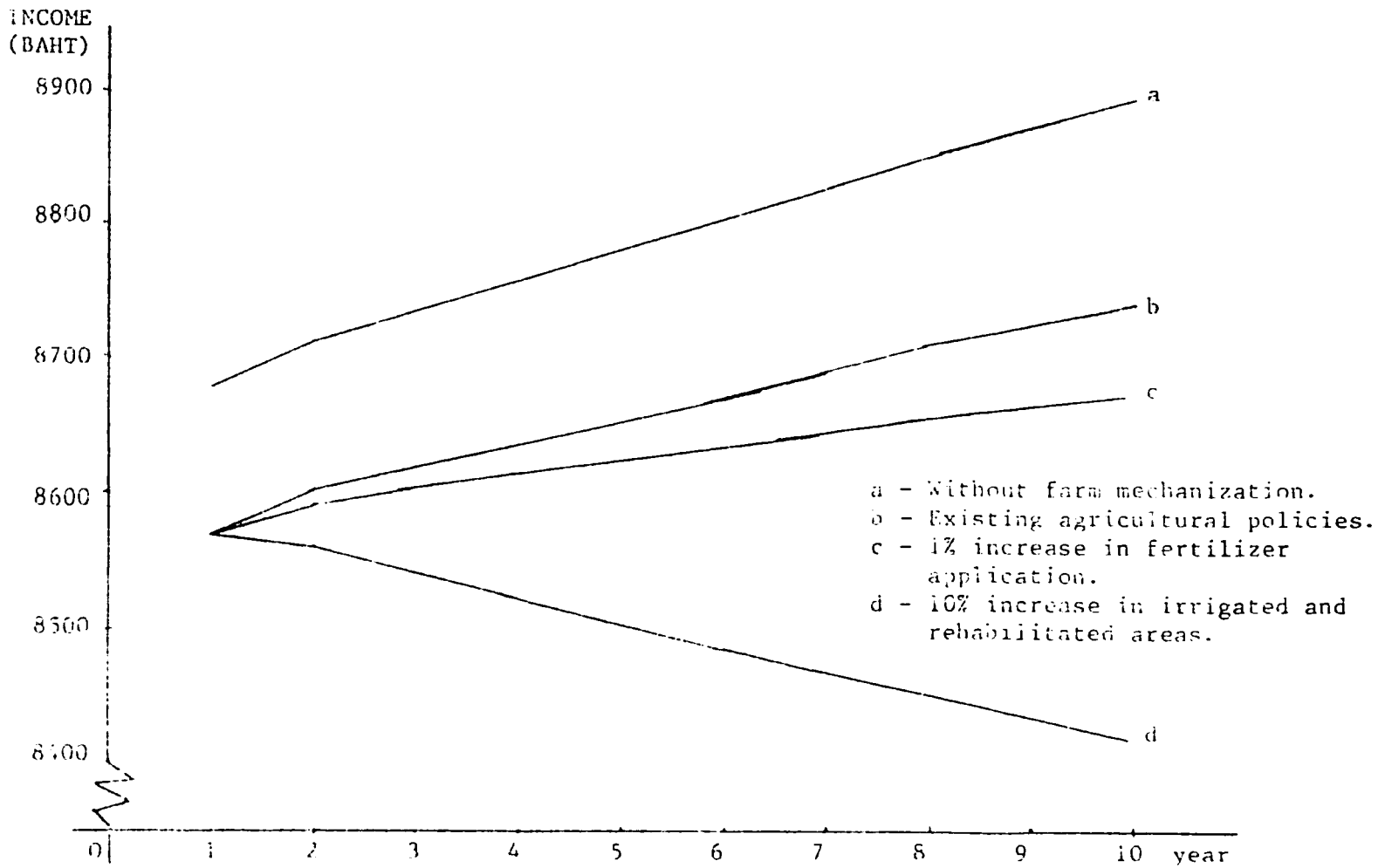

FIGURE 7: IMPACTS OF AGRICULTURAL POLICIES ON PER CAPITA INCOME OF SMALL FARMERS, THAILAND.

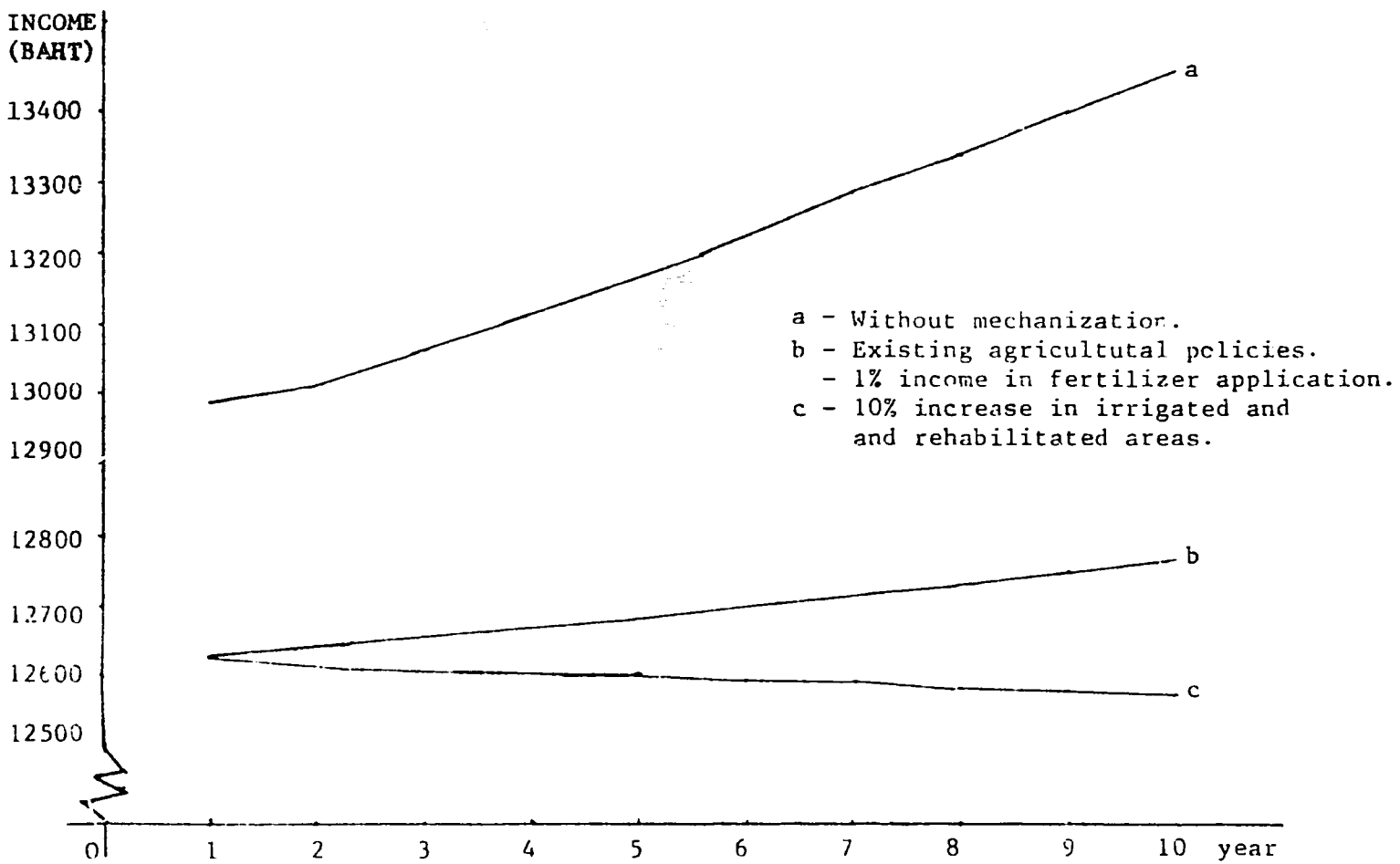

FIGURE 8: IMPACTS OF AGRICULTURAL POLICIES ON PER CAPITA INCOME OF LARGE FARMERS, THAILAND.

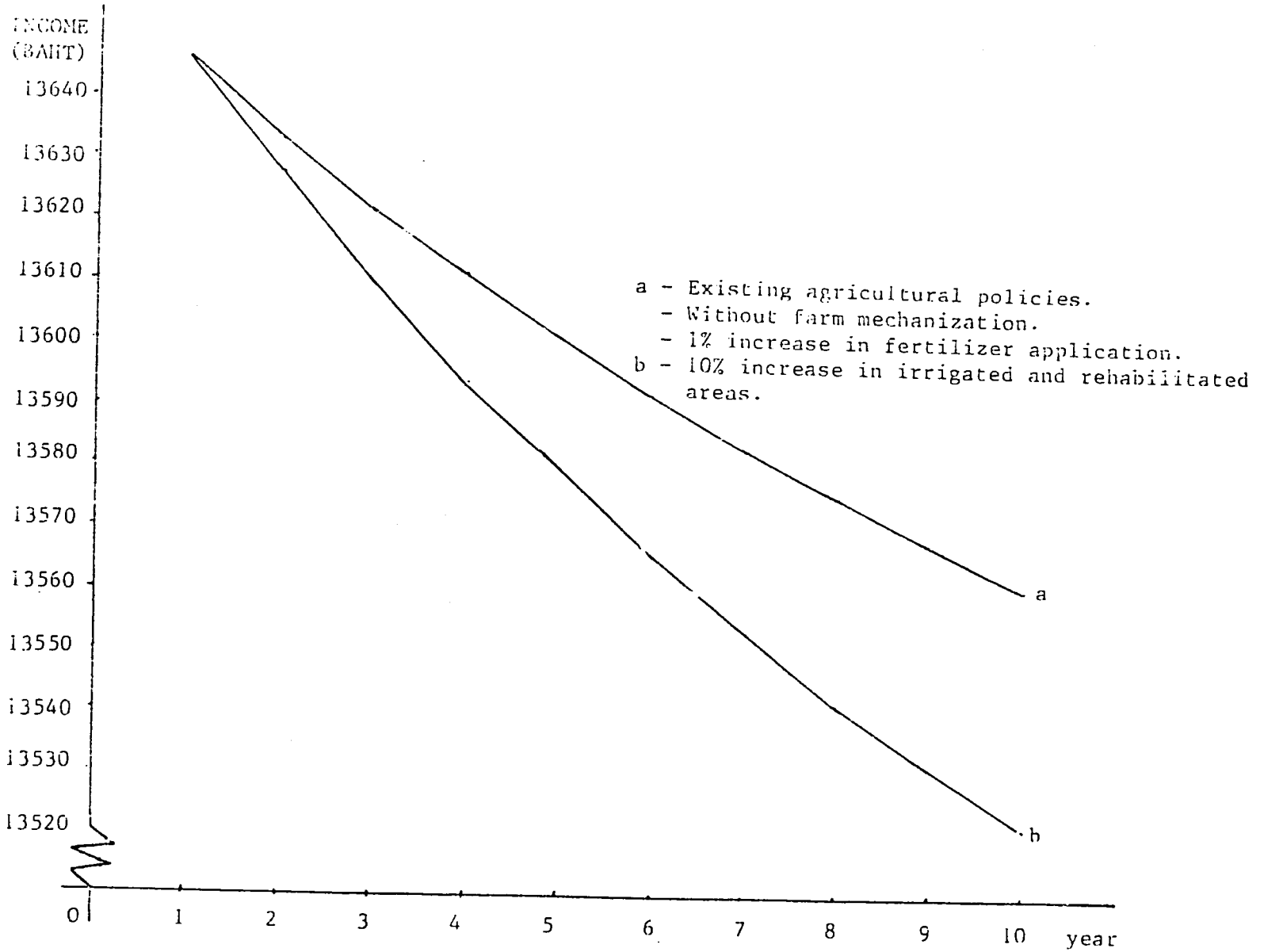

FIGURE 9: IMPACTS OF AGRICULTURAL POLICIES ON PER CAPITA INCOME OF URBAN CLASS THAILAND.

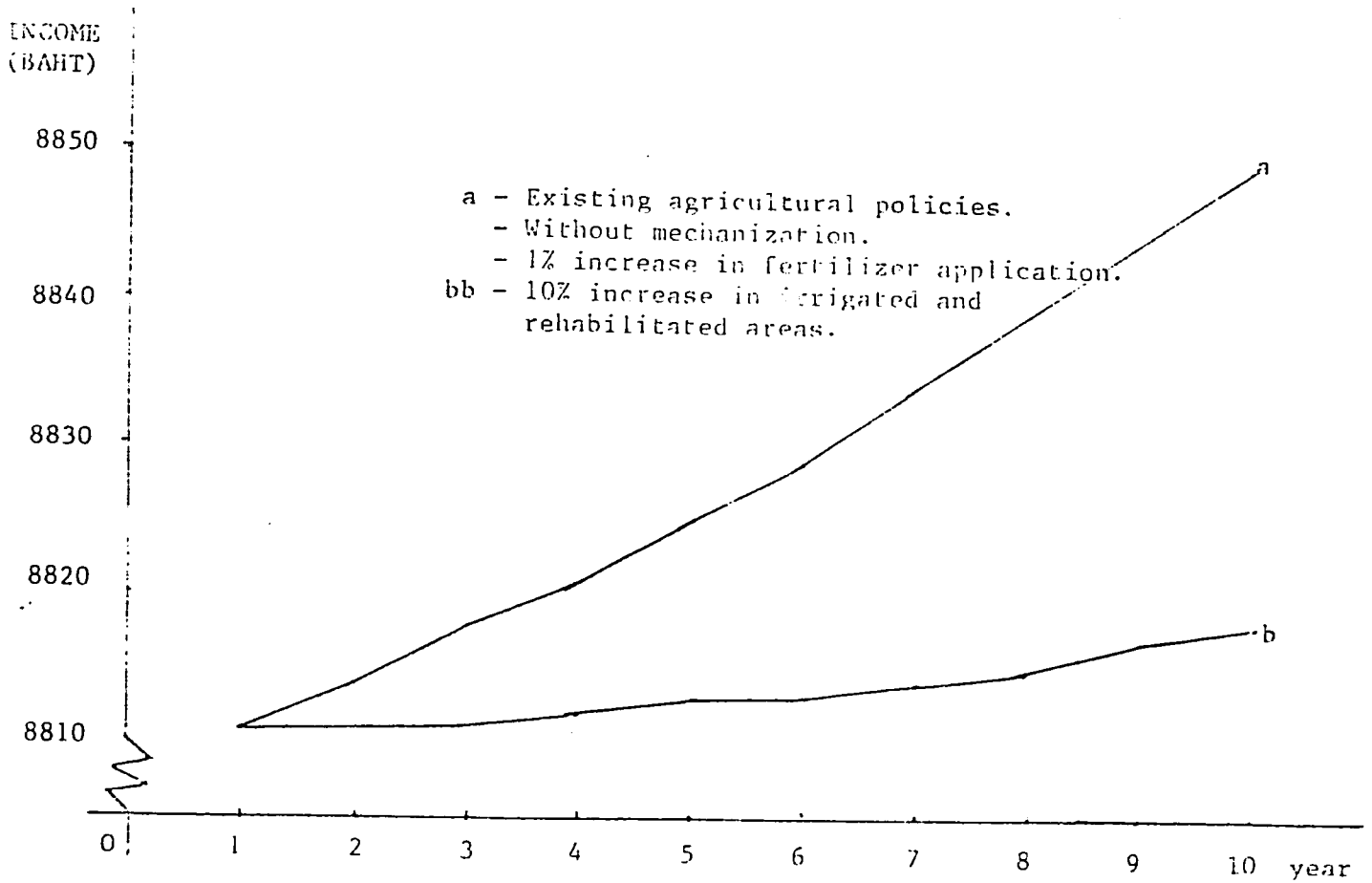

FIGURE 10: IMPACTS OF AGRICULTURAL POLICIES ON PER CAPITA INCOME OF RURAL NON-FARM, THAILAND.