

## Economies of Size for Dairy Farming : A Linear Programming Analysis

Somsak Priebprom<sup>1</sup>

### ABSTRACT

The main objective of this study was to assess the economies of scale of dairy farming in the study area with a view to improving dairy productivity and increasing farm income. Forty-five dairy farms in the Muak Lek and Pakchong Districts were randomly selected for study. These sample were stratified into 3 operational size classes : small ( 10 dairy cows), medium (11-20 dairy cows), large ( 20 dairy cows). Linear programming model was developed to represent dairy farms with 3 operational size groups in the study. The major results indicated that net farm income would be increased through reallocation of land and labor. More productive cows per farm could be raised under the same resource constraints if optimally allocated. The net income derived from the model was higher than actual net income by 45, 39 and 57 percent for small, medium and large farms, respectively. The study also indicated that if dairy farmers raise only milk cows (instead of raising female calves as well which most do now), they will increase their income using the same amount of resources. The net income generated from the model is higher than that of the actual practice by 28, 44 and 39 percent on small, medium and large farms, respectively. This analysis showed that the net income for all sizes of dairy farms could be increased by optimal re-allocation of available resources.

### INTRODUCTION

Commercial dairy farming in Thailand was first established in 1961 by the Royal Thai Government (RTG) with the assistance of the Danish Government at Muak Lek District, Saraburi Province. At that time, there were only 114 dairy farmers with about 3,450 dairy cows. Since then, dairying has rapidly spread to other areas such as areas near Bangkok to Ayadhaya, Nakorn Pathom, Ratchaburi, Chiengmai, and Prachaup Khiri-Khan Provinces. There has been a marked increase in the number of dairy farmers since 1961, and in the number of dairy cows raised.

---

<sup>1</sup>Dept. of Agricultural Economics, Faculty of Economics and Business Administration, Kasetsart Univ.

In 1984 there were 4,000 dairy farmers with 23, 850 dairy cows in Thailand. These dairy farms helped employ 1,500 laborers in rural areas. The quantity of fresh milk produced was 12,2000 tons in 1977, 43,429 tons in 1984 (OAE, 1985). However, even with such increases, total Thai milk production is still below the target set in the National Social and Economic Development Plan. For instance, total domestic milk production was 26,400 in 1982, 38,000 tons in 1983, and 43,429 tons in 1984. The national targets for milk production were set at 33,000 tons for 1982, 40,500 tons for 1983, and 45,997 tons for 1984. (OAE, 1985).

The failure of domestic milk production to reach the targets was a result of the industry's low productivity. According to a survey in 1983 by the OAE, Thai dairy cows averaged only 7.38 kgs. of milk per day compare to 15 kgs. per cow per day in the United States.

In 1984 production of fresh raw milk in Thailand was 118.98 tons a day (43,429 tons per year). Domestic milk production amounted to only 5 percent of the country's total domestic consumption of milk and dairy products. The total consumption of milk and dairy products is equivalent to 2,536 tons of fresh milk per day, or 925,640 tons of fresh milk a year (OAE, 1984). To meet this demand, dairy products worth about 2 billion baht were imported in 1984. Modified milk for infants, powdered non-fat milk, and butter fat are the major imported dairy products accounting for 52 percent of dairy import value. Approximately 46 percent of dairy import value is not-fat dry milk and butter fat. These are used by domestic dairy product industries as raw materials in, for example, such as ready-to-drink milk, sweetened condensed milk, modified milk for infants, ghee, cheese and ice-cream. Imported dairy products contributed to Thailand's unfavorable balance of trade. Thailand faced a large deficit balance of trade of 69,376 million baht in 1984 (OAE, 1985).

Therefore, it may be helpful to understand what Thai dairy farmers do and why, and to seek the optimal size of dairy farming operation. Without a clearer understanding of dairy farm operations and the problems related to optimal scale of milk production, it may be difficult for the RTG to determine what policies and programs will improve productivity, reduce production costs, and increase the domestic supply of milk.

This study aims to assess the optimal scale of dairy operations for small, medium and large farm size by taking into account the dairy farm households' resource constraints and other restrictions faced by dairy farmers. Results of this study may be useful to dairy farmers who want to increase both productivity and income from milk production. The information obtained from this study may also be used by the government to design and initiate appropriate policies to over-come domestic milk production problems.

## METHODOLOGY

Muak Lek District in Saraburi Province and Pakchong District in Nakorn Ratchasima Province were selected as the study area. There are many dairy farmers in both locations. This makes it possible both to stratify and compare these farms in 3 different operational size classes with samples of sufficient number of samples. Forty five dairy farms were randomly selected for data collection. Of these 45 farms 18, 19 and 8 farms were randomly chosen from small, medium and large size farm groups, respectively.

Both descriptive and quantitative analyses were employed in this study to achieve the objectives. Descriptive analysis provides a better understanding of dairy farm production practices and the behavior of dairy farmers in the study area. Under descriptive analysis some basic statistical techniques such as simple averages, frequencies, and percentages are used. The analysis serves as a source of preliminary information for the quantitative analysis namely, linear programming model for the representative farms.

## GENERAL CHARACTERISTICS OF DAIRY FARMS

The dairy farms in the study are grouped into 3 different size classes, small, medium and large depending on the number of dairy cow raised. Small farms are those with less than 10 head. Farms with 10 to 20 head are considered to be of medium size. Large farms are those with more than 20 dairy cows. The general characteristics and resource constraints of each class of dairy farm in the study area are presented and compared in this section.

### Family Composition and Labor Force

The family size of all dairy farms averaged 4.6 persons per family. The number of persons per family varied by farm size. Larger farms had larger families than small farms. Size of small farm families averaged 4 persons, while those of both medium and large farm families averaged 5 members per family.

As is typical with Thai farmers, the main source of labor for these dairy farm operations came from the family, itself. Few workers were hired, except on the larger farms. In this study, family labor force refer to any member aged 12 to 60 years. This study also classified the labor force into full-time and part-time workers. Family workers who devoted at least 8 hours a day to farm work were classified as full-time labor. Part-time labor refers to family members who worked less than 8 hours a day, usually about 2 to 4 hours. This definition will assist in the estimation of family labor supply available for dairy farming in the subsequent analysis, where the optimum herd size for each family size is determined. The supply of family labor is one of the major constraints on the number of cattle which could be handled by any farmers.

For each farm, there were 2.1 persons or 46 percent of all family members in the labor force. Of these 1.8 persons or 40 percent were full-time workers and the other 0.3 persons or 6.7 percent worked on a part-time basis.

The number of family members in the labor force did not vary by size of dairy farm. Medium farms had a larger family labor force than small and large farms. There were about 2.5 persons or 52 percent of the members in the labor force of the medium size farm households. The small and large farm households had only 1.7 (46 percent) and 2 persons (40 percent), respectively, in the labor force.

### **Size of Land Holding and Land Use**

The size of land, and particularly the size of pasture held by dairy farmers, affects the number of dairy cattle which can be raised on a farm. It appears that the size of land holding, allocated for pasture, accounted for 72 percent of the total land holdings. The size of land holding of small dairy farms allocated for pasture was 17 rai or 77 percent of their total land holding. About 1.3 rai was used for the home stead and shelter for dairy cattle. The remaining 3.7 rai, unsuitable for pasture, was either occupied by a pond or was idle. The average land holding of the medium size farms was 26 rai. Approximately 23 rai or 88 percent of the total land holding was pasture. Only 1.6 rai or 6 percent was used as farmers' housing and cattle shelter. The remaining 1.4 rai was not cultivated. For the large dairy farms, land holdings averaged 100 rai per farm. About 68 rai was pasture. Housing compound, cattle shelter, and barn was about 3 rai. The remaining 29 rai were not cultivated because additional pasture was not yet needed. Some large farmers planned to expand their dairy business in the future. Naturally, the larger dairy farms have much more potential to expand their operations.

### **Household Income and Expenditures**

Household income of dairy farmers is generated by the sale of milk, male calves and cull cows. Dairy farmers may also sell some of their dairy cows if they urgently need cash. The average income earned was about 294,500 baht a year. The main source of household income was from selling milk. On the average, income from the sale of milk accounted for 93 percent of the total household farm income. Income from the sale of dairy cows accounted for only 5 percent, from the sale of calves and cull cows only about 2 percent. As expected, annual household income increased with farm size. Annual income of small and medium farmers was 120,500 baht and 260,900 baht, respectively. The annual income earned by large dairy farmers (501,958 baht) was more than four times of that of small farmers. Proportionally the income obtained from the sale of dairy cows by medium farms was higher than for large farms. The medium farmers tended to face more severe cash flow problems.

Household expenditures of dairy farmers were classified into consumption and production expenses. Household consumption expenditures included outlays for food and non-food. Non-food expenses included education, medicine, clothing, and social and religious activities. Household consumption expenditures averaged 63,612 baht a year, 22 percent of annual household income. Of these expenses, 45,215 baht was spent on food and 18,397 baht on non-food items.

Expenses for dairy production accounted for 54 percent of total farm income or 159,531 baht a year. Household expenditures for consumption and production purposes varied by farm size. Consumption costs increased with size of farm. Large farms also spent a higher percentage of farm income on production costs. Large dairy farms spent 57 percent of their total income on production while small and medium farmers spent 52 and 49 percent, respectively.

Net farm household income is what remains after the deduction of both consumption and production expenditures from total gross farm income. The average net household income earned by the dairy farms in total was 71,340 baht a year. The annual net income earned, respectively, by small, medium and large farms averaged 6,946, 74,595 and 122,476 baht.

### **Dairy Farming Credit**

Dairy farming requires a relatively high capital investment. The production of high quality milk requires a high quality milking parlor and the sanitary requirements are stringent. In addition, the cost of buying a young dairy cow is approximately 20,000 baht. Meeting hygienic requirements plus the costly initial investment makes dairy farming a capital intensive business. In the early stages of dairy farming, most farmers have insufficient funds and must borrow additional money. The Public Welfare Department makes loans of 60,000 baht at 6 percent interest rate over ten year for dairy farming. Most of the farmers in the sample had already repaid this original loan. At present, approximately 60 percent of them continued to require credit in order to expand their dairies, buy additional land, machinery or equipment, and construct and repair dairy sheds, milking parlors, and water supplies. Most outstandings loans were for 5 year terms. The Bank for Agriculture and Agricultural Cooperatives (BAAC) is the major lender to dairy farmers, charging 14 percent interest for intermediate term loans. One-year loans in kind (animal feed, fertilizer, chemicals) are usually obtained from the Dairy Farming Promotion Organization (DPO) or from local merchants. The current average debt carried by small farms was 39,333 baht. Medium and large farms had average debts of 56,890 and 71,625 baht, respectively.

### Dairy Farming Operations

Most dairy cattle in the study area are cross-breeds suitable for Thailand's climate. The Livestock Department of the Ministry of Agriculture and Cooperatives has established an artificial insemination program. This program aims to produce and improve cross-bred dairy cattle to develop the dairy industry in Thailand. The success of this program can be seen in the large number of cross-bred cattle currently being raised by farmers. The dairy industry in Thailand now depends on cross-breds of exotic cattle.

#### Size of Dairy Herd

The size of the herd in the sample averaged 33 heads, including 6 calves, 7 heifers (1-2 years old cattle), 3 pregnant heifer (2-3 years old) and 17 dairy cows (more than 3 years old). Number and age of cattle per farm was found to vary among farm sizes. Small farms, averaged 16 head, i.e., 3 calves, 3 young heifers, 2 pregnant heifers and 8 milking cows (two of them dry). These 6 milking cows can produce about 48 kg of milk per day (27.4 kg in the morning and 20.5 kg in the afternoon). Average milk production per milk cow was 8.3 kg per day. Medium size farms averaged 27 head of cattle. The herd included 5 calves, 5 young heifers, 3 pregnant heifers and 14 milk cows, 3 dry, which produced 94 kg of milk per day (54 kg in the morning and 40 kg in the afternoon). The milking cows averaged a 8.84 kg of milk per day. Large farms averaged 58 heads, including 11 calves, 12 young heifers, 5 pregnant heifers, and 30 milk cows (9 of which were dry). The total milk given daily by the 21 milking cows was 180 kg (103 kg in the morning and 77 kg in the afternoon). Each milk cow produced an average of 8.6 kg of milk. Dairy farmers in the study area tended to sell their male calves within 2 weeks after birth. Male calves were sold for about 500 baht each. A few farmers kept one or two male calves on their farms to encourage the cows to give more milk during the milking period.

#### Dairy Farm Activities and Labor Needs

Dairying requires a lot of labor. It is a full-time job throughout the year. Unlike crop production in which labor requirements vary widely by season, dairy farming requires a steady year-long labor. Dairy cattle must be fed and milked at least twice a day. To better understand and analyze the labor requirements for dairy farm operations, all activities were classified into 2 groups; (i) care and management of the herd and (ii) milking and related activities.

Care and management of the herd includes the labor required to water and feed the dairy herd, to prepare feed concentrate and roughage such as silage, straw, and hay, and to cut forage and take care of the herd. It also includes the labor to irrigate and renovate the pasture, to clean dairy shed and equipment, and to repair and maintain buildings and equipment.

Milking labor is required twice a day, in the morning and afternoon. Each time requires about 10-20 minutes for hand milking. The milking period is 5-8 AM and 15-17 PM. Labor utilization on the three farm size classes is shown that the larger the dairy farm, the less labor is required per cow. Labor use per cow, per year, on small, medium, and large farm is 347, 274 and 196 hours, respectively. Labor use per cow on larger farms is less than on small farms, since the larger farms use more labor-saving machines.

### Animal Feeds

The essential nutrients for dairy cattle feed are proteins, carbohydrates, fats, minerals, and vitamins. They are required for: (1) maintenance of body weight; (2) production of milk; (3) growth of the fetus; (4) growth when the animal is immature and (5) gains in weight if thin. Feeds containing the above nutrients should be given in the amount that will maximize milk production. About half of the ration consumed by the cow is used to maintain her body weight and to nourish her unborn calf. Maintenance costs will be almost the same for all cows of equal weight, no matter what their milk flow is. That is why "good milkers" are so important for profitable production.

There are two major categories of dairy cattle feed, namely, roughage and concentrate. A balanced ration of both is required to maintain body weight, to produce calves, and to produce the proper amount of milk.

### Structure of the LP Model

The general form of this LP model can be expressed as follows:

$$\text{Maximize } Z = \sum_{j=1}^n C_j X_j$$

$$\text{Subject to } \sum_{j=1}^n A_{ij} X_j \leq b_i$$

$$X_j \geq 0$$

Where:  $Z$  is an objective function

$C_j$  is a net return per unit of activity  $j$

$b_i$  is available quantity of input  $i$

$A_{ij}$  is quantity of input  $i$  required to produce one unit of activity  $j$  (or technical coefficient)

$i$  is row 1, 2, ...,  $m$

$j$  is column 1, 2, ...,  $n$

The structure of the model employed in this study is presented in the tableau of Figure 1, it is designed to capture the conditions prevailing in the representative farm households. This model is composed of 3 different parts: objective junction, dairy farm activities and resource constraints.

The objective function of the basic model composes of the total returns dervied from the farm enterprise, less the tatal production cost. In the basic model, the objective function is comprised of the sum of all incomes earned from selling milk and male calves, less all milk production expense, less the cost of raising female calves on the farm.

There are twelve activities included in the LP model. The first activity is associated with milk production per dairy cow. It is classified into sub-activities of different possible rations fed to dairy cows. (i.e.  $X_{1.1}$  = milk production activity with first ration,  $X_{1.2}$  = milk production activity with second ration,  $X_{1.3}$  = milk production activity with third ration,  $X_{1.4}$  = milk production activity with forth ration). The second activity ( $X_2$ ) is associated with pasture production. This activity is measured in terms of cultivated area devoted to pasture. The third activity ( $X_3$ ) is concerned with the amount of hay bought by dairy farmers for feed. It is measured in kilograms of hay. The fourth activity ( $X_4$ ) is associated with the amount of rice straw bought by dairy farmers for feed. It is measured in kilograms. The fifth activity ( $X_5$ ) is concerned with the amount of silage purchased as feed. It is measured in kilograms. The sixth activity ( $X_6$ ) is concerned with the amount of high protein concentrate bought for feed. It is measured in kilograms. The seventh activity ( $X_7$ ) is associated with milk sold. All milk production is on the basis of kilograms sold. The eight activity ( $X_8$ ) is concerned with the number of cows raised in the herd. The ninth activity ( $X_9$ ) is the number of calves born. Based on empirical data, the birth rate is 0.75 per cow year. The tenth activity ( $X_{10}$ ) is the number of male calves sold. The ratio of male to female calves born to each cow is approximately 50 percent. The eleventh activity ( $X_{11}$ ) is the number of female calves raised. The twelfth activity ( $X_{12}$ ) is concerned with hired in labor.

Several dairy farm resources and constraints faced by the representative farmers are included in the model. The first constraint is the availability of land for pasture among different sizes of farms. The constraints of pasture land available for small, medium and large farms are 17, 23 and 68 rai respectively.

The availability of family labor is the second constraint incorporated in the model. This constraint depends on the number and age of persons in the household labor force. The labor force includes persons ranging in age from 12 to 60 years old. In dairy farming, all labor forces are able to work everyday throughout the year. The supply of family labor seems to be fixed for every day throughout the year. Young boys and girls from 12 to 15 years old, are able to work 2 hours a day, 730 hours per year. Men over 15 years of age are able

	B	S I N	Milk Production Activities Per Cow with Different Feed Rations				$X_2$	$X_3$	$X_4$	$X_5$	$X_6$	$X_7$	$X_8$	$X_9$	$X_{10}$	$X_{11}$	$X_{12}$	
			$X_{1.1}$	$X_{1.2}$	$X_{1.3}$	$X_{1.4}$												
C		N	$-C_{1.1}$	$-C_{1.2}$	$-C_{1.3}$	$-C_{1.4}$	$-C_2$	$-C_3$	$-C_4$	$-C_5$	$-C_6$	$+C_7$			$+C_{10}$	$-C_{11}$	$-C_{12}$	
Land	B	L					1											
Labor	B	L	$a_{21}$	$a_{22}$	$a_{23}$	$a_{24}$									$a_{211}$		$-1$	
Grass	O	E	$a_{31}$	$a_{32}$	$a_{33}$	$a_{34}$	$-y_{31}$								$a_{311}$			
Hay	O	E	$a_{41}$	$a_{42}$	$a_{43}$	$a_{44}$		-1							$a_{411}$			
Straw	O	E	$a_{51}$	$a_{52}$	$a_{53}$	$a_{54}$			-1						$a_{511}$			
Silage	O	E	$a_{61}$	$a_{62}$	$a_{63}$	$a_{64}$				-1					$a_{611}$			
Concentrate	O	E	$a_{71}$	$a_{72}$	$a_{73}$	$a_{74}$					-1				$a_{711}$			
Milk	O	E	$y_{81}$	$y_{82}$	$y_{83}$	$y_{84}$						-1						
Cows	O	E	I	I	I	I							-1					
Calves	O	E											0.75	-1				
Male Calves	O	E												.5	-1			
Female Calves	O	E												.5		-1		

Figure 1. LP Model for Representative Dairy Farms (in one year period)

to work 8 hours a day. Females over 15 years of age are able to work 4 hours a day. According to this information, the estimation of available family labor supply for small, medium and large farms is 3,538, 4,687 and 4,471 hours per household, respectively.

The last constraint included in the model is the availability of hired labor. Since dairy farming is highly labor intensive, available family labor is insufficient, and hired labor is needed. Hired labor must be both skilled and diligent in dairy farming. From the survey, medium and large farms usually hired 1 and 2.5 laborers, respectively. Small farms hired no laborers. Therefore, constraint of hired labor estimated in terms of hour available for medium and large farms is 2,920 and 7,300 hours, respectively.

### PROGRAMMING SOLUTIONS OF THE BASIC MODEL

Table 1 presents an estimate of net income generated from the optimal plan for farms of each size class. This table indicates that the net income for small, medium, and large farms average 94,270, 180,254, and 473,425 baht per farm per year, respectively. After subtracting fixed expenses, the net profit per farm was 22,422, 59,996 and 222,556 baht, respectively. It was found that, in general, net income and net profit are directly proportional to the dairy farm size.

The results of the programming model indicate that small farms should raise 10 milking cows, 3 female calves, and utilize 15 rai of land utilized 3,535 hours of family labor per year. Actually, small farms utilize 17 rai of pasture land and use only family labor. This would earn net income amounting to 94,270 baht, and objective which would be realized only if dairy farmers apply the recommendations for milk production. The best alternative pattern of milk production activities per cow per year is the use of 1.28 rai of land, 326 hours labor, 323 kg of hay, and 1,557 kg of concentrate to produce 2,629 kg milk per cow.

**Table 1.** Optimum Size of Herd per Farm and the Selected Pattern of Milk Production per Cow

Items	Small	Medium	Large
	(No hired labor)	(hire 1 laborer)	(hire 2 laborers)
1. Maximum net income (baht)	94,270	180,254	473,425
2. Number of cows raised (heads)			
- dairy cows	10	17	40
- female calves	3	6	11
3. The optimum pattern			
- Land used (rai)	1.28	1.15	1.45
- Labor used (hours)	326	262	204
- Hay feed (kg)	323	103	—
- Straw feed (kg)	—	306	594
- Concentrate feed (kg)	1,557	1,789	1,833
- Milk production (kg)	2,629	2,923	3,195

The model indicates that dairy farmers on medium size farms should employ 282 hours of hired labor per year in addition to family labor. They should raise 17 dairy cows and 6 female calves with the 23 rai of pasture. Under this plan the maximum income generated would be 180,254 baht per farm per year. The best alternative relative to this optimal plan is using 1.15 rai of pasture land, 262 work-hours, 103 kg hay feed, 306 kg straw feed, and 1,789 kg concentrate feed per cow, and 2,923 kg milk per cow per year will be produced

The optimal plan for large farms also calls for hired labor. Family labor available is not sufficient to meet the necessary labor requirements for production. The study results suggest that dairy farmers on large farms should raise 40 dairy cows, 11 female calves, utilize 68 rai of pasture land, use 4,471 man-hours of family labor and 5,233 hours of hired labor. (Approximately 2.0 laborers are specified since one full time labor works 2,920 hours per year). The optimal plan will maximize income at 473,425 baht per year. The most appropriate pattern in this optimal plan is to utilize 1.45 rai of pasture land or feed 11,597 kg green roughage, utilize 204 hours of labor, 594 kg straw and 1,833 kg concentrate. This will produce 3,195 kg of milk per cow per year as shown in Table 1.

Some conclusions can be derived from the optimal production plan for each of the three farm size categories. One indication is that a larger pasture area enables the

household to earn extra income. The shadow price of resources indicated which resources are not fully utilized and the additional gain in income which will be obtained through the addition of one unit of that limiting factor. The higher the shadow price, the more limiting the resource. The programming results show that to fully utilize pasture in the short-run requires hired labor in addition to family labor on farms of every farm size class. In addition, the shadow price per rai of pasture land was found to be 5,066 baht for small farms, 10,190 baht for medium farms, and 6,603.8 baht for large farms, respectively. These figures indicate that expanding pasture on small, medium and large farms as well as hiring additional labor would be important factors in raising farm income. More cows could be raised profitable on all farms. Medium size farms are the most profitable.

The results of the study also show that available family labor does not fully utilize the available land on any of the farmers. Family labor is fully utilized and has a shadow price of 26.64, 36.50 and 5.45 baht per hour. These shadow prices are quite high relative to the hourly wage rate in the study area, which is 5.45 baht per hour. These results indicate that it would be more profitable for each farmer to run more cows, even though additional labor would have to be hired.

The results of the study indicate that farmers could earn more net income under the same resource constraints of farm resources were used to best advantage

### **PROGRAMMING SOLUTIONS OF THE ASSUMED SITUATION MODEL**

These situations were assumed in order to investigate the possibility that dairy farmers in the study area could under some conditions, expand their cattle herds. In the first hypothetical situation, the farmers could employ more hired labor than in the basic model. This was hypothesized because it was found that most small dairy farmers had some land left uncultivated for pasture. The second assumed situation allowed the farmers to sell not only female calves but also male calves. This situation was expected to be more profitable and was, in fact, found to be practiced by some farmers in the study area.

#### **Assumed Situation I : Employ Additional Hired Workers on Small Farms.**

Not all the land on small dairy farms was fully cultivated for pasture because of the limited supply of family labor. This implies the possibility of raising more cattle by employing additional hired dairy workers. It is necessary to analyse the optimum number of cattle in such a situation, assuming the dairy farmer could hire more workers to work on the small dairy farm. The programming results of this assumed situation were analysed and presented below.

The model indicated that if small farmers hired some part-time additional labor, they would obtain a higher income. They would still have 2 rai of unused pasture land and

the opportunity cost of family labor on dairy farms would be 27 baht per hour, while the actual cost per hour is only 5.5 baht. The model suggests that small farmers should raise more cows and hire 525 hours labor annually in order to fully use the 17 rai of pasture land available to them. This would increase net income to 105,404 baht.

**Assumed Situation II: Sell both Male and Female Calves.**

The maximum net incomes generated from the model for this assumed situation are higher than net incomes generated by the basic model in which only male calves are sold. In keeping the female calves on the farm the farmer has some extra expenses in feeding, with no return until the calf is 2-3 years old. In keeping only productive cows, all feed goes to cows who are earning income. In addition, in raising only productive cows farmers can support more productive cows on the same resources. Consequently, net income would be maximized.

## **SUMMARY AND IMPLICATIONS OF STUDY**

This study attempts to analyse current dairy farming practices and to assess the possibilities for improving the income of farmers in Muak-lek and Pakchong District. Linear programming analyses were employed to assess the optimum size of dairy herd which would maximize profits on farms. The analyses cover the 1983-1984 records of 45 dairy farms in the study area. The descriptive analyses of general characteristics of the study area and of the sample dairy farm households were introduced to serve the quantitative analysis. The important findings and implications of the study are summarized as follows:

1. Net farm income would be increased through proper reallocation of available resources since dairy farmers in the study area did not operate with optimal size herds, nor did they use the optimal pattern of inputs under the resource constraints in their dairy enterprises. Net household income generated by the theoretical optimal plan for small, medium, and large farms were higher than that of the actual practice by 90, 68 and 139 percent, respectively.

2. Programming results indicated that the average medium size farm should hire one full-time labor and that 2 full-time laborers should be hired by large farmers. It was also suggested that, if the small farmers hired part-time laborers for 525 hour of work, their net returns would be increased to 105,404 baht. Because small farmers now utilize only family labor, they have 2 rai of idle land.

3. Land is fully utilized and becomes the most limiting resource, especially for the small and medium size farms. On medium size farms land has a higher shadow price compared to land on small and large farms. The small, medium, and large farms generate shadow prices of land amounting to 5,066, 10,190 and 6,603 baht per rai, respectively. This implies that some expansion of farm land holdings should be given more attention

on medium size farms. Each additional unit of land used by the medium size farmers generates more returns than does each unit of land on small and large farms.

4. In the case of raising only milking cows, farmers would get more net income with the same amount of resources than if they also raised calves, by 28 44 and 39 percent on small, medium and large farms, respectively.

#### LITERATURE CITED

Arunee Grittayanawach. 1985, *An Economic Analysis of Dairy Farms Around Muak Lek Dairy Farm Promotion Center, 1983-1984*, M.S. Thesis, Dept of Agricultural Economics, Kasetsart University.

Brown, G.W. and G.H. Arscott. 1960. "Linear Programming and Economies of Size". *Journal of Farm Economics*, XLIII (February, 1960).

Heady, E.O. and W. Cancler. 1973. *Linear Programming Method*, Ames, Iowa State University Press.

Office of Agricultural Economics (OAE), Ministry of Agriculture and Cooperatives). 1983. *The Report of the Survey on Dairy Cows and Milk Production during December 1982-May 1983*.

\_\_\_\_\_. 1984, 1985. "The Dairy Acceleration of Thailand" *Agricultural Economics Research*.