1985

Potential development of dairy production in Sichuan Province, China

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Potential development of dairy production
in Sichuan Province, China

by

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A Thesis Submitted to the
Graduate Faculty in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE

Department: Economics
Major: Agricultural Economics

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Iowa State University
Ames, Iowa

1985

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I. INTRODUCTION

1.1 Background to the Study

Historically, livestock production was considered a supplementary or complementary operation in the intensive areas of China. This relatively low position for livestock resulted from an over-emphasis on grain self-sufficiency. Because livestock production was complementary or supplementary, few studies have examined the economies of livestock production. Analyses of specialized livestock production were even more out of the question.

Since 1978, however, Chinese agriculture has been undergoing a rapid economic transformation. In that year, the Chinese government adopted a series of policies to stimulate agricultural development. These new policies included practicing the household production responsibility system[1], raising the prices of agricultural products, importing more grain to keep domestic procurement low, and encouraging household sideline occupations and rural trade fairs.

Two other important policy goals were to (1) increase the quantity, quality, and variety of animal products available to consumers, and (2) improve farmers' incomes through livestock production. Livestock production in China increased slowly before 1978 and quite rapidly thereafter. Figure 1.1 shows that certain species have been favoured in both periods

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[1]The farm household contracts a plot of land with the collective, pays the agricultural tax, and sells a required quota of products to the state. After paying a share of their earnings to the collective, the farm household can freely deal with the remaining portion of output.

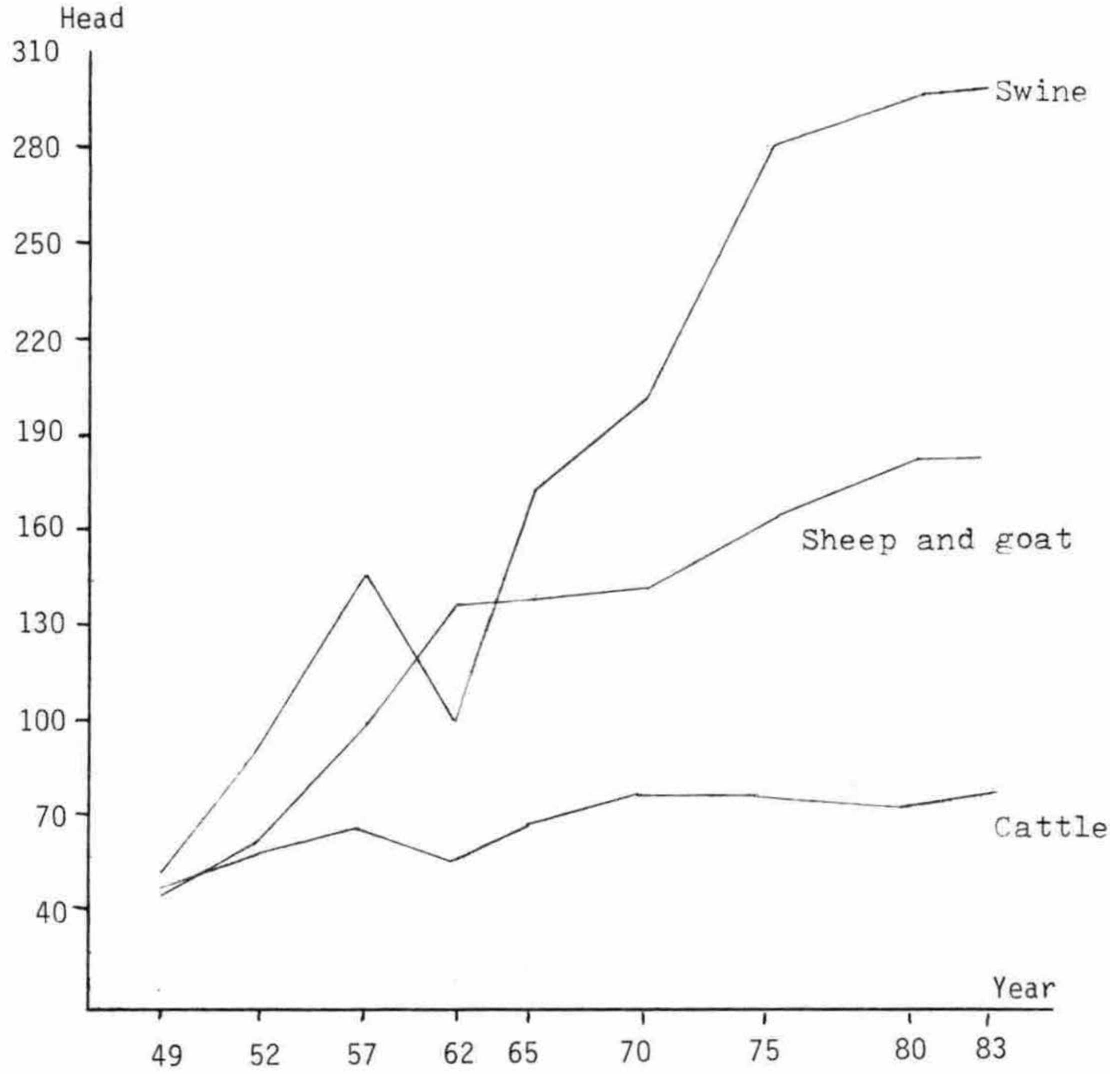

Figure 1.1. Selected livestock population in China, 1949-1983 (million head) (1, pp. 177-178).

Swine production has been developing quickly since 1949, except in 1962. Sheep and goats have been increasing at a medium rate. Cattle numbers, however, have remained relatively constant.

Livestock production plays an essential role in the agriculture of Sichuan, the most populous province in China. Animal agriculture directly contributes draft power for cultivation and transport, animal manure for fertilizer, and such export commodities as hog bristles, sausage casing, hides, and sheep wool.

Today, the rational use of agricultural resources is being strongly emphasized in accordance with conditions existing in different regions of China. This nationwide thrust and the policy encouraging animal agriculture have reinforced the development of livestock production. Table 1.1 indicates that the population of most livestock species in Sichuan has increased substantially from 1978 to 1981, with swine by 18%, buffalo 2%, yaks 12%, and sheep 7%, respectively. The decrease in cattle numbers can be attributed to the relatively low, if stable, price for beef. However, the increase in both population and productivity per head have resulted in overall increases in the consumption of pork, beef, mutton, and milk during the same period.

Nevertheless, per capita consumption levels of animal products in 1981 were still much lower than in either developed countries or even the world average (Table 1.2 and Figure 1.2). Nor was meat composition balanced, with about 96% of the total coming from pork (Table 1.3). Milk, by contrast, was used mainly for children and for older people with particular dietary needs. On the one hand, the insufficient and

Table 1.1. Animal numbers in Sichuan Province, China (in millions) (2, p. 70)

	1978		1981		
Species	Number	Percent	Number	Percent	% Increase
Total	61.87	100.00%	70.10	100.00%	13.30
Swine	42.63	68.90%	50.23	71.65%	18
Cattle	2.79	4.51%	2.69	3.84%	-4
Buffalo	3.16	5.11%	3.24	4.62%	2
Yaks	2.93	4.74%	3.27	4.67%	12
Goats	6.75	10.91%	6.81	9.71%	1
Sheep	3.58	5.78%	3.82	5.45%	7
Horses, donkeys	0.03	0.05%	0.04	0.06%	19

Table 1.2. Levels of consumption of animal products per capita in selected countries, 1981 (kg.)[a]

Country	Meat	Milk
World	31.55	104.85
Canada	99.60	331.95
China[b]	12.11	1.49
Denmark	261.80	970.75
France	103.30	653.15
India	1.30	44.80
Japan	25.50	55.65
U.S.A.	110.90	267.00
U.S.S.R.	57.45	331.70

[a]Source: (3, p. 545).

[b]Source: (4, p. 21).

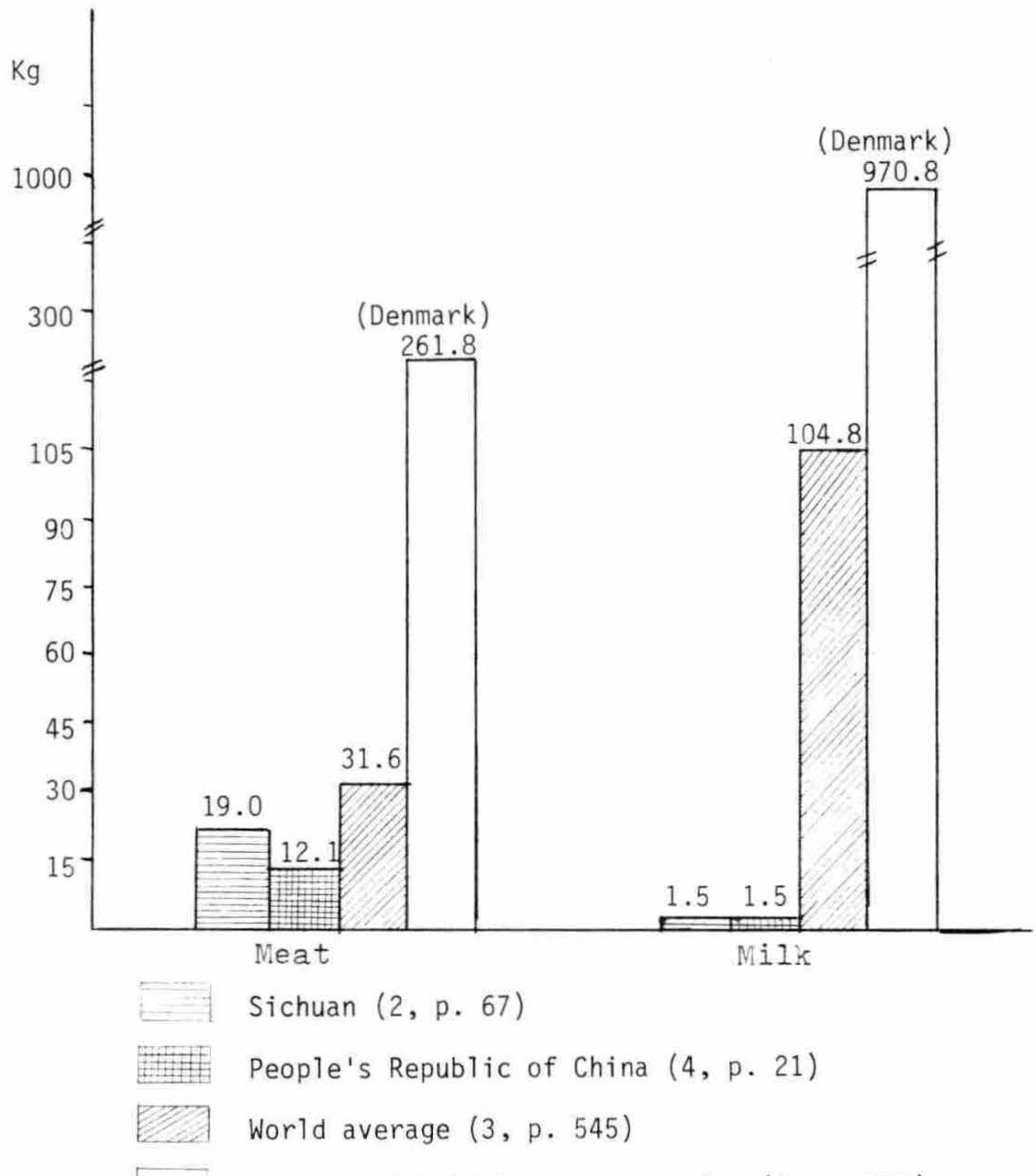

Figure 1.2. Per capita consumption levels of animal products in 1981

Table 1.3. Meat and milk production in Sichuan Province, China (1,000 m.t.) (2, p. 68)

Product	1978	1981	% Increase
Pork[a]	1066.7	1818.5	70
Beef[a,b]	25.5	36.6	44
Mutton[a,c]	24.4	35.7	46
Milk[d]	107.7	142.4	32

[a]Carcass weight.

[b]Cattle and buffalo only.

[c]Sheep and goats.

[d]Cattle only; 1980 MT of goat milk was also produced in 1981.

unbalanced consumption can be attributed to dietary and cultural preferences, or physiological limits. On the other hand, underdevelopment of animal agriculture physically restricted quantitative and qualitative improvements in consumption.

Let us suppose, however, that the per capita consumption level of the world was the consumption criterion for Sichuan province in 1981. Total provincial demands for meat and milk would be 3,257.15 million kg. and 9,671.23 million kg., respectively. Actual 1981 production levels of meat and milk were only 189.08 million kg. and 142.47 million kg. (Table 1.3). To this extent, demand would exceed supply by 3,068.07 million kg. and 9,528.16 million kg., respectively.

1.2 Problems to Be Addressed in This Study

Five problems face the development of animal agriculture in the farm households of the Sichuan Basin. First, farmers do not make scientific use of the existing natural resources. As a result of the overemphasis on grain production in the period 1949-1978, almost all arable lands have been assigned to grain production regardless of the land characteristics. Consequently, the productivity of these lands has not reached the level it should, nor has an adequate feed supply developed for animal agriculture.

The second problem is that the supply of improved livestock breeding stock with high potential for milking, draft power, and meat production appears to be much less than the demand. For instance, the cattle are mostly triple-purpose animals. They are raised primarily for draft power or milk. They are eaten for beef after they are no longer useful as milk or draft animals. More genetic changes need to be introduced to increase the potential for animal production.

The third difficulty is with feed. Currently, most farmers feed their livestock with whatever they have, such as by-products of grain production from private plots, and some concentrates subsidized by the government. These feeds cannot meet the nutrient requirements of animals in terms of either quality or quantity, especially in winter months. At present, China's animal husbandry is at a basic, low-technology stage: natural rearing. This has its limitations in terms of the kind of forage crops used, and in the subsequent development of livestock breeding. The feed production and processing industries need, therefore, to be developed.

The fourth consideration is poor management practices in livestock production (5, p. 25). This is evident in four aspects. The first is that livestock breeds are not properly grouped according to various natural resources. For example, swine accounted for 72% of total livestock in 1981 (Table 1.1). The second aspect is that the relative numbers within the herd of certain types of animals have not been assessed scientifically. For instance, female breeding stock with reproductive potential appear to be too few. The third aspect is that very few farmers feed animals with scientifically formulated rations. This could satisfy neither the nutrient requirements of animals, nor the least feed cost. The fourth aspect of poor management is an erroneous emphasis on the number of animals rather than the productivity of meat or milk per head.

These four aspects of poor management reduce both animal production and farmers' incomes.

The last problem is that China is short of sufficient financial resources and technology. This places restrictions on the development of livestock production in Sichuan province.

Our study will address the first, third, and fourth problems, which are essentially economic, given the assumptions of current technology and animal availability. We also assume that the results of the study will help guide both the importation of improved stock (problem two) and extension and development programs by the government (problem five).

1.3 Objectives of the Study

It is intended that the results of this study should provide farmers and the Chinese government with recommendations and background information which will help them in their decision-making processes. Specifically, this study will attempt to:

(1) Describe the current situation of both animal agriculture and the resources which are potentially available to the development of livestock production in Sichuan, China.

(2) Develop optimal plans for mixed crop-animal production with and without labor hiring, specialized livestock production with limited labor hiring, and specialized livestock production with unlimited labor hiring.

(3) Measure the cost economies of livestock production on the best of

the six different farms, and a simulated "specialized household".[1] Comparisons of the levels of production and resource productivity will be made among the various specifications of the best crop-animal operation and the specialized livestock household.

(4) Provide an economic analysis of least-cost feed rations for all the different farms. Specific decisions about what animals should be fed with what kinds of feed will be made.

(5) Assess the development potential that could result from changes in labor hiring, the prices of inputs, and the prices of outputs, as well as government subsidy and credit policies.

(6) Suggest directions for livestock nutrition research.

1.4 Hypotheses of the Study

The hypotheses of the study are:

(1) Net farm income will be increased by introducing dairy cattle production into mixed crop-animal operations in Sichuan province, even without changing existing resources or policies.

(2) So much labor is already used in crop and livestock production that net farm income will be substantially increased through a policy allowing additional nonfamily labor hiring.

(3) Specialized dairy production is more profitable than mixed crop-animal production if resources, technology, and policies remain unchanged.

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[1]New Chinese agricultural policy announced in 1978 that a farm household could specialize in one occupation. Chapter 3 will interpret this policy in detail.

(4) A one percent reduction in the price of a key feed input will induce a more than proportional increase in the demand for that input.
(5) A one percent increase in milk output price will induce a more than proportional increase in milk supply.
(6) Farmers will respond to changes in government policies, such as subsidies and improved credit terms.

1.5 Limitations of the Study

This study is confined to the Sichuan Basin, one of the most intensive agricultural areas of China, and focuses on cattle, buffalo, goats and swine. There are two reasons for limiting the thesis in this way. First, in 1981, the total number of livestock fed in Sichuan was 69.55 million, of which 13% were large animals and 87% small animals. Water buffalo and cattle were the most important large animals, while swine, goats and sheep were the most popular small animals (Tables 1.4 and 1.5).

Second, approximately 100% of the buffalo, 99% of the swine, 86% of the cattle, and 80% of the goats and sheep in the Sichuan Province were found in the intensively farmed regions chosen for the focus of this study. Buffalo and cattle provide draft power for most of the land preparation in the region. More and more dairy cattle were raised because of increasing demand for cattle milk in urban areas which are located in the Sichuan Basin.

Swine is the most popular type of livestock in the basin. The examination of swine production is used to evaluate the relative position of dairy in terms of resource use.

Table 1.4. Large livestock numbers (in millions) and percentages in Sichuan in 1981 (2, p. 70)

	1978		1981	
Species	Number	Percent	Number	Percent
Total	8.91	100.00	9.24	100.00
Cattle	2.79	31.31	2.69	29.11
Buffalo	3.16	35.47	3.24	35.39
Yaks	2.93	32.88	3.27	35.39
Horses, Donkeys	0.03	0.34	0.04	0.43

Table 1.5. Small livestock numbers (in millions) and percentages in Sichuan in 1981 (2, p. 70)

	1978		1981	
Species	Number	Percent	Number	Percent
Total	52.31	100.00	60.31	100.00
Swine	42.63	81.50	50.23	83.29
Goats	2.93	5.60	3.27	5.42
Sheep	6.75	12.90	6.81	11.29

The study is also focused on individual farm households in the area. The people's communes, formulated in 1958, were the basic administrative unit of rural China. Communes were subdivided into brigades (about 15 per commune), and further into production teams (with an average of 30 families each), by which almost all production activities were operated. However, under the new production responsibility system, an individual family may contract with the brigade or production team and carries on specific agricultural activities. Now individual farmers are free to make both economic decisions and profits. For instance, they can employ their surplus family labor in sideline activities such as livestock production. This "freeing" of the work force, i.e. moving from one sector to another, requires a more sophisticated analytic approach than before, i.e. one must study simultaneously the quantities of inputs needed, the yield expected, and the capital required, all of which form the basis for further technological advance in China's agriculture. State farms also should be reevaluated. However, the state farms are beyond the scope of this study because of the quite different problems facing them.

1.6 Structure of This Thesis

Chapter 2 will describe current livestock production in Sichuan Province. Specific physical resources available for livestock production, alternative production systems, the current distribution of production systems, the current distribution of production activities, the economic and nutritional contributions of animal agriculture, and the nutrient requirements of livestock are illustrated. Chapter 3 will present the linear programming model that was used in this study. The results of this study will be shown and analyzed in Chapter 4. Chapter 5 will summarize the study and draw pertinent conclusions.

2. LIVESTOCK PRODUCTION IN SICHUAN PROVINCE

2.1 Physical Resources of Livestock Production

2.1.1 Five geographical regions

Sichuan Province, with a population of more than 100 million people, is located in south-central China. The province is divided into five geographical regions based on similar characteristics in the physical resources. In this study, we will concentrate on Region V. The regions outlined in Figure 2.1 consist of:

I. Northwestern Plateau

Region I, a high plateau at elevations ranging from 3,300 to 5,000 meters, is mostly above the forest line. Table 2.1 and Table 2.2 show that the area of Region I is about 11.6 million ha., which accounts for 20.5% of that of the province. More than 65% of the region's land, about 7.6 million ha., is grassland, which contributes to the characteristic of alpine and subalpine grazing in the area.

II. Western High Mountains and Valleys

The high mountains and deep gorges of the region are covered by dense forests and grasslands. Of the 12.5 million ha. total area, only 0.8% is cropland. The topography, elevation range and climatic conditions are the principal limitations to agriculture in the region.

III. Southwestern Mountains

The steep to precipitous intermediate-sized mountains, with deep, usually narrow valleys, make up more than 95% of the region's land in grassland,

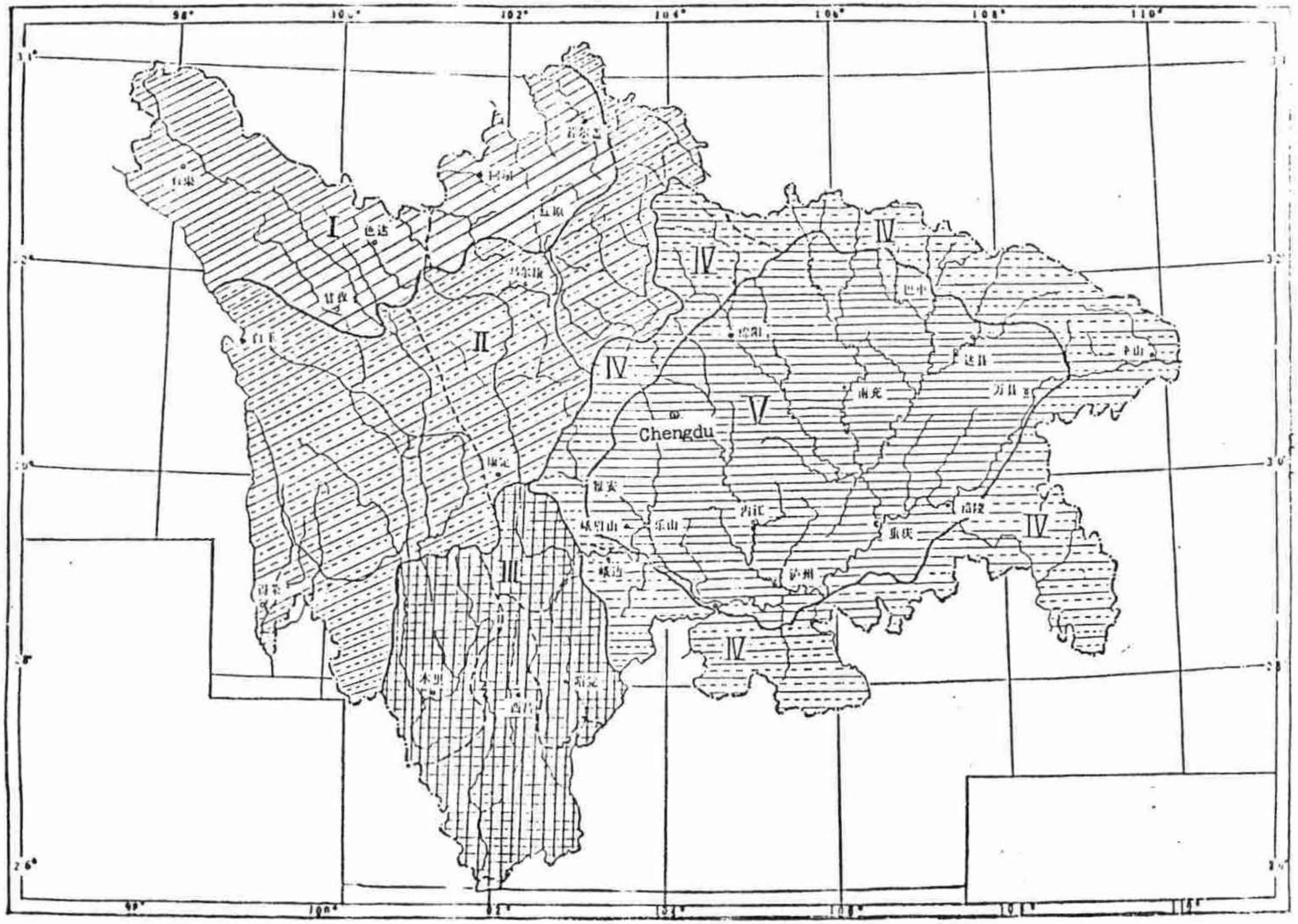

Figure 2.1. Major ecological zones of Sichuan Province, China (2, p. 11)

Table 2.1. Land use by region in Sichuan Province (ha x 1000) (2, p. 19)

	Cropland				Grassland		Forests, water, barren and others		
Region	Upland	Paddy	Total	Percent	Ha x 1000	Percent	Ha x 1000	Percent	Total
I	87	--	87	1.31	7,600	46.42	3,913	11.62	11,600
II	107	--	107	1.61	3,187	19.46	9,206	27.33	12,500
III	227	67	294	4.43	1,097	6.70	4,809	14.28	6,200
IV	740	413	1,153	17.36	2,972	18.15	6,175	18.33	10,300
V	2,200	2,800	5,000	75.29	1,520	9.27	9,580	28.44	16,100
TOTALS	3,361	3,280	6,641	100.00	16,373	100.00	33,686	100.00	56,700

Table 2.2. General topography and elevation range of the five ecological zones of Sichuan (2, p. 19)

Region	General Topography	Elevation range meters	Area Ha x 1000	% Total
I	Rolling, high plateau with occasional high peaks	3,300 - 5,000	11,600	20.5
II	Steep, high mountains, narrow gorges	2,000 - 4,000	12,500	22.0
III	Steep to precipitous intermediate mountains, deep, usually narrow valleys	800 - 3,000	6,200	10.9
IV	Heavily dissected foothills to steep, low mountains	600 - 2,000	10,300	18.2
V	Level (Chengdu Plain) to rolling and steep hills and mountain foothills	400 - 900	16,100	28.4
		400 - 500	56,700	100.0

or 1.097 million ha. The area in forest, water, barren land and others accounts for approximately 4.809 million ha. Terrain and soil permit only 5% of the region to be used for cropland.

IV. The Rim of Mountains Surrounding the Sichuan Basin

Region IV, where the elevation ranges from 600 to 2,000 meters, is characterized by heavily dissected foothills, which grade into mountains, 1.153 million ha. are in cropland (17.36% of the province) and 2.97 million ha. are in grassland (18.15%).

V. Sichuan Basin

Table 2.1 indicates that there are 5 million ha. in cropland, 31% of the total area in the region. For this reason, the region is intensively farmed with only the steepest and thinnest soils left in grassland or forest. The Chengdu Plain is centered in the western part of the basin and slopes to the east where it is characterized by rolling to steep hills and mountainous foothills. Both plain and hills are extremely productive under very intensive agriculture. For this reason Region V has been chosen as the focus of this study.

2.1.2 Cropping systems

Given stable physical conditions in terms of physiography, climate and soil, the intensive cropping patterns used throughout the Sichuan Basin have developed over many centuries. Some typical cropping systems are described in Table 2.3 along with the estimated total farm production of grains, tubers, fodder and by-products used for feed. Figure 2.2 illustrates the typical crop rotations in the Sichuan Basin.

Table 2.3. Yields of grain, tubers, and crop by-products from typical Sichuan Basin cropping system (2, pp. 27-29)

Crop Season	Crop	Yield (kg/ha)	Index[a]	Grain Output (kg)	Feed/Grain Ratio[b]	Feed	Feed Output (kg)
A. Chengdu Plain Paddy Farms (4.5 family members x 0.06 ha. = 0.27 ha.)							
Summer	Rice	6,000	1.00	6,000	1.0	Rice straw	6,000
Winter	Wheat	3,375	0.88	2,970	1.1	Wheat straw	3,267
	Rapeseed	1,500	0.02	30			
	Broadbeans (H)	1,350	0.02	27	1.0	Dry stem	27
	Broadbeans (F)	112,500	0.01			Green Feed	1,125
	Vetch	60,000	0.07			Green Feed	4,200
	Fresh Grass[c]	5,000				Fresh Grass	5,000
B. Eastern Sichuan two-crop paddy farms (4.5 x 0.086 = 0.39 ha)							
Summer	Rice	5,250	1.00	5,250	1.0	Rice straw	5,250
Winter	Wheat	2,625	0.88	2,310	1.1	Wheat straw	3,176
	Rapeseed	1,350	0.02	27			
	Broadbeans (H)	1,350	0.02	27	1.0	Dry stem	27
	Broadbeans (F)	112,500	0.01			Green Feed	1,125
	Vetch	54,000	0.07			Green Feed	3,780
	Fresh Grass[c]	5,000				Fresh Grass	5,000
C. Eastern Sichuan three-crop paddy farms (4.5 x 0.086 = 0.39 ha)							
Summer 1	Early Rice	5,250	1.00	5,250	1.0	Rice straw	5,250
Summer 2	Late Rice	22,500	1.00	1,875	1.0	Rice Straw	1,875
Winter	Wheat	3,375	0.93	2,441	1.1	Wheat straw	2,685
	Rapeseed	1,500	0.03	45			
	Broadbeans (H)	1,350	0.02	30	1.0	Dry stem	30
	Broadbeans (F)	112,500	0.02			Green Feed	2,250
	Fresh Grass[c]	5,000				Fresh Grass	5,000

D. Chengdu Plain Dryland Farms (4.5 x 0.0733 = 0.33 ha)

Summer	Maize	3,000	0.40	1,200	10.0	Maize Stone	12,000
	Sweet Potato	22,500	0.60	13,500	10.0	Green Stem	135,000
Winter	Wheat	3,375	0.88	2,970	1.1	Wheat Straw	3,267
	Rapeseed	1,500	0.02	30			
	Broadbeans (H)	1,350	0.02	27	1.1	Dry Stem	27
	Broadbeans (F)	112,500	0.01			Green Feed	1,125
	Vetch	60,000	0.07			Green Feed	4,200
	Fresh Grass[c]	5,000				Fresh Grass	5,000

E. Eastern Sichuan two-crop dryland farms (4.5 x 0.1 = 0.45 ha)

Summer	Maize	3,000	0.40	1,200	10.0	Maize Stone	12,000
	Sweet Potato	22,500	0.60	13,500	10.0	Green Stem	135,000
Winter	Wheat	3,375	0.88	2,970	1.1	Wheat Straw	3,267
	Rapeseed	1,500	0.02	30			
	Broadbeans (H)	1,350	0.02	27	1.1	Dry Stem	27
	Broadbeans (F)	112,500	0.01			Green Feed	1,125
	Vetch	60,000	0.07			Green Feed	4,200
	Fresh Grass[c]	5,000				Fresh Grass	5,000

F. Eastern Sichuan three-crop dryland farms (4.5 x 0.1 = 0.45 ha)

Summer 1	Sweet Potato	22,500	0.50	11,250	10.1	Green Stem	112,500
	Maize	3,000	0.50	1,500	10.1	Maize Stone	15,000
Summer 2	Irish Potato	10,500	0.50	5,250	10.1		
Winter	Wheat	3,375	0.50	1,687	1.1	Wheat Straw	1,856
	Broadbeans (F)	112,500	0.50			Green Feed	56,250
	Fresh Grass[c]	5,000	0.50			Fresh Grass	5,000

[a]Index equals fraction of cropland planted to crop in a given cropping season.

[b]Ratio if feed item produced to grain or tubor.

[c]Fresh grass is cut from the border of crop lands and other nonarable land. This is done year round except for 2-4 months in the winter.

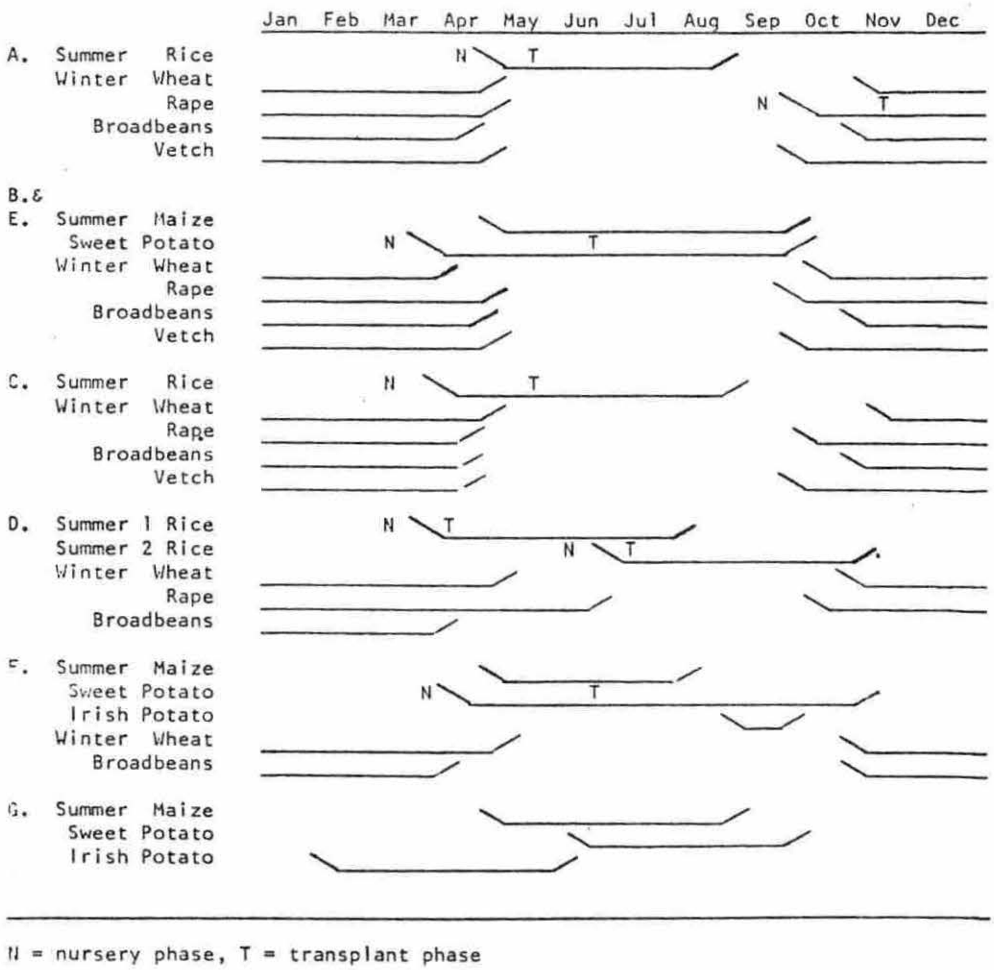

Figure 2.2. Typical crop rotations in the Sichuan Basin (2, p. 32)

In addition to the systems chosen for description, there are many others varying in terms of complexity and detail.

In some regions, intercropping[1] is the norm. Intercropping of corn and beans or sweet potatoes and corn is generally practices in upland farming areas. Peas are frequently planted with winter wheat, and relay cropping (overlapping of crops in time on the same land areas) is common. In drier regions, paddy fields sometimes are left fallow. Periodic flooding during the winter months conserves water and permits the planting of early rice for the next year.

These cropping patterns, as well as feed marketing, have a substantial effect on both the quantity and quality of feeds (Table 2.3). However, wider, more intense use of ruminants may lead to an increase in the efficiency of crop by-product use. Another factor which may aid in this increase is the abundance of grasslands which supplement these agricultural residues and by-products.

2.1.3 Natural grasslands

The native flora in the hilly grasslands is rich and varied, with many valuable grasses and legumes along with weeds, shrubs, and poor quality grasses. Table 2.4 shows the most common native grasses and legumes in the Basin.

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[1]Planting two crops which have similar growth and development durations and different morphological characteristics on the same tract of land, with each having its own row and the row ratio of the former to the latter unchanged.

Table 2.4. Principal native forage species in Sichuan basin (2, p. 90)

Grass	Legume
Lalang grass	Bush vetch
Hispid arthraxon	Twining rhynchosia
Goosegrass	Black medic
Common crabgrass	Birdsfoot trefoil
Redhair plumegrass	California burclover
	Kudzuvine
	Tick clover

Sichuan's natural grasslands total an estimated 16.4 million ha. (Table 2.1). More efficient use of these grasslands would provide a major opportunity for expanding animal production, especially for expanding ruminants. Although the grasslands in the Sichuan basin are limited and intensively grazed or cut for green feed, the pressure on grassland declines as the terrain becomes more hilly and the percentage of arable land falls sharply.

Table 2.1 indicates that the Basin has approximately 1.52 million ha. of grassland with an estimated carrying capacity of 7,600 goats/ha. and 1,520 cattle/ha., respectively, principally in the hilly central and eastern sectors. If one compares the estimated current stock in terms of cattle equivalents with the estimated carrying capacity of this pasture area, the animal stock exceeds the carrying capacity of the grassland by a big margin. This grassland limitation contributes to the high percentage of livestock that are fed crop by-products and cut green fodder.

2.2 Livestock Production Systems

Livestock production systems in Sichuan Province are of two major kinds. One is the pastoral system in the western mountains and plateaus. The other is the mixed crop-animal system in central and eastern Sichuan or in the Basin.

2.2.1 Pastoral systems

The Western Sichuan, characterized by Region I and Region II, consists primarily of rangeland. Rough topography, limited rainfall, and low temperature have narrowed opportunities for crop production. Animal production, primarily livestock grazing, is the principal agricultural activity.

2.2.2 Mixed crop-animal systems

Intensive crop production is practiced on approximately 12% of the provincial land area and is focused in central and eastern Sichuan. As long as rainfall is abundant or irrigation water is available, the land is cropped throughout the year.

These cropping systems influence the type of animal production undertaken. In the intensive farming areas, livestock must be confined for most of the year. They are fed green fodder (leaves and vines from sweet potatoes and beans, ratooned sorghum grass cut from field borders, etc.), crop residues (rice straw, dry leaves, and stalks), and concentrate feeds (rice bran, wheat bran, grain, oilseed meal, and tubers).

Cattle and buffalo raised for draft power are often grazed along field boundaries, on roadsides, and on river banks, where goats are often tethered. Grazing is generally supervised by the younger or older members of the family.

2.3 The Distribution of Livestock Production

All kinds of livestock except camels can be found in one or more regions of Sichuan. Livestock grazing is the principal agricultural activity in western Sichuan, while confined animal husbandry is the traditional supplement in the intensely cultivated areas of the east. As a result, the number of animals per capita in western Sichuan is much higher than in eastern Sichuan (Figure 2.3).

2.3.1 Swine

Sichuan was the largest swine feeding province of China in 1981, with 50.23 million head. This figure represented 15% of the nation's total and 72.22% of the total livestock raised in the province. About 99% of the swine are raised in intensive farming areas. Swine forms the largest population of livestock fed both in the Sichuan Basin and the mountain areas along the edge of the Basin (Figure 2.4).

Most swine are of mixed breeds, primarily black, thin-haired, and early maturing. About 10 million are crosses between native and imported breeds. Most of the local types reach slaughter weights of 70 to 90 kg. at 8 to 12 months of age.

2.3.2 Water buffalo

Sichuan had the largest provincial buffalo population in 1981, an estimated 3.24 million head (3, p. 58). More than 98% of the draft power required in paddy work was supplied by water buffaloes. Most, if not all, of the buffalo were centered in intensive farming areas. This can be observed in Figure 2.5.

The native breeds are fairly small "swamp" buffalo. Adult cows weigh 450 to 550 kg.; bulls are 25 to 30% heavier. Murrah buffalo, imported from India, are much larger than the local breed. It is observed that Murrah cows tend to be 30% to 50% heavier than swamp cows.

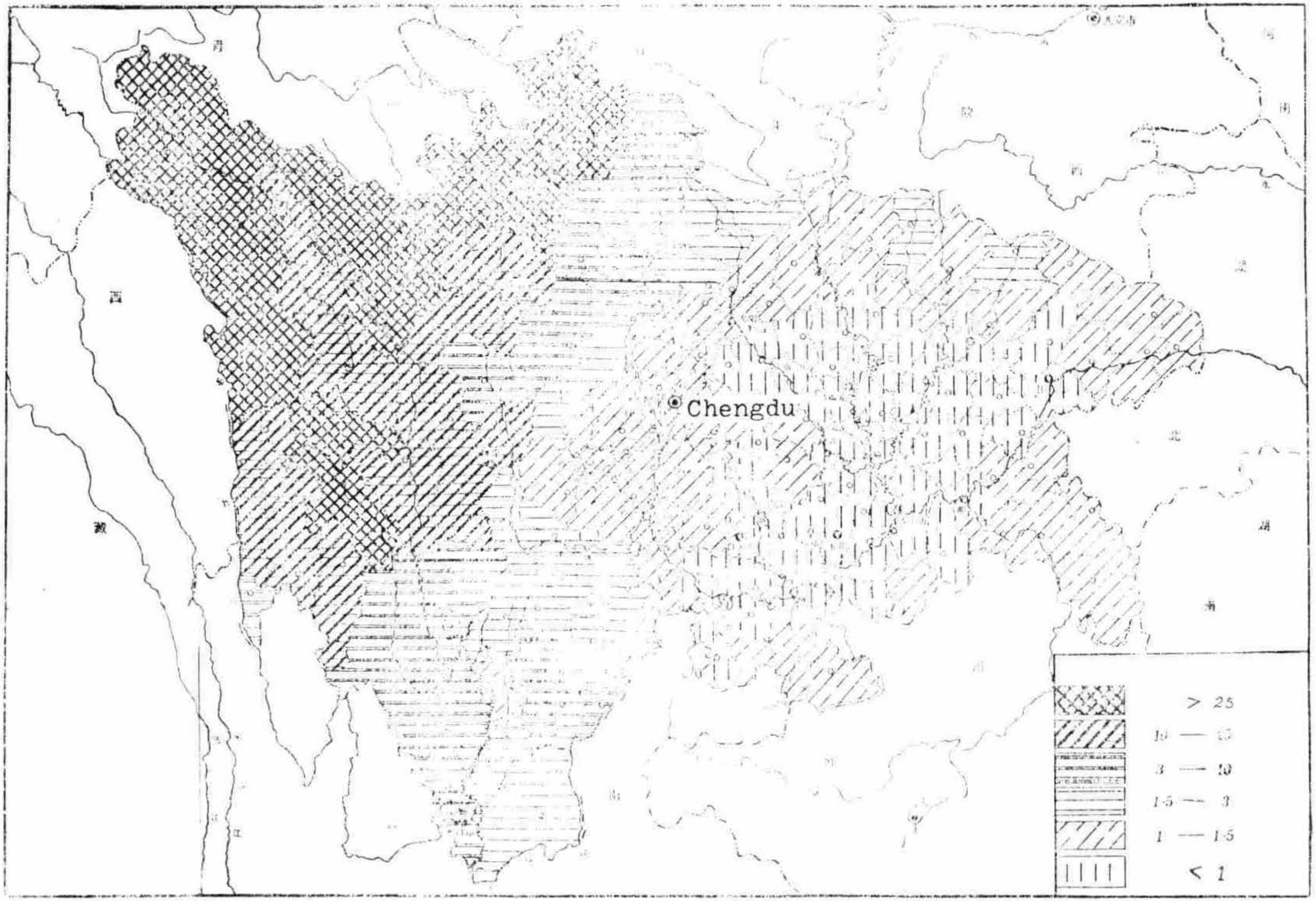

Figure 2.3. The number of animals per capita of agricultured population in Sichuan Provice, China (6, p. 102)

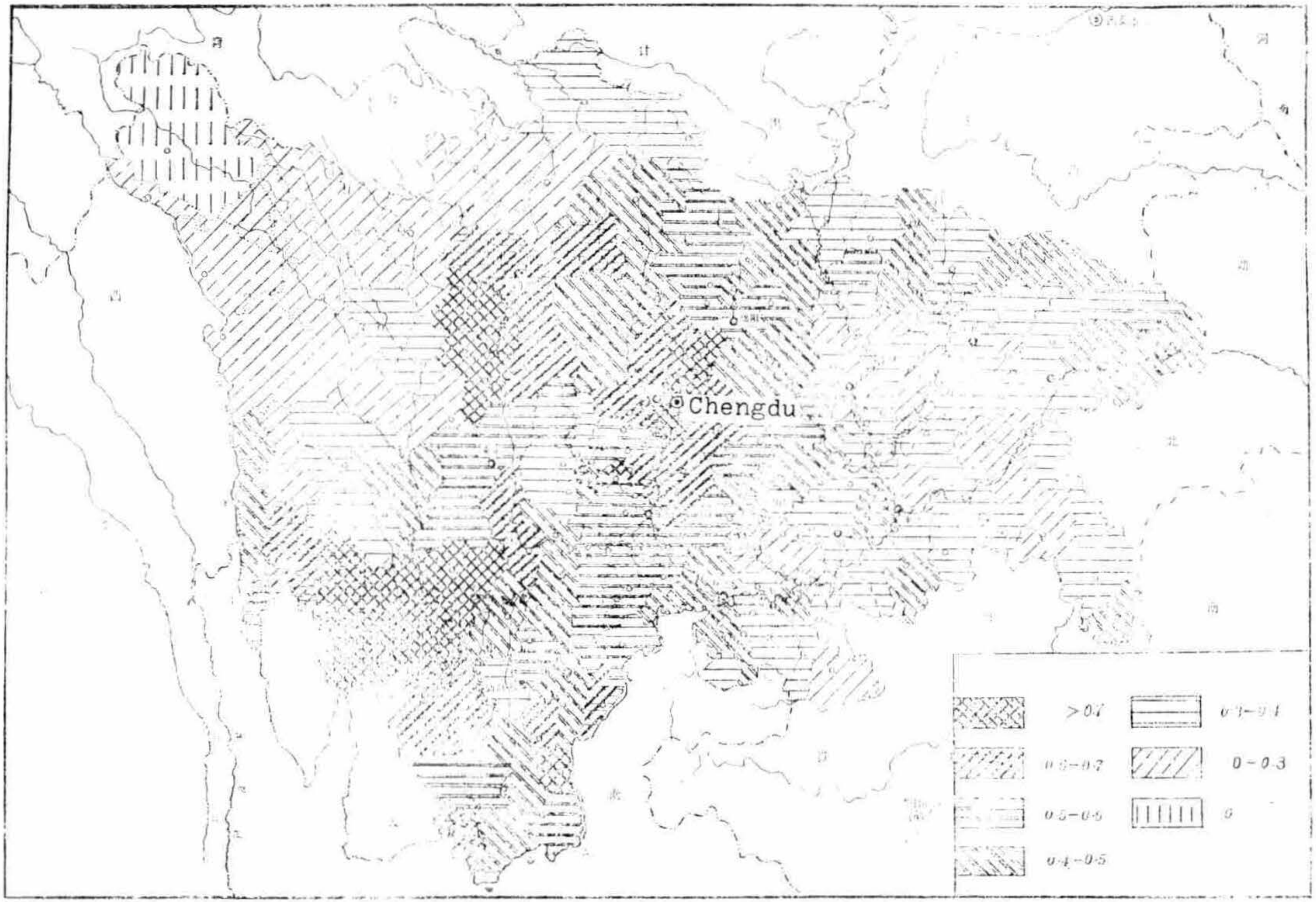

Figure 2.4. The number of swine per capita of agricultured population in Sichuan Province, China (6, p. 104)

2.3.3 Yellow cattle

As a major source of draft power, yellow cattle are widely distributed over the hilly land inside the Sichuan Basin, the mountain areas along the edge of the Basin, and the eastern mountain regions of the province (Figure 2.5). Of the total 2.69 million head, 86% are fed in these cultivated areas.

Crossing local yellow cattle with Holstein and Simmental breeds will increase draft potential (2, p. 137). The crossbred cattle may be as much as 50% larger in body size than the native yellow cattle, which weigh 400 to 500 kg.

2.3.4 Goats

It is estimated that the provincial population of goats is 6.89 million head. Goats are fairly widely scattered in the province (Figure 2.6). Recognized breeds, which account for 50.8% of the total, are claimed to number 3.46 million. The remaining 3.35 million are distributed among purebred and high grade milking goats (mostly Saanen and Saanen-cross) and nondescript native goats.

There are 100 purebred Saanen and Toggenburg goats in Sichuan and 600 Saanen X Tong FI does in and around Chengdu. An estimated 33,100 goats are classified as diary goats producing milk for commercial markets, including 4,000 head in Chengdu, 4,100 in Ya'an, and 2,500 in Daiyi (2, p. 144).

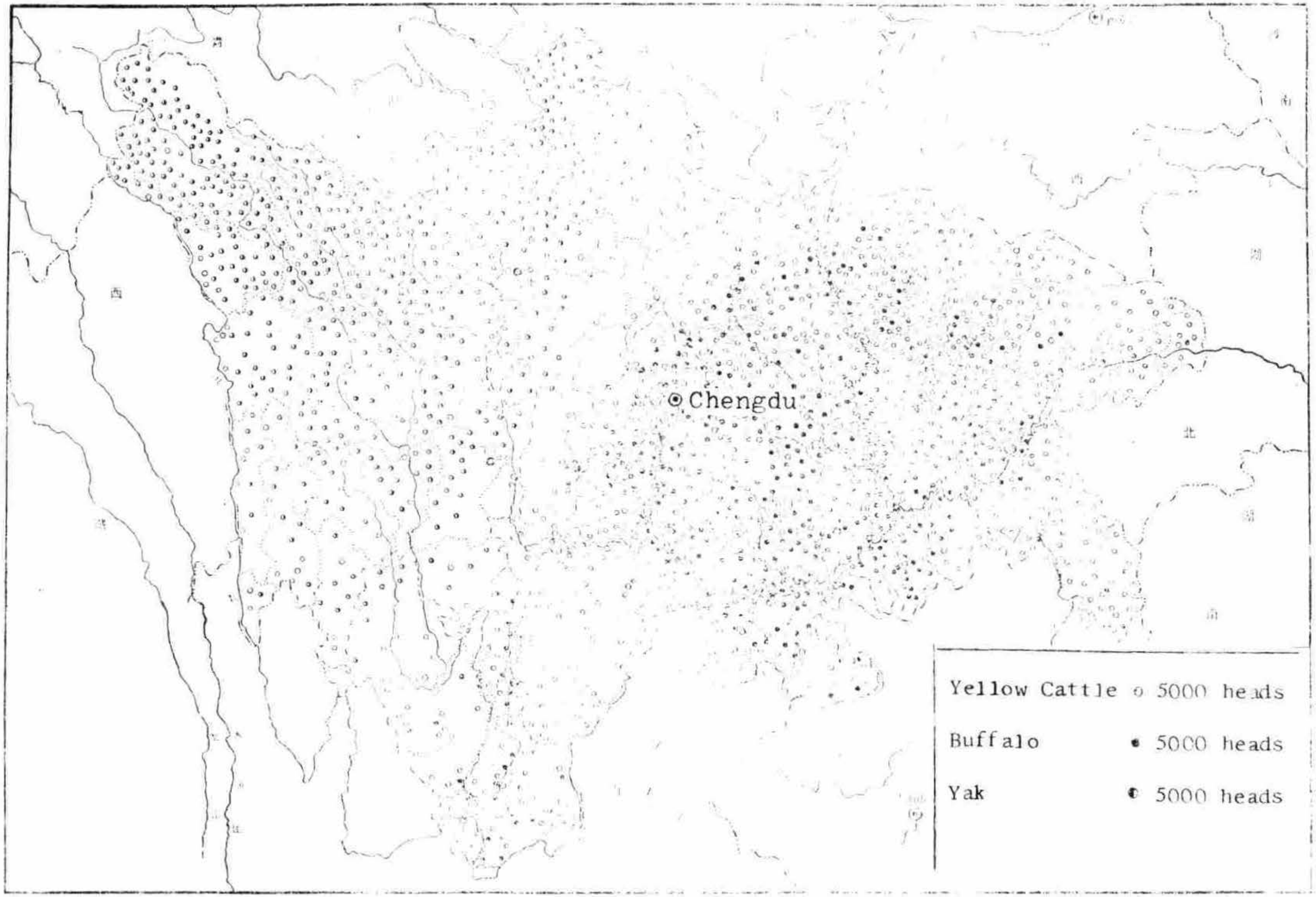

Figure 2.5. Yellow cattle, buffalo and yak distribution in Sichuan Province, China (6, p. 106)

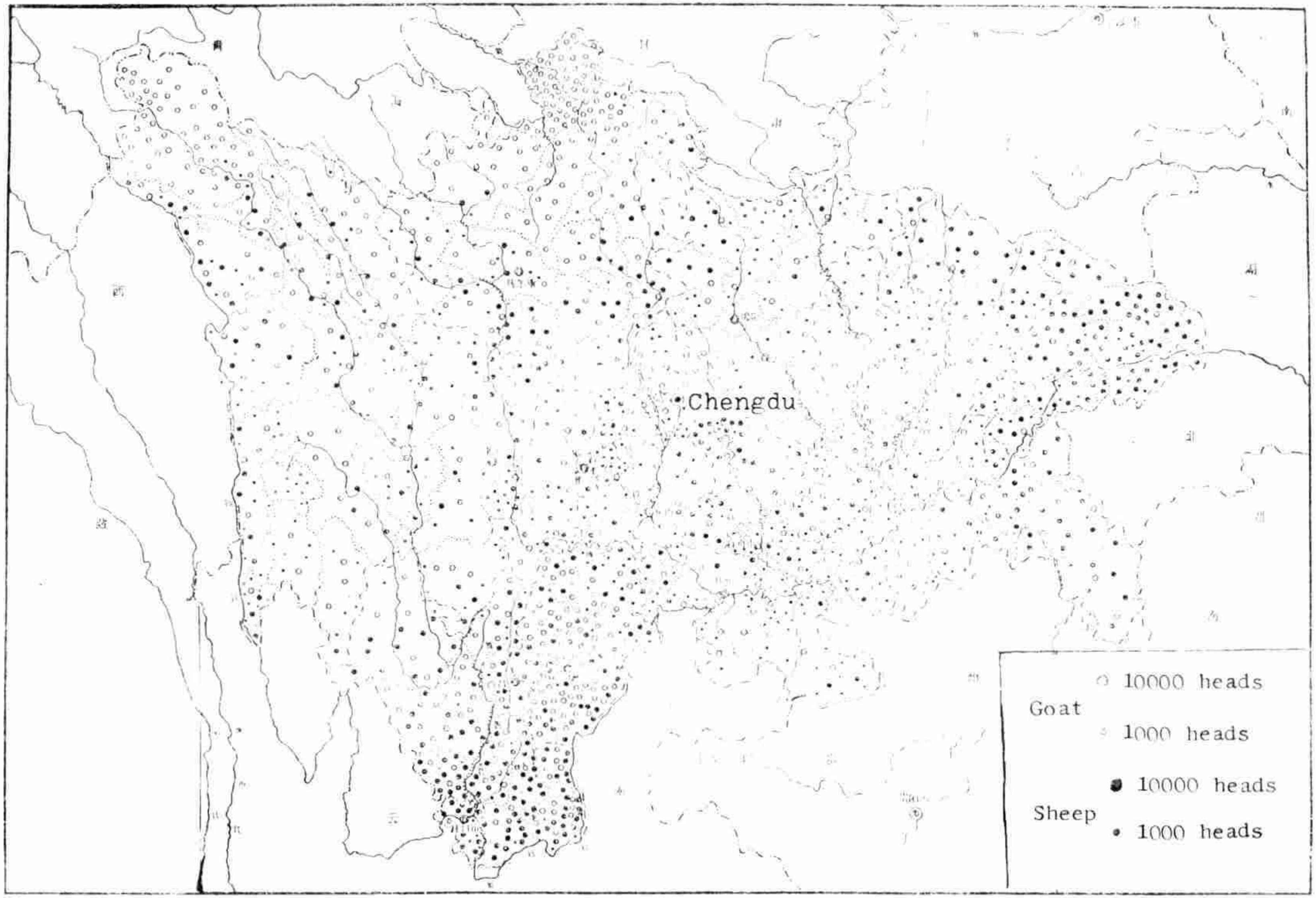

Figure 2.6. Goats and sheep distribution in Sichuan Province, China (6, p. 108)

2.3.5 Dairy cattle

In 1981, Sichuan Province only had about 20,000 head of dairy cattle (3, p. 58), most of which were fed by the state dairy cattle stations. The keeping of dairy cattle in farm households is fairly recent. Individual farmers are encouraged to raise dairy cows; they can obtain dairy cattle and concentrate feed from state feed companies.

Improved females such as Holstein and Simmental, are available in Sichuan. Crossing local yellow cattle with Holstein or Simmental, or local buffalo with large Murrah will increase milk yield substantially.

2.4 The Contribution of Animal Agriculture

2.4.1 Draft power

Buffalo and yellow cattle are raised primarily to provide draft power. This draft power is used mainly for field preparation before planting and in transportation, especially for farm households.

Buffalo are the favorite draft animals for paddy fields. Cattle are poorly suited to this type of work because of their smaller and sharper hooves and smaller size. By contrast, cattle are preferred for field work in hilly and/or dry land. Moreover, their faster pace is an advantage in carrying loads.

2.4.2 Meat

Swine and meat goats are kept primarily for meat production. Pork suits cultural tastes and is China's traditionally preferred meat. Most meat animals are sold to local butchers and slaughtered in small facilities in "xiang" or villages (formerly communes). In Chengdu and

Chongqing, however, there are large slaughter and cold-locker facilities for swine. Farmers slaughter animals for family consumption only in the winter months when the meat is preserved by the cooler temperatures, combined with salting, for special occasions such as wedding banquets.

2.4.3 Milk

Improved dairy cattle, such as Holstein and Simmental, have high potential milk yields. Thus, cattle milk output can be raised readily. Although the level of goat milk production is much lower than that of cattle, the small body size of goats enables them to produce where feed is insufficient to support a freshened cow. The assumption that milk was sold to dehydration plants at the state price is made in our model.

2.4.4 Manure

Manure has been the primary conventional source of fertilizer in China, including Sichuan province. In recent years, the development of biogas, units to supply gas for home use, has increased the demand for manure.

Estimate of annual production of manure (wet weight) by different species include: cattle and buffalo, 7-9 t.; goats, 1 t.; and swine, 2 t. (2, p. 78).

2.4.5 Hides

Hides are an important by-product of livestock production. For instance, the uniform quality of Tong goat hide is cited as a particularly favorable attribute. The swine carcass, which is generally butchered with the hide on, is another example.

2.5 Animal Nutrient Requirements

There are many factors which influence the quality and quantity of animal products. The feed ration is one of the important factors. A "feed ration" is the feed provided for an animal for a day. A "balanced" ration is one in which the nutrients balance the animal's nutrient requirements for growth, maintenance and milk production, in kind as well as in amount. Either underfeeding or overfeeding--that is, supplying more nutrients than the livestock can utilize or supplying less nutrients than they require--will lead to waste surplus nutrients or the inability to attain genetic potential or produce plentiful output. Both certainly result in unprofitable production. The requirements of animals under different conditions must be, therefore, understood in terms of nutrients, as well as the amount and kind of nutrients in the feed.

2.5.1 Metabolizable energy

An adequate supply of energy is imperative to the efficient utilization of nutrients. This, in turn, is of primary importance in determining how productive the livestock will be. A deficiency in energy affects early growth, retards puberty, lessens fertility, and decreases the yield of milk or growth rate of the animal. If this insufficient supply of energy is sustained, the animal will suffer even greater consequences, e.g., a reduction in resistance to infection, diseases, and parasites.

2.5.2 Crude protein

Protein is needed to furnish the animal with amino acids which are necessary for various synthetic processes in the body. Amino acids are the building units of all the cells and tissues in an animal's body, including the blood, skeleton, vital organs, brain, muscles, and skin. All protein secretions in the body, including enzymes, hormones, mucin, and milk require specific combinations of amino acids.

2.5.3 Calcium

Calcium is a critical nutrient in ration formulation for all species of livestock. The importance of the interaction of calcium and phosphorus should be borne in mind throughout. Recommendations on the requirements for calcium or phosphorus imply that a correct amount of each is being supplied. A deficiency of calcium in young animals leads to retarded growth and development, and can predispose them to tickets. Because milk is high in calcium, rations for lactating cattle, goats, and sows need a higher calcium level. Otherwise milk yield will be reduced.

2.5.4 Phosphorus

Phosphorus is required for both tissue and bone development. With phosphorus deficiency, the mineral content of the bones is low, and they become fragile. Appetite declines, growth rate is retarded, and feed utilization efficiency is reduced. Anestrus and low conception rates may be manifested in females of breeding age with inadequate phosphorus intakes, but the phosphorus content of the milk does not decline. The general conclusions about calcium-deficiency diets also apply to phosphorus.

All of the above background information on available resources, alternative production systems, and the nutrient requirements of livestock was used to build the linear programming model and interpret the results of this study.

3. PRESENTATION OF THE MODEL

3.1 Overview of the Linear Programming Model

A linear programming approach was designed to maximize the profits of six alternative farm operations, each with a different cropping pattern. Then, the operation which best typified all six farms was chosen for further analysis. This farm was allowed to respond to different policy alternatives both as a mixed crop-animal farm, as at present, and as a "specialized household," producing only livestock commodities.

The matrix structure of our linear programming model is shown in Table 3.1. The objective function is:

Max: $Z = C'X$

Subject to: $AX\ (< = >)\ B$

where

X: the level of activities;

C': the objective function coefficients of activities. These include prices of output for selling activities, production costs for production activities, purchase prices for buying activities, and 0 for transfer and nonpurchase-consumption activities;

B: the resource restraints;

A: the coefficients of the resources required by the activities.

By definition, the optimum C row value includes an implicit return to cost items not specified in the model. The signs of production, consumption purchase, and input buying activities are negative because those

Table 3.1 Matrix diagram used in this linear programming model

	Crop Production	Livestock Raising	Grain and Feed Transfer	Nutrient Transfer	Buying Activities	Buy Subsidied Corn	Borrowing and Hiring	Saving	Free Market Selling Grain or Feed	Quota or Above Quota Grain Selling	Selling Animal Products	Family Grain Consumption	Family Consumption of Meat	Row Type	RHS
Objective Function	-c . . -c	-c . . -c	. . 0 . .	. . 0 . .	-c . . -c	-c . . -c	-c . . -c	c . . . c	c . . . c	c . . . c	c . . . c	. . 0 . .	c . . . c		
Resource Restraints	$a_{ij} \cdots a_{ij}$: : $a_{ij} \cdots a_{ij}$	$a_{ij} \cdots a_{ij}$: : $a_{ij} \cdots a_{ij}$					a_{ij}^{-1} . a_{ij} . . a_{ij} -1	$-a_{ij}$ 1 $-a_{ij}$ . . $-a_{ij}$ 1						L	B_j
Grain and Feed Pool	$-a_{ij} \cdots -a_{ij}$: : $-a_{ij} \cdots -a_{ij}$		$-a_{ij}$ 1 $-a_{ij}$ . . $-a_{ij}$ 1	1 . . 1	-1 . . -1	-1 . . -1			1 . . 1	1 . . 1		1 . . 1		L	0
Nutrient Pool	$a_{ij} \cdots a_{ij}$: : $a_{ij} \cdots a_{ij}$			$-a_{ij}$ . . $-a_{ij}$										L	0
Livestock Product Pool		$-a_{ij} \cdots -a_{ij}$: : $-a_{ij} \cdots -a_{ij}$									1 . . 1			L	0
Subsidy Pool						1 . . 1					$-a_{ij}$ . . $-a_{ij}$			L	0
Bounds on Selling										1 . . 1				G	B_j
Lower Bounds on Consumption												1 . . 1	1 . . 1	G	B_j
Upper Bounds on Borrowing and Hiring							1 . . 1							L	B_j

activities will reduce the value of the program; while the signs of the prices of selling activities are positive.

There are three types of restraints: (1) maximum, (2) minimum, and (3) equality which are labeled by L, G, and E, respectively. The coefficients of B or the "right-hand sides" specify the magnitude of restraints. For transfer rows, the right-hand sides are equal to zero.

Coefficients in all cells of a row are formed on the basis of a common unit. All the coefficients in the same row on both the A-matrix side and the right-hand side adhere to the row definition. Furthermore, all coefficients in a column relate to one unit of activity defined. For L rows, a negative sign is used for activities which supply to the original B column value; while a positive sign is employed for those that demand from the original B column value. For the two other row types, the reverse is true.

The same linear programming model and procedure were used for our 9 models: 6 basic models, the best mixed-crop-livestock model with limited labor hiring, 1 specialized model with limited labor hiring, and the specialized model with unlimited labor hiring. All of the models designed in this study reflected the current conditions of farms in the Sichuan Basin and their response to government policy alternatives.

Three major new agricultural policies were modeled. The first was permission to hire labor. Before 1978, labor hiring had been forbidden because of the ideological premise that anyone who hired labor was exploiting that labor. Since 1981, the opposite was claimed to be true as long as the labor was paid fairly. This led to the appearance of labor hiring. However, a constraint on the number of laborers hired was still imposed. We assumed that 5 laborers, or 3,000 hours of labor per quarter, were allowed by ordinary farms, three times that much by specialized farms. Although there have been no formal announcements setting these limits, they were consistent with levels generally allowed by local officials.

Second, a new policy adopted in 1978 allowed and encouraged farmers to open and specialize in a new occupation. Since then, more and more farmers have been moving out of less profitable and into more profitable activities.

Third, the new agricultural policies also involved a market aspect. Very few agricultural commodities remain under strict government control in terms of price. In other words, the prices of agricultural products fluctuate more and more according to market demand and supply. The government also periodically adjusts the price system consistent with the market situation.

3.2 Basic Models

We designed six basic models, each of which was characterized by a different cropping pattern to reflect six typical crop farms in the Sichuan Basin (Table 2.3). The mathematical structure of all six models was the same.

3.2.1 Crop production activities

Among the six farms, A, B, and C produced on paddy fields; while D, E, and F used dryland. A two-crop-per-year rotation was modeled for farms A, B, D, and E; while farms C and F produced three crops per year. Estimated annual variable costs, yield levels, tax assessments, quota sale levels, collective fund contributions, and labor requirements per quarter are illustrated in Appendix 8.1.

3.2.2 Livestock raising

3.2.2.1 Dairy cattle Three breeds were included in the models: Holstein X Yellow, Simmental X Yellow, and Simmental. It was assumed that half of the male calves were slaughtered at birth and half of the female calves were raised and sold immediately at weaning.

The nutrient requirements of a dairy cow depend on (1) the size of the animal, (2) the amount of milk produced, (3) the percentage of milk fat, and (4) the stage of her life cycle. Appendix 8.2 describes the nutrient requirements of dairy cattle, their productivity, and the basic production costs included as the C-row value.

The following example illustrates the procedure for calculating these C-row values:

Total cost = 235 kg. of milk fed to female calf @ ¥ 0.4 per kg. at 50% probability that the calf is female + depreciation (purchase of heifer ¥ 2,200 over 8 years - cull value of cow ¥ 600 over 8 years) + servicing + medicine - value of 0.5 male calf slaughtered at birth - value of 0.5 female calf weaned + death loss (1% of total cost) (2, p. 117)

= (235 * 0.4 * 1/2 + (275 - 75) + 5 + 9 - 15 - 80) * (1

+ 1%) = ¥ 167.6

3.2.2.2 Draft animals Buffalo are kept to provide draft power for irrigated crop production on farms A, B, and C in the model. Yellow cattle are raised for draft power in crop production on farms D, E, and F, which are located in dryland areas. We assumed that both buffalo and yellow cattle work under normal conditions and provide 1.5 ha. draft power per quarter (2, p. 73).

The nutrient requirements of draft yellow cattle of similar sizes were similar to the estimates for lactating cows. Appendix 8.3 describes the nutrient requirements of draft animals along with C-row costs, land and labor requirements. The following method was used to estimate C-row costs:

Total cost = depreciation (price of working cattle after 10 years - price of cull cattle for slaughter over 10 years) + medicine + halter + repair + purchase salt + death loss (1% of total cost) (2, pp. 114-115)

3.2.2.3 Dairy goats Three breeds (Saanen, Saanen X native, and Tong) were considered in our model. Farmers were assumed to sell two kids immediately after weaning.

In determining the nutrient requirements of dairy goats, the following factors should be considered: (1) body weight, (2) level of muscular activity, (3) stage of life cycle, and (4) percentage of milk fat. Appendix 8.4 shows the nutrient requirements of the three dairy goat breeds, along with their production potential.

The land and labor requirements of dairy goats can be observed in Appendix 8.4. The annual C-row costs of raising dairy goats were computed by the equation:

Total cost = depreciation (cost of yearling kids at ¥ 10 spread over 7 years - cull value of goat at ¥ 18.9/7) + servicing + 75 kg. milk for raising 2 kids @ ¥ 0.3 per kg. - sale of 2 kids @ ¥ 25/hd + death loss (1% of total cost) (2, p. 119)

= (10 - 2.7 + 1 + 75 * 2 * 0.3 - 2 * 25) * (1 + 1%) = ¥ 3.33

3.2.2.4 <u>Meat goats</u> It was assumed that a farmer buys a weaned kid in quarter 2, feeds the goat and then sells it in quarter 4. The estimated products were 10 kg. of mutton plus the hid. Nutrient requirements were determined according to target body weight in each quarter. These, along with C-row cost, land and labor requirements, are described in Appendix 8.4.

3.2.2.5 <u>Swine raising</u> Three types of swine raising activities were built into our model: farrow-to-finish, farrow-to-feeder, and feeder-to-finish hogs. Each type comprised four activities, one for each quarter. The C-row costs, land and labor requirements and nutrient requirements are summarized in Appendix 8.5.

3.2.3 Transfer activities

The model included two types of transfer activities. The first was to transfer grain or feeds from one quarter to another in order to satisfy the requirements of feeding livestock, family consumption and selling activities in different quarters.

Second, some feeds which suited cattle, goats, yellow cattle, and buffalo were transferred from feed pools into nutrients--ME[1], CP[2], DM[3], CA[4], and PH[5]--pools. Similarly, separate nutrient transfer activities were developed for swine. Appendix 8.6 indicates the nutritive values of the feedstuff used in this model.

3.2.4 Buying and selling

Buying activities were limited to items available in local markets. One unusual feature in China is that farmers can buy 0.5 kg., 1 kg., and 2 kg. of subsidized corn at the state price, about 42% below the free market price, for each 1 kg. of milk, 1 kg. of pork, and 1 head of weaned piglet, respectively, sold to the state purchasing agency (2, pp. 53-54).

Three groups of outputs were identified in selling activities in our models to reflect actual conditions within the marketing process for agricultural products in China. First, farmers who contract a plot of land with a collective team are responsible for paying 8% of their standard farm production of grain as a state agricultural tax in kind.

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[1]Metabolizable energy

[2]Crude protein.

[3]Dry matter.

[4]Calcium.

[5]Phosphorus.

Second, after paying the tax, farmers are required to sell 7% of the output to the state at the state quota price. Third, the rest of the output, after deduction for family consumption, can either be sold on the free market, used for feeding livestock, or sold to the state at the above quota price, which is up to 50% higher than the state price.

We assumed that milk and meat were sold to local state processing plants. It is typical and profitable for farm households in China to sell their animal products to the state rather than door-to-door.

The price levels for both input and output used in this model were those of 1981. Notably, the state prices in China are set by the government and generally do not change. Also, free market prices are rough approximations and cannot reflect actual fluctuations in different quarters. Price estimates for selected products are presented in Appendix 8.7.

3.2.5 Borrowing and saving

The Chinese government provides a loan up to ¥ 200 per quarter to farmers to encourage production of crops and livestock. The interest rate is 1.25% per quarter (3, p. 84), higher than that of saving, 0.72% per quarter (3, p. 84). Each borrowing or saving activity was designed such that the farmer paid back or withdrew the money respectively in the following quarter.

3.2.6 Family consumption

Family consumption requirements were determined by the following factors: the total physical requirements of all family members, the composition of different grains within total grain consumption, and what the farmer actually produced. Any pork consumed was, however, bought from the market, as interpreted in Chapter 2.

An average 4.5-member farm family (2, pp. 27-29) was employed in our models. We assumed that 225 kg. of grain were needed per capita per year. Thus, the amount of grain consumed by one family was estimated at 1,012.5 kg. per year, or 253.125 kg. per quarter. We also assumed that each person consumed 12 kg. of pork per year, i.e., one family required 54 kg. of pork per year, or 13.5 kg. per quarter. These figures reflect typical levels of current consumption in rural Southwest China.

3.2.7 Resource restraints

The amounts of land available for the six basic models can be observed in Table 2.3. In the basic models, all work was done by family members who were not paid cash wages. We assumed that each family averaged three laborers, who worked eight hours per day, 25 days per month. The total labor hours supplied were, thus, 1,800 hours per quarter. The net income per capita of agricultural population in 1980 was ¥ 191.33 in China (3, p. 87). It was assumed that 50% of the income, or ¥ 95.67 could be saved to invest in the following year's production. The total investment for the 4.5 members of the family was, therefore, ¥430.50.

3.3 Basic Model with Limited Labor Hiring

The number of head of livestock raised was limited by the farm family labor constraint in the basic model. To reflect labor hiring as allowed under current Chinese policy, the basic model was changed in the following aspects:

First, a labor hiring activity was added for each quarter. We assumed the farmer paid ¥ 0.4[1] per hour for hired labor. Second, labor hiring makes it possible for the farmer to raise more livestock if no other resource is restricted. But here, an economic question arises, "how much more " Given the equation:

$$C = \sum_{i=1}^{n} X_i$$

where

C: Total cost required of dairy cattle

X_i: The coefficient of costs for the i^{th} cow.

The first order condition is:

$$\frac{dC}{dX} > 0$$

This means that the total cost required of cattle raising increases as the number of cows in the herd is enlarged.

However, we assume the following second order condition:

$$\frac{d^2C}{dX^2} < 0$$

The negative sign points to progressively smaller amounts of cost

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[1]Other studies (e.g., 2) have reported a wage rate of ¥ 0.25. However, this collective wage must be augmented by the recognition that the new labor hiring policies demand either: 1) a higher fair-market wage, or 2) the provision of meals.

required per unit of activity as a higher leve of this same activity is involved. We posit this as a negative value because of economies in hauling, cleaning, milking, feeding, and selling. These, we believe, offset diseconomies involved in searching farther and farther for feed.

Three considerations of a production relationship of this type in our model are labor required, the average cost per cow, and the capital requirement in each quarter. Appendix 8.8 summarizes the decreasing coefficients as the number of cows increases.

3.4 Specialized Household Model with Limited Labor Hiring

By a specialized household, we mean a household which engages in livestock production only. Crop production and relevant activities were, therefore, taken out of the previous models. In addition, grain buying activities were included to meet family consumption requirements. All else in this model was kept the same as the basic model with labor hiring except we changed the incremental increase in herd size in the cattle raising activity from one head to five. This modification was made in preparation for parametric programming under the assumption that specialized households can utilize their inputs more efficiently and, therefore, can expand production scale more significantly than other farm households. The annual cost, land, and labor requirements used in this model are shown in Appendix 8.8.

3.5 The Specialized Household
Under No Limitation on Labor Hiring

All assumptions and activities in the previous model were employed except that the limitation on labor hiring was removed.

4. RESULTS AND ANALYSIS

The results of the basic models of the six farms turned out almost the same in terms of economic scale, the feed cost per head of hogs or cattle, and the optimal feed ration. Farm E had, however, the highest net farm income. Because this research was designed to measure the potential of the best farm to expand into dairy production, the following analysis is focused on Farm E.

The present study analyzed the following farm situations for this farm:

1. Simulation of production under current resource and agricultural policy constraints, which do not allow private farmers to hire labor and raise dairy cattle;
2. Optimal dairy production under a prohibition on labor hire;
3. Optimal dairy production with limited labor hire;
4. Optimal specialized dairy production with limited labor hire;
5. Optimal specialized dairy production under no limitation on labor hire; and
6. Parametric analysis of input demand and output supply.

4.1 Simulation of Current Production (Non-cattle)

An optimal farm plan was derived under existing resources and the given agricultural policy in effect from 1949 to 1978, whereby labor hiring and dairy cattle raising were forbidden in the private production sectors. The programming results (Table 4.1) showed a net farm income of ¥3,706. Significant economies of scale occurred as the farm increased

Table 4.1. Optimal solutions and shadow prices from five linear programming models of Farm E, Sichuan Province, China

	Simulation	Basic	Basic with labor hire	Specialized with limited labor hire	Specialized with unlimited labor hire
Net farm income (Yuan)	3,706	5,707	12,044	48,779	497,429
Land use (ha)	0.45	0.26	0.45	0.05	0.45
Labor use (hrs)					
Quarter 1	1,217	1,510	4,228	10,800	88,139
Quarter 2	1,800	1,800	4,800	10,800	88,139
Quarter 3	1,745	1,629	4,435	10,800	88,139
Quarter 4	1,800	1,800	4,668	10,800	88,139
Livestock production					
Dairy cattle (head)	0	2.43	7.28	32.47	321.43
Dairy goats (head)	3.69	0	0	0	0
Hog 2 (litter)	0.60	0	0	0	0
Hog 11 (head)	0	0.79	0	0	0
Shadow prices					
Land	4,236	0	1,167	0	1,109,105
Labor					
Quarter 1	0	0	0.41	0.41	0.41
Quarter 2	0.89	3.31	2.37	0.41	0.41
Quarter 3	0	0	0.41	0.41	0.40
Quarter 4	0.47	0.32	0.40	6.05	0.40

production to 3.78 head of Saanen dairy goats and 0.6 head of Hog 2. (Note we did not use integer programming for the time being.)

Diverging from the continuous optimum would cause a decrease in net farm income. The results indicated that an income penalty of ¥48.92 per goat arose for any level of goat raised below the optimum. If goat numbers were pushed beyond the optimum, the penalty would be ¥23.91 per goat. The same penalty applied until the number of goats increased to 4.06. Similar results were obtained for the other activities.

The linear programming method ensured that the feed rations could meet the nutrient requirements of the animals at minimum cost. The optimal feed ration per dairy goat was estimated to be 464.17 kg. of maize stover in quarter 1; 215.45 kg. of grass and 128.55 kg of rice bran in quarter 2; 10.95 kg. of grass and 487.04 kg. of maize stover in quarter 3; and 215.45 kg. of grass, 48.87 kg. of rice bran and 87.54 kg. of maize stover in quarter 4.

The optimal feed ration per litter of Hog 2 was estimated to be 71.08 kg. of rice bran and 212.76 kg. of rapeseed oil cake in quarter 1; 216.69 kg. of rice bran and 971.29 kg. of vetch in quarter 2; 222.4 kg. of rice bran and 180.22 kg. of vetch in quarter 3; and 335.76 kg. of rice bran and 642.89 kg. of sweet potato vines in quarter 4.

Unused resources provide conditions for future economic growth on the farm. These resources have the potential for increasing productivity. Their identification will aid economic planners and lead to greater economic growth. The linear programming analysis identified potential areas for profitable expansion through the shadow prices. These values indicated how net farm income would increase if one additional unit of resources were available for production.

Table 4.1 shows that income would increase by ¥4,236 per year for the last hectare of land resource used in production. This figure suggests that if an additional hectare of land could be transferred at a cost of less than ¥4,236, it would increase the net farm income. Thus, the addition of land to the farm would constitute one potential area of business expansion if the policy environment should change.

Labor resources were identified as another constraint on farm growth under the present policies. The results (Table 4.1) indicated that income was raised by ¥0.89 in the second quarter or ¥0.47 in the fourth quarter for the last hour of labor resource used in production. The range analysis[1] showed that these values would remain the same from the 1,800 hours used currently up to 1,831 hours in quarter 2 or 1,824 hours in quarter 4, respectively, if all prices and other restraints remained fixed. This means that if an additional hour of labor were employed at the present wage (¥0.4), net farm income would rise.

The shadow price for capital was ¥0.03. The range analysis showed that this value would be in effect up to infinity. So, Farm E would be well-advised to borrow money at the present interest rate of 1.25% to expand production.

Two sorts of efficiencies were analyzed in this study: technical efficiency and allocative efficiency. The former was measured by output

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[1]Range analysis shows the range of an activity or resource over which the unit shadow price of that activity or resource will not change.

of milk and milk income per labor hour, annual milk income per yuan of cost and output of milk per kg. of feed and per yuan of feed cost. These, we assume, were employed to evaluate labor efficiency, capital efficiency, and feed efficiency. This sort of efficiency in Marxist theory is used in China to make comparisons with other farms in the present and with one's own farm in the past.

By contrast, allocative efficiency was assessed by examining whether the ratio of the value marginal product to the price of each resource was greater than, equal to or less than unity. Unity ratios showed that the farmer had achieved allocative efficiency if no capital constraint existed. Ratios for all resources greater than unity but still equal to each other showed that the former had achieved allocative efficiency under a binding budget constraint. Any ratio higher than the others pointed to some inefficiency and told the former where to invest first. Any ratio less than unity pointed to absolute over-investment in that resource.

The total, marginal, and average product curves for the general production function $Q = f(\text{labor} | x_2, x_3, \ldots x_n)$ are depicted in Figure 4.1. From Marxian economists' point of view, the most efficient production occurs when the highest average product is reached (g in Figure 4.1a and k in Figure 4.1b). However, neoclassical economists believe that the optimal production level lies somewhere in Stage II (between g and a in Figure 4.1a). In the following sections, we present the results derived from the analysis of various efficiency measures described above.

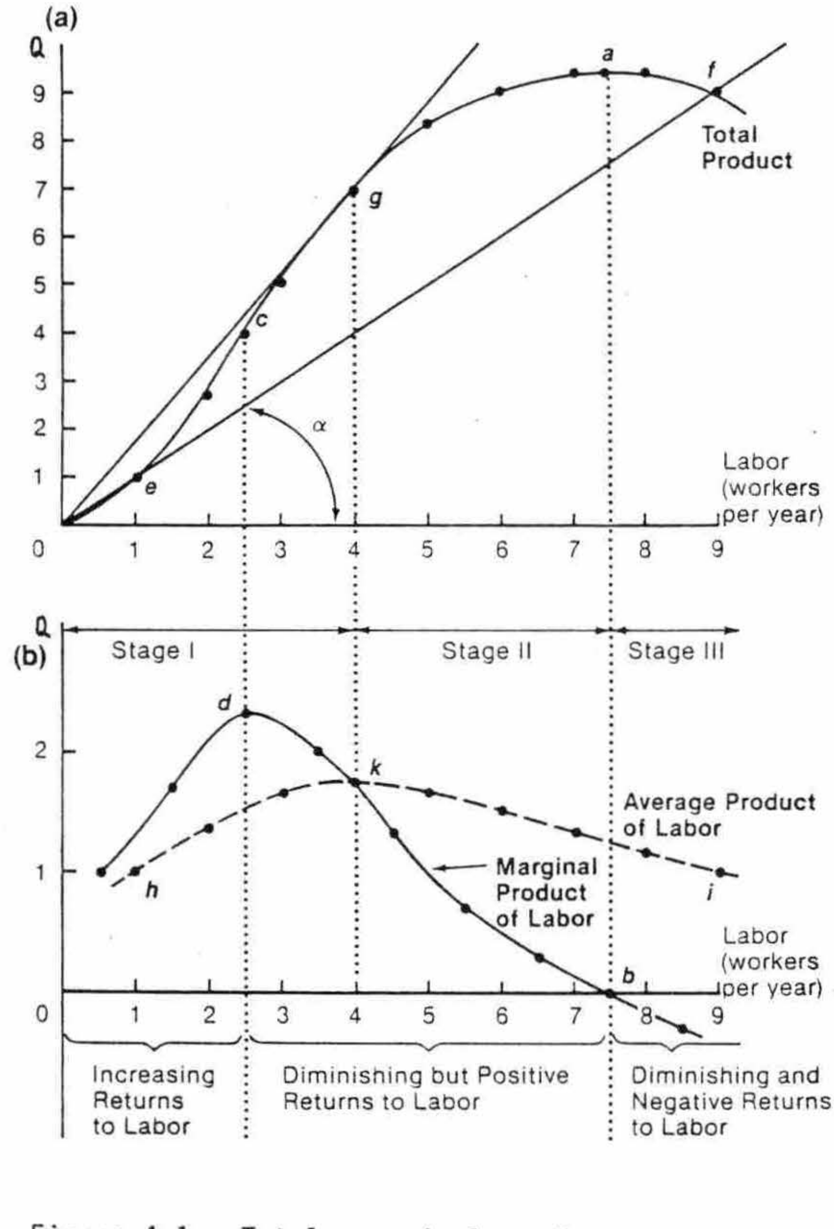

Figure 4.1. Total, marginal, and average product

Let us first concentrate on the analysis of technical efficiency. We found that labor efficiency in the simulation of dairy goat production was more than 25% higher than the actual dairy goat farm in Sichuan (Table 4.2). Feed efficiency, in terms of output of milk per yuan of feed, in our optimal plan improved remarkably due to the scientific feed ration, even though the output of milk per kg of feed decreased. As the result of improvements in labor and feed efficiencies milk income per yuan of cost increased 47%.

The analysis of allocative efficiency between labor and capital showed, first, that resources were allocated fairly efficiently in the optimal solution because the ratios for capital and peak season labor were nearly identical, and all ratios were greater than 1.0. Second, the farmer should invest in capital before increasing labor use because capital had higher ratio of the value marginal product to its price (2.4) than labor (2.3 in quarter 1 and 1.8 in quarter 4).

The programming results also indicated that the most critical nutrient was calcium in quarter 1, at shadow prices of ¥17.15 per kg. for goats and ¥32.48 per kg. for hogs. The range analysis illustrated that this value was relevant up to 0.13 kg. of calcium for goats and 0.76 kg. for hogs. If the farmer could get calcium at a cost lower than the shadow price, net farm income would rise.

Table 4.2. Measures of comparative technical efficiency in dairy production

	Actual Dairy Goat Production[a]	Simulation of Dairy Goat Production	Actual Dairy Cattle Production[b]	Optimal Dairy Cattle Production	U.S. Dairy Cattle Production[c]
Labor efficiency					
milk (kg/hour)	0.75	0.94	2.1	2.1	109.3
milk income (¥/hour)	0.22	0.28	0.84	0.84	12.63
Capital efficiency					
milk income (¥/¥ of cost)	0.43	0.63	0.82	1.56	1.04
Feed efficiency					
milk (kg/¥ of cost)	6.67	23.36	0.27	0.71	0.87
milk (kg/kg)	2.00	0.45	3.85	35.33	0.89

[a]Source: (2, p. 119).

[b]Source: (2, p. 116).

[c]Source: Adapted from (7, pp. 7-14).

4.2 Optimal Dairy Production Under No Labor Hiring

This section will allow the introduction of dairy cattle to the farm to reflect a policy of the Chinese government begun in 1978. Labor hiring is still prohibited. We found that the introduction of dairy cattle production would increase net farm income by ¥2,001 if all resources and prices remained unchanged (Table 4.1). This result led to the acceptance of the hypothesis 1, that net farm income will be increased by introducing dairy cattle production into mixed crop-animal operation. The optimal combination of production on the farm included 2.43 head of Simmental X Yellow dairy cattle and 0.79 head of Hog 11. For the sake of simplicity we did not examine the integer situation in this analysis. The range analysis gave little information on the income penalty of decreased farm size. However, if the cattle number were pushed above the optimum, the penalty would be ¥56.72. The optimal solution would not change as long as the basic production cost (C-row) of raising cattle varied between ¥186.26 and ¥110.94.

The same analysis could be applied to Hog 11 production. Diverging from the optimum, either up or down, generated an income penalty (¥2.17 or ¥23.52). The level of Hog 11 would stay the same with basic production costs (C-row) varying between ¥39.81 and ¥65.5.

The least-cost feed ration for dairy cattle can be observed in Table 4.3. The feed ration for Hog 11 per head consisted of 83.12 kg. of rice bran and 93.46 kg. of rapeseed oil cake in quarter 1; 36.8 kg. of rice bran and 25.4 kg. of vetch in quarter 3; 159.37 kg. of rice bran and

Table 4.3. Feed rations per head of dairy cattle derived from the optimal solutions of four LP runs of Farm E, Sichuan Province, China (kg)

	Basic	Basic with labor hire	Specialized with limited labor hire	Specialized with unlimited labor hire
Quarter 1				
Rice bran	0	0	0.77	0.08
Maize stover	2,461.67	2,461.67	2461.22	2,461.62
Grass	0	0	0	0
Quarter 2				
Rice bran	951.77	951.77	951.77	951.77
Maize stover	0	0	0	0
Grass	291.62	291.62	291.62	291.62
Quarter 3				
Rice bran	29.44	44.33	44.33	44.33
Maize stover	1,247.58	990.77	990.77	990.77
Grass	192.54	195.22	195.22	195.22
Quarter 4				
Rice bran	44.33	44.33	44.33	44.33
Maize stover	990.77	990.77	990.77	990.77
Grass	195.22	195.22	195.22	195.22

257.88 kg. of sweet potato vine in quarter 4. Beyond the optimal feed combination an income penalty would arise.

The programming results showed that land was not fully used. The reason was that raising dairy cattle was very profitable. The farmer should put most of the family labor into cattle production, which requires little land. The unutilized land might be used to expand production in the future.

The value marginal productivities on labor indicated that if one additional labor hour could be hired at less than ¥3.31 in the second quarter, net farm income would increase. The range analysis showed that this value would stay unchanged from the current 1,800 hours up to 1,877 hours in quarter 2, given all other resources and prices constant.

No money borrowing activity was involved in this plan. However, the results showed that one additional unit of capital invested in farm production at a cost below ¥0.3 would increase net farm income.

Once again, calcium was the most critical nutrient. Its shadow price per kg. was ¥17.15 for dairy cattle and ¥32.48 for hogs. The range analysis indicated that this value would not change until the amount of calcium reached 0.23 units for cattle and 0.44 units for hogs. As long as the farmer could get one additional kg. of calcium at a cost lower than the shadow prices, net farm income would increase.

Since we were interested in the development of dairy production and we knew that unutilized land made it possible to enlarge production scale, we wished to identify which resource was the most critical in limiting the economic growth of the farm. It turned out (Table 4.1) that all 1,800 hours of family labor were used in quarter 2 and quarter 4, with the highest shadow price ¥3.31 in quarter 2 among the limiting resources. The analysis of allocative efficiency suggested that Farm E should expand production by first hiring labor in quarter 2, because VMP_{L2}/P_{L2}=3.31/0.4= 8.28, while VMP_k/P_k=0.03/0.0125=2.4, for capital.

The average cost per cow derived from the programming results was ¥1170.68 of which basic production costs (C-row) were ¥167.6, labor costs were ¥873.6 and feed costs were ¥129.48.

The programming results (Table 4.2) showed that the technical efficiency in this optimal plan was substantially improved over the actual dairy farm reported by A. J. De Boer. Because our model borrowed labor:output ratios from the De Boer study, the output of milk and milk income per hour of labor remained constant. However, through a superior choice of feed ration one yuan of total cost could bring ¥1.56 cash income, 190% higher than that in the actual dairy production. The output of milk per kg of feed jumped from 0.27 kg in actual production to 0.71 kg in this plan, and the output of milk per yuan of feed raised from 3.85 kg to 35.33 kg. To contrast these figures with the United States, Snyder estimated that one hour of U.S. labor could produce 109.28 kg. of milk in 1981 (7, p. 7), approximately 52 times that much of this optimal farm in China, which was worth $7.43 (7, pp. 3, 7) or ¥12.63. He reported that one dollar of feed could yield an average 15.08 kg. of milk

(7, pp. 12-14)[1] and one kg. of feed could generate 0.89 kg. of milk (7, p. 14), about 25% higher than that of this optimal plan in 1981. However, as a result of high labor and feed costs in the U.S., the average return per dollar of total cost was \$1.04, only two-thirds of the corresponding profit rate in China.

4.3 Optimal Dairy Production With Limited Labor Hiring

The purpose of this section is to analyze the optimal plan for the farm with limited labor hiring as a further resource for farm growth. We assumed that the number of outside labor hours available was limited at 3,000 hours per quarter. Net farm income increased from ¥5,707 to ¥12,044, turning Farm E into a "ten thousand *yuan* household." This result led to acceptance of the hypothesis 2, that potential exists for an increase in net farm income through a policy allowing additional non-family labor hiring.

In this situation, the optimal plan was dominated by Simmental X Yellow dairy cattle at an optimal level of 7.28 head. Any lower level of dairy production would result in an income penalty of ¥953.38 per head. An income penalty of ¥336.99 per head would arise if the number of cattle were higher than the optimum. However, the optimal level would not change at basic production costs (C-row) ranging between negative

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[1]This figure implies an output of 8.9 kg per Chinese yuan, only about one-fourth of the corresponding ratio in Sichuan. Clearly, the high cost of feed in the U.S. leads to lower economic output despite higher absolute physical efficiency.

¥169.33 to positive ¥1,121.04. Clearly, these results are very insensitive to changes in cattle production costs. The programming results also indicated that Hog 2 raising would replace dairy cattle production only if the basic production cost (C-row) of cattle was increased to ¥1,121.04.

The feed ration described in Table 4.3 was formulated to meet the nutrient requirements of dairy cattle at minimum cost. Departing from the optimal formulation would reduce net farm income but not necessarily satisfy animal nutrient requirements. Again, the most critical nutrient for cattle was calcium, with a shadow price of ¥17.15, the highest shadow price per kg. among all the nutrients.

It was found that all the existing resources were used. Table 4.1 shows the value marginal productivities of these scarce resources. The shadow price on land indicates that if the farmer could contract with the collective team or were otherwise transferred possession of one additional ha. of land, net farm income would increase by ¥1,167. In addition, this value can aid the government and farmers in their determination of equitable payments for land transfers.

Allocative efficiency analysis again pointed to labor as the most promising source of farm growth. The ratio of the value marginal product of labor to the wage rate in quarter 2 was 1.96/0.4, or 4.9, while the ratio of the value marginal product of capital to the interest rate was only 0.03/0.0125, or 2.4. As noted, the farmer was forbidden to rent or sell land, so this third investment option was not open to him.

To evaluate technical efficiency at different levels of dairy herd size, we respecified the linear program to include integral levels of dairy raising from 1 to 10 head. The number of cows in the herd for the year was used to measure farm size because it measured the variability in the key source of production of the dairy herd. The relevant net farm income, costs, total labor hired, total milk produced, and technical efficiency are summarized in Table 4.4.

There was a strong relationship between farm size and net farm income. Table 4.4 indicates that the number of cattle had a direct bearing on net farm income. One reason was that larger farms made possible more efficient use of inputs such as labor.

The costs in this section are per head of dairy cattle. The total cost is broken down into basic production cost (C-row), feed cost and labor cost. Unpaid family labor was charged to the farm at the present wage rate of ¥0.4 per hour to show the effect of increasing size on these three types of costs, which are given in Table 4.4.

The average total cost per cow decreased as the size of the farm increased (Table 4.4). The costs declined rapidly with an increase in herd size for the first six levels of production. These decreases derived primarily from improved feed and labor efficiency. Beyond this level, however, the costs then tended to be relatively constant.

The relationship between average labor productivity, in terms of either milk output or labor returns per hour, and farm size were positive (Table 4.4). The positive relationship could be attributed to more efficient labor usage. The positive relationship was slight, however,

Table 4.4. Measures of technical efficiency for ten integral levels of dairy cattle herd size in the basic model for Farm E, Sichuan Province, China

Item \ Production Level (head)	1	2	3	4	5	6	7	8	9	10
Net farm income (yuan)	4,857.42	5,827.64	7,835.46	9,145.97	10,480.40	11,832.24	13,203.85	14,594.21	15.996.80	17,405.09
Total milk produced (kg)	4,575	9,150	13,725	18,300	22,875	27,450	32,025	36,600	41,175	45.750
Total labor hired (hr/yr)	0	0	0	2,698	4.271	5,764	7,147	8,586	9,947	11,296
Average basic production cost (C-row)	167.66	166.82	165.99	165.16	164.33	163.51	162.70	161.88	161.07	160.27
Average labor cost	873.6	785.6	723.2	672.0	632.0	600.0	576.0	558.4	547.2	542.4
Average feed cost	152.82	151.84	125.02	130.35	125.82	124.75	124.75	124.75	124.75	124.75
Average total cost (yuan/hd)	1,194.08	1,104.26	1,014.21	967.51	922.15	888.33	863.45	845.03	833.02	827.42
Labor efficiency										
(milk/hr)	2.10	2.21	2.31	2.39	2.48	2.56	2.64	2.70	2.76	2.81
(milk income/hr)	0.84	0.88	0.92	0.96	0.99	1.03	1.05	1.08	1.10	1.12
Capital efficiency (milk income/yuan)	1.53	1.66	1.80	1.89	1.98	2.06	2.12	2.17	2.20	2.21
Feed efficiency										
(milk/yuan)	29.94	30.13	36.59	35.10	36.36	36.67	36.67	36.67	36.67	36.67
(milk/kg)	0.59	0.64	0.74	0.70	0.74	0.74	0.74	0.74	0.74	0.74

because of the intensity of labor use in cattle production.

Dairy cattle feed costs must be analyzed by examining the entire feeding program, including both feedstuffs purchased from the market and those produced on the farm itself. The feeds from the private plots were charged at market prices in consideration of the opportunity costs of the feeds.

The feed cost per head (Table 4.4) decreased rapidly at first, becoming more constant as herd size increased. Beyond six head, feed costs per unit became fixed. This result indicated that feed efficiency increased significantly at first and then slowed, eventually becoming relatively constant.

The reason for this phenomenon is that the farm could use crop residues to feed a small dairy herd. However, the household needed to buy feeds from markets to meet the feed requirements of a larger herd.

When we compared the optimal plan with an actual farm (2, p. 116) on a one-head basis, we found that the optimal feed cost was decreased by ¥1,035 per head. Feed cost accounted for 12.8% of the total cost in our optimal plan, while the feed cost comprised 53.29% of the total cost on that actual farm. The difference can be attributed to a more scientific combination of the feed ration. The farmer on the actual farm fed cattle with 625 kg. of concentrates, 2,730 kg. of silage, and 910 kg. of hay per quarter (2, p. 116), while the farmer on this optimal farm fed his cattle with maize stover, rice bran, and grass (Table 4.3).

Because capital is a major production resource on farms, it is important to analyze how efficiently it is used. It was found that no capital borrowing was involved in this optimal results. The farmer used his own capital endowment and the income from milk selling. Table 4.4 shows that capital efficiency increased at high rates first and then relatively slowly. Maximum capital efficiency was probably not attained because of the limitation on labor hiring.

4.4 Optimal Dairy Production with Limited Labor Hiring and Specialization (No Crop Production)

This section focuses on specialized dairy production. It reflects the current Chinese agricultural policy that encourages and supports specialized household production by providing more credit, allowing specialized farmers to hire more labor, etc. It was assumed that up to 9,000 hours of labor could be employed by this specialized household per quarter. All other resources and prices remained unchanged except that there was no crop production.

It was found that net farm income reached ¥48,779 at an optimal production level of 32.47 head of dairy cattle (Table 4.1). The result of this situation led to acceptance of the hypothesis 3, that specialized dairy production is more profitable than mixed crop-animal production.

At any level between 3.03 and below the optimum an income penalty of ¥7,702 per head would occur. By contrast, the farm would suffer an income penalty of infinity at any level above the optimum. Only when the basic production cost (C-row) of raising the 31st to 35th dairy cow increased to ¥8,416, could the optimal level decrease.

The feed rations were presented in Table 4.3. The linear programming approach ensured the feed ration to be balanced in terms of nutritive values at minimum cost. Range analysis showed that diverging from the feed combination would affect net farm income negatively. As in preceding models, calcium was the most critical nutrient because its shadow price was the highest, at ¥17.15 per kg., among all same unit of nutrients in this model.

It was found that this farm used up family labor and hired the maximum labor allowed. Table 4.1 indicates the value marginal productivities of family labor in quarter 4 at ¥6.05 and hired labor in quarter 4 at ¥5.64. This implied that using one additional hour of labor could lead net farm income to increase. Only about 10% of the total land (Table 4.1) was utilized. On the one hand, the 90% idle land provided the farmer an opportunity to expand production. On the other hand, labor resources restricted farm production. The resulting conflict suggests the need to either adjust land distribution or allow the farms to hire more labor.

Allocative efficiency of labor and capital indicated that if one additional hour labor were employed first in dairy production, net farm income would increase by a big margin. The reason was that the ratio of the value marginal product of labor to the current wage rate was fairly high, at 5.64/0.4, or 14.1, while the ratio of the value marginal product of capital to the interest rate was 0.03/0.0125, or 2.4. These two areas were considered as the potential areas for farm growth.

Technical efficiency is examined in this section by setting different integer levels of dairy production. Net farm income, total production cost, and other data derived from the programming results can be observed in Table 4.5.

Once again, we used the number of cows per herd as the measure of farm size. As shown in Table 4.5, farm size and net farm income were closely and positively related, i.e., the larger the farm size, the higher the net farm income. As the size varied from 5 to 10, the net farm income rose from ¥8,377 to ¥44,976. The fact that larger farms can utilize their inputs more efficiently explains this economic phenomenon.

The average total cost per cow (Table 4.5) declined with the increase in farm size due to more efficient utilization of inputs. Costs decreased with an increase in the farm size most markedly in the early stages of production (Table 4.5) because of improved feed and labor efficiency. Further expansion eventually led to relatively stable average costs.

There was a positive, but not strong, relationship between labor efficiency and farm size (Table 4.5). The intensive labor usage in cattle production could be attributed to the slight relationship.

Since this specialized farm engaged in dairy production only, all feeds needed were bought from markets. The programming results gave the least cost feed rations for different levels of production. As observed in Table 4.5 there was no significant relationship between feed costs and farm size, i.e., the feed costs stayed relatively constant.

Table 4.5. Measure of technical efficiency for six integral levels of dairy cattle herd size in the specialized household model with limited labor hiring, Sichuan Province, China

Item \ Production Level (head)	5	10	15	20	25	30
Net farm income (Yuan)	8,377.26	15,330.42	22,505.45	29,861.01	37,360.89	44,975.79
Total milk produced (kg)	22,875	45,750	68,625	91,500	114,375	137,250
Total labor hired (hr/yr)	2,016	9,076	15,640	21,812	27,676	33,304
Average basic production (C-row) cost	165.99	161.89	157.89	153.99	150.18	146.47
Average labor cost	737.28	564.80	525.12	493.76	469.12	450.24
Average feed cost	124.81	124.77	124.76	124.76	124.76	124.75
Average total cost (Yuan/hd)	1,028.08	851.46	807.77	772.51	744.06	721.46
Labor efficiency						
(milk/hr)	2.48	2.81	3.00	3.15	3.28	3.39
(milk income/hr)	0.99	1.12	1.20	1.26	1.31	1.36
Capital efficiency (milk income/Yuan cost)	1.78	2.15	2.26	2.37	2.46	2.54
Feed efficiency						
(milk/Yuan)	36.66	36.67	36.67	36.67	36.67	36.67
(milk (kg)/kg)	0.74	0.74	0.74	0.74	0.74	0.74

Thus, feed efficiency was also relatively stable given the productivity per cow. Table 4.5 indicates that capital efficiency increased as the number of cattle was raised. The rate of increase was high at first and then slowed.

4.5 Optimal Dairy Production With No Limitation On Labor Hiring for Specialized Production

This section will analyze the optimal plan for the specialized dairy farm under unlimited labor hiring, given all resources and prices unchanged. The greatest economies of size occurred when 321.43 head of dairy cattle were raised. This scale brought in a net farm income of ¥497,429 more than 10 times than the specialized dairy production with a limitation on labor hiring. This result strengthened the acceptance of the hypothesis that net farm income will be increased through a policy allowing additional nonfamily labor hiring.

The range analysis indicated that any level of production below 321.43 head would reduce net farm income by ¥7,764. This income penalty per head continued until cattle decreased to 69.2 head. Below that level, the income penalty increased. From another perspective, the optimal level of production would not drop to 69.2 head unless basic production costs were raised from the current ¥646.64 to ¥8,460. The programming results also showed that a slight increase in farm size would result in the income penalty becoming infinity.

The feed rations (Table 4.3) in this situation were exactly the same as those reported for the specialized dairy farm with a limitation on labor hiring. The range analysis showed once more that the most critical nutrient was calcium, whose shadow price reached ¥17.15 per kg.

The programming results illustrated that the farm hired up to 86,339 hours of labor per quarter, an increase of 959% because of the larger volume of dairy production than the farm under a limitation on labor hiring. The value marginal product of labor was ¥0.41 per hour, which was still higher than the going wage rate, ¥0.4 per hour. In other words, if the farmer hired the 86,340th hour of labor at the prevailing wage rate, the net farm income would still be positively affected.

In this optimal plan, all existing resources were fully used. The value marginal product of land per year was extraordinarily high: ¥1,109,106. This high value reflected the fact that dairy production made land much more valuable than crop production.

The value marginal product of capital was still ¥0.03 (Table 4.1). As between labor and capital, the more profitable area for expansion was capital. The ratio of the value marginal product of capital to the current interest rate was still 2.4, higher than that of labor at 1.025, now that unlimited hiring was allowed.

The average cost per cow was estimated at ¥693.23, which consisted of basic production costs of ¥139.33, labor costs of ¥428.16, and feed costs of ¥124.74 (Table 4.5). The average cost decreased 2% because of a decline in basic production costs of 2.5%, labor cost of 2%, and feed cost of 0.01%. Labor efficiency was improved, varying from 3.44 kg. to 4.27 kg. of milk per hour. This latter figure represents an increase of 24% over specialized dairy production with a limitation on labor hiring. Feed efficiency stayed almost the same. However, capital efficiency increased from ¥2.6 to ¥2.64 per yuan invested.

Since calcium was the most critical nutrient in all situations, we would suggest three policy and research directions. First, the government could provide calcium-rich feedstuffs to farmers at a subsidized price. Second, agronomists are encouraged to develop new feedstuffs which are rich in calcium. Third, the government could make available research funds to animal nutritionists for verifying the true requirements for calcium in dairy animals. Any result that suggested lower requirements could significantly reduce feed costs.

4.6 Parametric Analysis

The purpose of this section is to analyze Farm E's optimal response to different policy environments. Four policy alternatives were considered: (1) a change in the price of the most critical feed in the optimal feed ration, (2) a change in milk price, (3) an increase in the government subsidy, and (4) an improvement in government credit terms.

4.6.1 Effects of a change in input price

Traditionally, feed and other input prices have been set by central and local planners. Farmers had to purchase almost all of their feed from state operated feed mills. This situation has been changing recently, however. By late 1985 or 1986, feed prices may be allowed to fluctuate freely with market conditions. Thus, some understanding of the shape of the demand curves for key feed components will be of help to the government planners as they try to predict the farmers' response to this policy change.

To determine which feed price to use in the parametric analysis, we first investigated the three feeds used to formulated feed rations: maize stover, grass, and rice bran.

Maize stover is the maize plant from which the ears have been removed. When mature maize is the primary crop sought, the remaining part of the plant also is mature and contains relatively less of the plant's nutrient value. The lower leaves are usually dry and are frequently lost in handling; so what remains is high in fiber and unpalatable. Maize stover is low in protein and very low in minerals. The amount of energy is relatively high (Appendix 8.6). The maize stover used in the optimal feed rations came mainly from farm by-products.

The nutrient value of grass varies with the types of grasses. The grass involved in our model was cut from the borders of farm fields. We assumed the grass contained the average level of nutrients (Appendix 8.6).

Rice bran is one of the most popular concentrates in the Sichuan Basin. It is obtained in milling rice for human food, together with such quantity of full fragments as is unavoidable in the regular milling operation. It contains a fairly high amount of protein and fat, 13% and 13.6%, respectively. It is rich in phosphorus than most of other feeds. When it is necessary to purchase concentrated feeds, rice bran is always high on the list, especially for Farm E, this farmer did not plant rice.

We decided to perform parametric price analysis to see how the optimal solution would vary in response to changes in the price of the richest feedstuff, rice bran. The price alternatives were ¥0.01, ¥0.03, and ¥0.04. Note that the going market price of rice bran was ¥0.024. The impacts on the optimal plans for Farm E in the basic model, the model with limited labor hiring, and the specialized production model under a labor hiring constraint are summarized in Table 4.6.

Decreasing net farm income in all models reflected the progressive increase in the prices of rice bran. However, farm size remained unchanged regardless of price level. Changes in the prices of rice bran had significant effects on the quantity demanded for rice bran by the farm.

The farmer's demand for rice bran was derived from the underlying demand for the milk produced on his farm. Thus, the rice bran demand function was: $X = X\ (R_1 \mid P_m, R_2, R_3, Z)$

where

P_m: the price of milk;

R_1: the price of rice bran;

R_2: the price of maize stover;

R_3: the price of grass;

Z: the other parameters, such as the price of other feeds, technology, etc.

In this parametric analysis, we assumed that all prices, except R_1, and the other parameters were exogenous. Therefore, the demand function was a function of the price of rice bran alone.

Table 4.6. Changes in the prices of rice bran and effects

Price Level (yuan)	Net Farm Income (Yuan)	Farm Size (cattle/hd)	Feed Cost (Yuan) Q1	Q2	Q3	Q4	Demand for Rice Bran (kg) Q1	Q2	Q3	Q4	Most Critical Nutrient	Shadow Price Yuan/kg
Basic Model E												
0.01	5,792.89	2.43 0.79 hog	42.40	14.18	28.33	14.81	11,005.33	2,309.92	100.59	2,537.34	Calcium in Q1	14.70
0.024	5,706.84	2.43 0.79 hog	49.23	27.51	28.50	23.99	65.81	2,309.92	100.59	233.77	Calcium in Q1	17.15
0.03	5,690.24	2.43 0.79 hog	49.23	28.55	28.92	24.27	65.81	2,309.92	100.59	233.77	Calcium in Q1	17.15
0.04	5,683.42	2.43 0.79 hog	49.23	34.34	29.21	24.71	65.81	209.24	100.59	233.77	Calcium in Q1	17.15
Model E with labor hiring = 3,000 hours per quarter												
0.01	12,284.17	7.28	49.20	14.18	14.81	14.81	30,701.42	6,924.31	2,172.68	7,227.77	Ca in Q1	14.70
0.024	12,043.55	7.28	49.23	27.51	24.00	24.00	0	6,924.31	322.50	322.50	Ca in Q1	17.15
0.03	11,997.19	7.28	49.23	33.22	24.27	24.21	0	6,924.31	322.50	322.50	Ca in Q1	17.15
0.04	11,982.36	7.28	49.23	34.28	24.71	24.71	0	627.22	322.50	322.50	Ca in Q1	17.15
Specialized household model with labor hiring = 9,000 hours per quarter												
0.01	50,058.31	32.47	49.20	14.18	14.81	14.81	136,993.61	30,877.80	32,232.11	32,232.11	Ca in Q1	14.70
0.024	48,778.72	32.47	49.23	27.51	24.00	24.00	0	30,877.80	1,414.29	1,414.29	Ca in Q1	17.15
0.03	48,572.27	32.47	49.23	33.22	24.27	24.27	0	30,877.80	1,414.29	1,414.29	Ca in Q1	17.15
0.04	48,506.83	32.47	49.23	34.28	4.71	24.71	0	2,774.24	1,414.29	1,414.29	Ca in Q1	17.15

The range analysis showed that the rate of change of the farmer's purchases of rice bran with respect to changes in its price with all other prices constant was always negative. We used the first quarter and the basic model as an example to illustrate the relationship between price and the quantity demanded. When the price of rice bran was between ¥0.0003 and ¥0.012 per kg. the quantity demand was 11,005 kg. In the price range of ¥0.012 to ¥0.022 per kg., purchases decreased to 763 kg. For increases in price from ¥0.022 to ¥0.063 per kg., quantity demand would be reduced to 65.81 kg. If the price rose to higher than or equal to ¥0.063, purchases would drop to 61.2 kg.

Decreasing demand resulted from increasing prices could be attributed to a substitution effect, or the tendency of producers to substitute relatively cheaper feed inputs for relatively expensive ones. For example, when the price of rice bran increased from ¥0.03 to ¥0.04 per kg. in quarter 2, the quantity demanded by the farmer fell from 2,309.92 kg. to 209.24 kg., the farmer then purchased 806 kg. of rice straw to substitute for some rice bran.

The programming results in all quarters in the three models obeyed the law of demand that the quantity of rice bran demanded by the farmer tended to increase as the price of rice bran decreased and tended to decrease as the price of rice bran increased, other things being equal.

The demand curve for rice bran was obtained by graphing the quantity demand as a function of the price of rice bran alone, on the assumption that all other feed prices, milk price, and parameters were constant. Figures 4.2 through 4.4 illustrate the demand curves in the 4 quarters

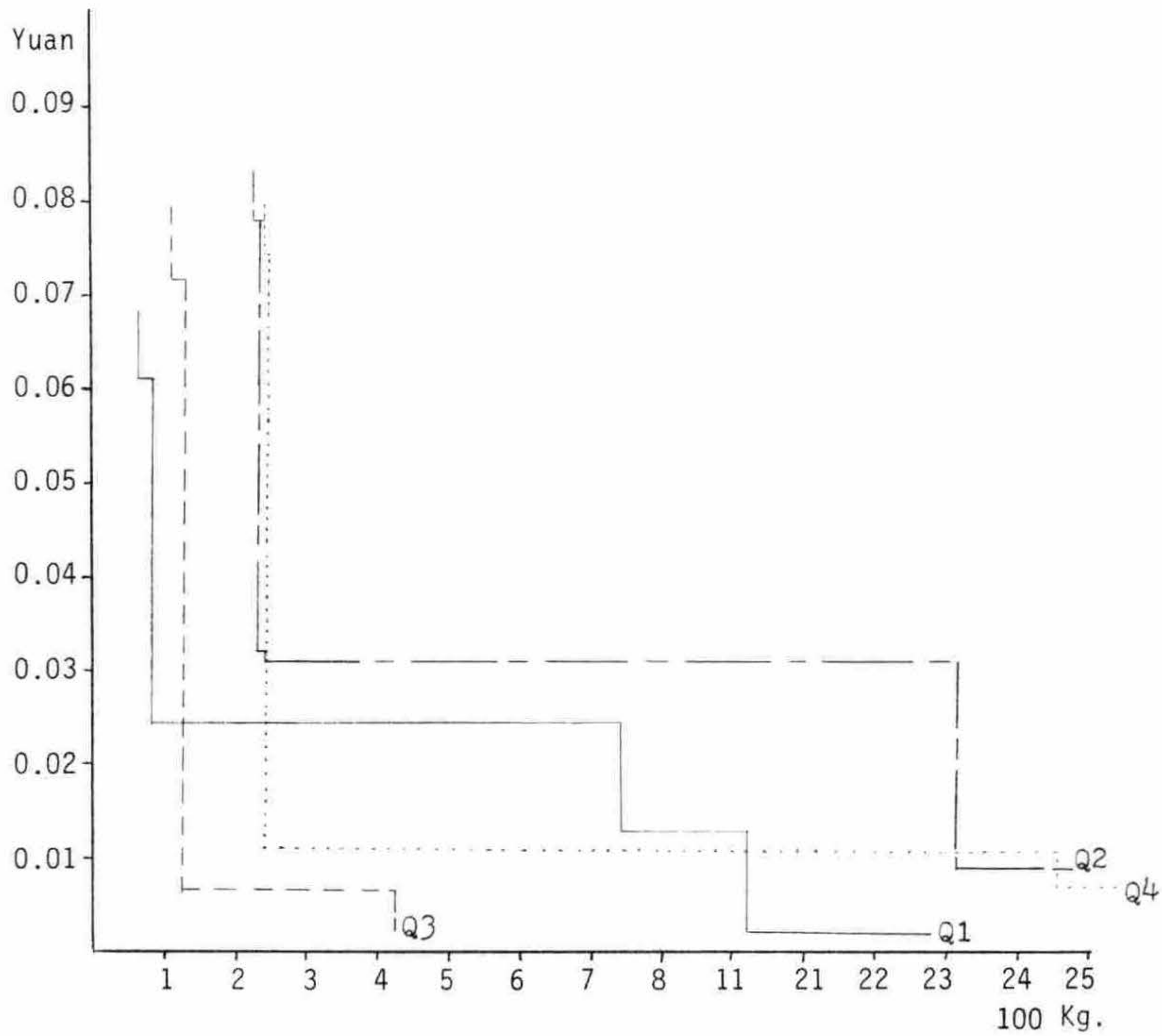

Figure 4.2. Demand Curves for rice bran in the basic model for Farm E, Sichuan Province, China

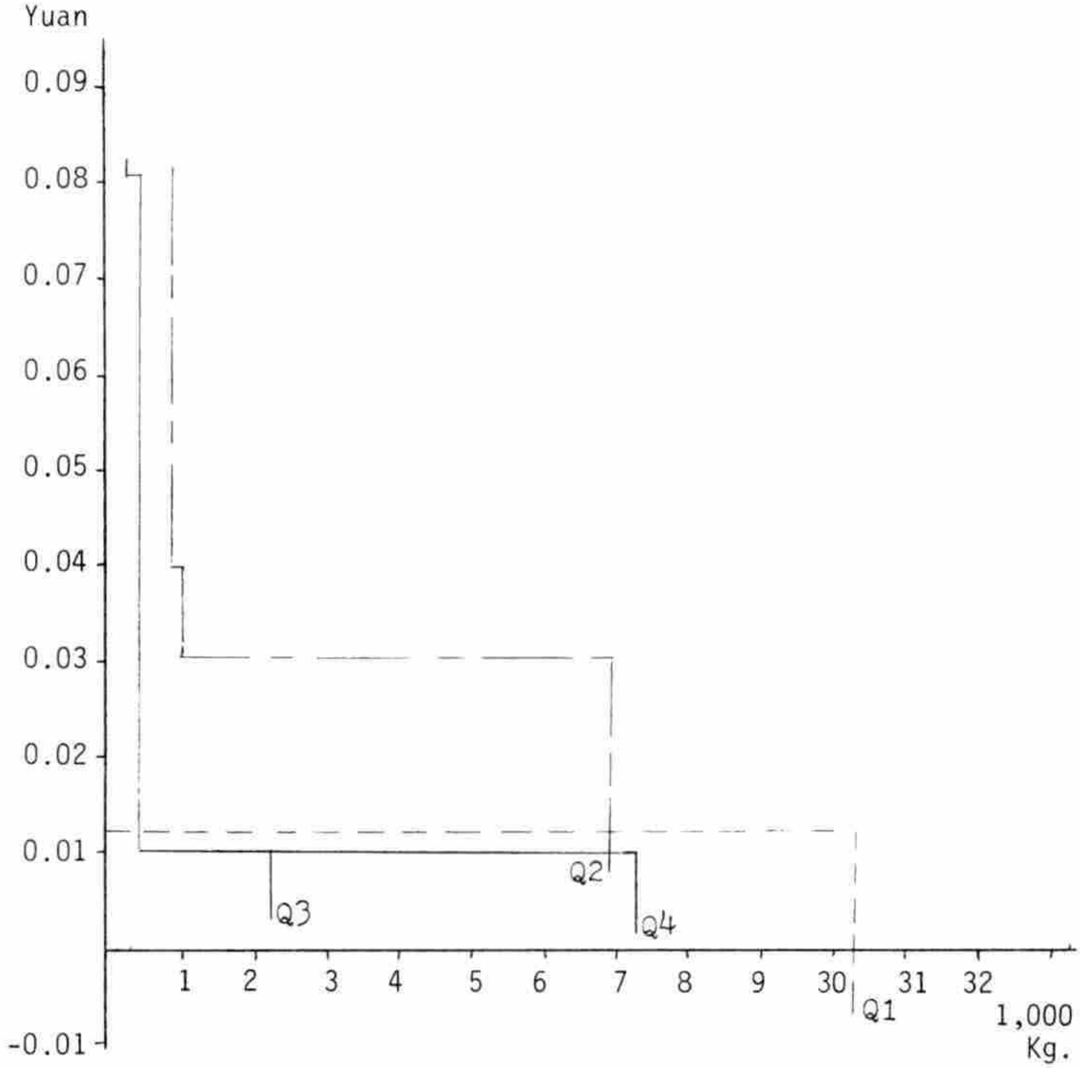

Figure 4.3. Demand curves for rice bran in the basic model with labor hiring for Farm E, Sichuan Province, China

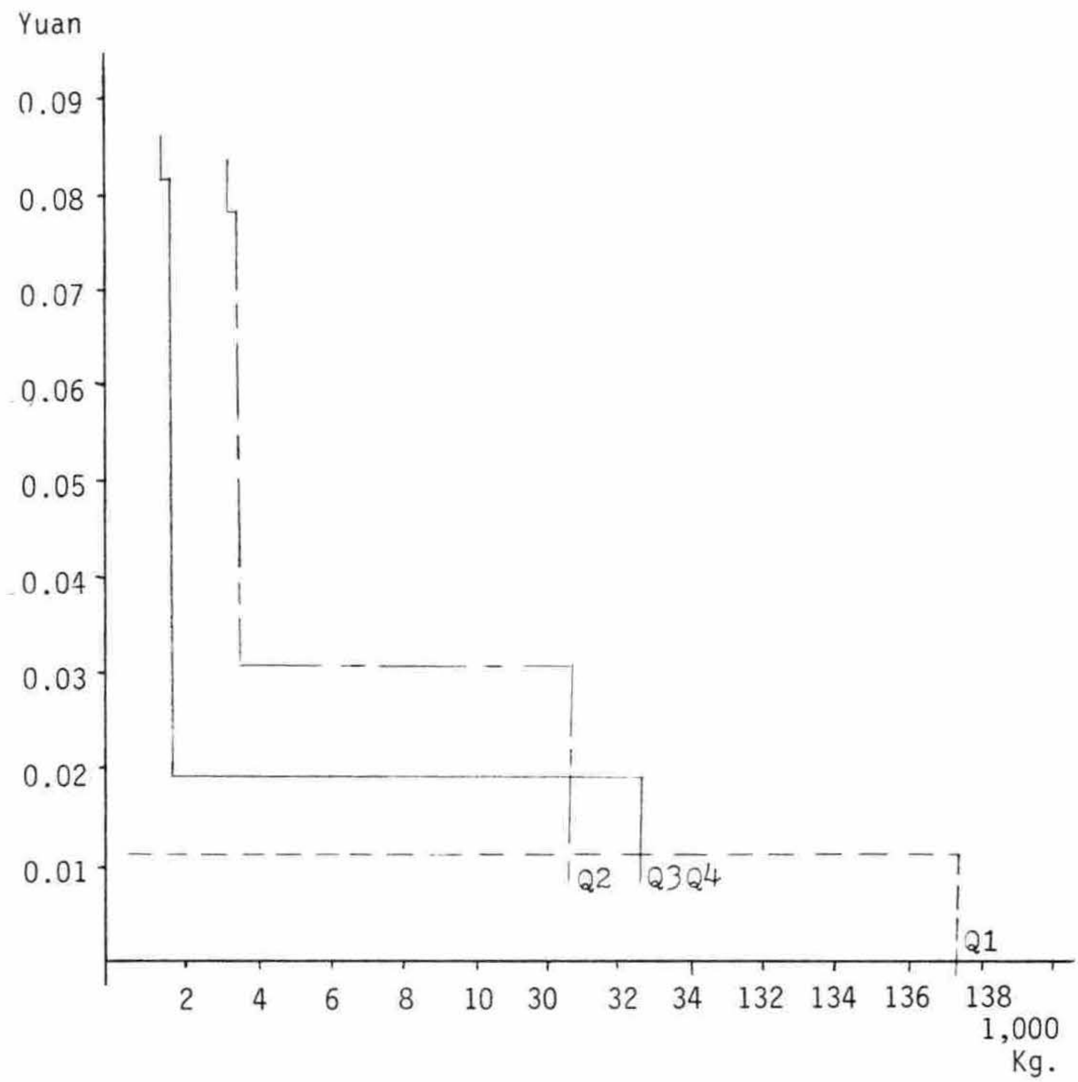

Figure 4.4. Demand curves in the specialized model with labor hiring, Sichuan Province, China

for the three models. The curves all slope downward.

The price elasticity of demand is defined as the ratio of the percentage change in the quantity demand for rice bran to the percentage change in the price of rice bran:

$$E = \frac{R_1}{x} \frac{dx}{dR_1}$$

The price elasticity of demand for price changes from ¥0.063 to ¥0.022 was less than unity. This means that a 1% change in price would result in a less than 1% change in the quantity demanded. This result led to rejection of hypothesis 4 that a 1% reduction in the price of a key feed input, rice bran will induce a more than 1% increase in the demand. Elasticity was greater than unity for price changes from ¥0.022 to ¥0.0003. This implies that a 1% change in the price would cause a larger percentage change in quantity demand. This result led to the acceptance of hypothesis 4. The same analysis can be applied to all of the demand curves. The interpretation of these price elasticities of demands are described in Table 4.7.

Changes in the prices of rice bran also had an impact on the composition of the optimal feed ration and feed cost. When the price in the first quarter was greater than or equal to ¥0.024 per kg., the farmer did not use rice bran to feed cattle ration. In the second quarter, the farmer used the same amount of rice bran, 952 kg., at price levels from ¥0.01 to ¥0.03. If the price was raised to ¥0.04, the amount of rice bran in the feed ration declined to 86 kg.; rice straw, grass hay, and more fresh grass were used as substitutes. The feed rations and

Table 4.7. Price ranges, quantities demanded and price elasticities of demand for rice bran

Model and Season	Quantity	Stage 1 Price range	E	Stage 2 Quantity	Price Range	Stage 3 E	Quantity	Stage 4 Price Range	E	Quantity	Stage 5 Price Range	E
Basic Model E												
Q1	61.2	P>.063	<1	65.81	.063>P>0.022	>1	763.47	.0227>P>.012	>1	11,005.33	.012>P>.0003	
Q2	203.33	P>.079	<1	209.24	.079>P>.0316	<1	212.58	.0316>P>.0303	>1	2,309.92	.0303>P>.0094	
Q3	97.88	P>.072	<1	100.59	.072>P>.007	∞	402.29	.007>P				
Q4	228.90	P>.074	<1	233.77	.074>P>.012	>1	2,537.00	.012>P>.0097				
Model E with Labor Hiring = 3,000 hours per quarter												
Q1	0	P>.0117	∞	30,701.42	.0017>P>-.00029							
Q2	609.50	P>.079	<1	627.22	.079>P>.04	<1	637.23	.04>P>.0303	>1	6,924.31	.0303>P>.0097	
03	301.35	P>.0823	<1	322.49	.082>P>.01	>1	2,171.68	.01>P>.0097				
04	318.17	P>.082	<1	322.49	.082>P>.0102	>1	7,227.68	.0102>P>.0097				
Specialized Household Model with Labor Hiring = 9,000 hours qer quarter												
Q1	24.92	P>.0012	>1	136,993.59	.0012>P>-.0003							
Q2	2,762.38	P>.079	<1	2,818.96	.079>P>.0316	∞	30,887.80	.0316>P				
Q3	1,402.59	P>.082	<1	1,414.29	.082>P>.0189	∞	32,232.11	.0189>P				
Q4	1,402.60	P>.082	<1	1,414.29	.082>P>.019	∞	32,232.11	.019>P				

their costs, reflecting changes in the price of rice bran, are described in Table 4.6.

The most critical nutrient was still calcium. Its value marginal product was fixed at ¥17.15 until the price of rice bran dropped to ¥0.01, when the value marginal product declined to ¥14.7 per kg. (Table 4.6).

4.6.2 Effects of a change in output price: milk price

Traditionally, central planners believed that relatively fixed output prices could best promote production. However, the Chinese government announced a sweeping reform of the price system in early 1985. The government would release its hold on agricultural products; that is, the equilibrium of the agricultural product market, or demand for and supply of farm products, would be adjusted by the market mechanism. This policy change makes it vitally important to estimate the producer supply curves for agricultural products. The linear programming model is particularly suited for such estimation through parameterization of output price with all other coefficients held constant. The results of this parameterization are given below and should be of great help to policy makers and analysts.

Model E with limited labor hiring was the most sensitive to changes in the price of milk, so output price parametric analysis focused on how the farm responded to four milk price levels: ¥0.1, ¥0.2, ¥0.6, and ¥0.7 per kg. It turned out that all results stayed as before, except that net farm income and the number of cattle raised were positively affected (Figures 4.5 and 4.6).

The parametric analysis indicated that milk supply and milk price were strongly related in all seasons. The supply curves derived from the linear programming results are presented in Figure 4.7. This curve describes the relationship between the price of milk and the quantity of milk supplied. If the price of milk in the first quarter rose to greater than ¥2.91 per kg., the amount of milk supplied would be 3,870 kg. If the price decreased to between ¥0.5 to ¥2.91 per kg., the amount of milk supplied would decline to 3,802 kg. For further decreases in price, the supply of milk would fall to 3,492 kg. Farmers would not supply any milk at a price below ¥0.2, because the marginal revenue of milk would be less than the marginal cost; the farmer would suffer an absolute loss from milk selling. The other three quarters also followed the law of supply, i.e., the quantity of milk supplied by the farmer tended to increase as the price of milk was raised, other things equal.

The price elasticity of supply is defined as the ratio of the percentage change in the quantity of milk supplied to the percentage change in its own price:

$$E = \frac{P}{Q}\frac{dQ}{dP}$$

We found that the elasticity of supply for price changes from ¥0.5 to ¥2.91 was less than unity. In other words, a 1% change in price brought about less than a 1% change in quantity supplied; supply was inelastic. The elasticity for price range between ¥0.2 and ¥0.5 was greater than unity. This result indicated that a 1% change in the price

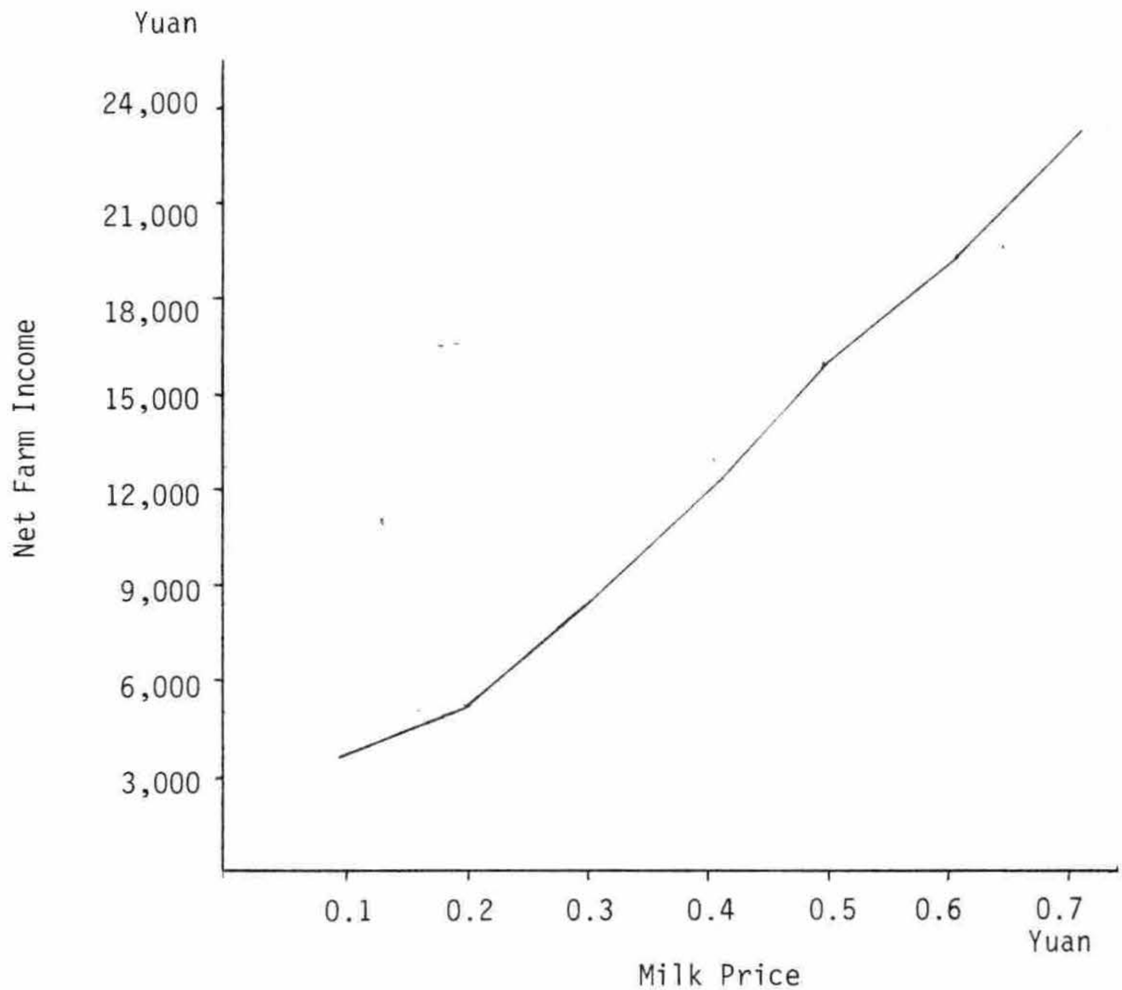

Figure 4.5. Milk price and net fram income in the basic model with limited labor hiring for Farm E, Sichuan Province, China

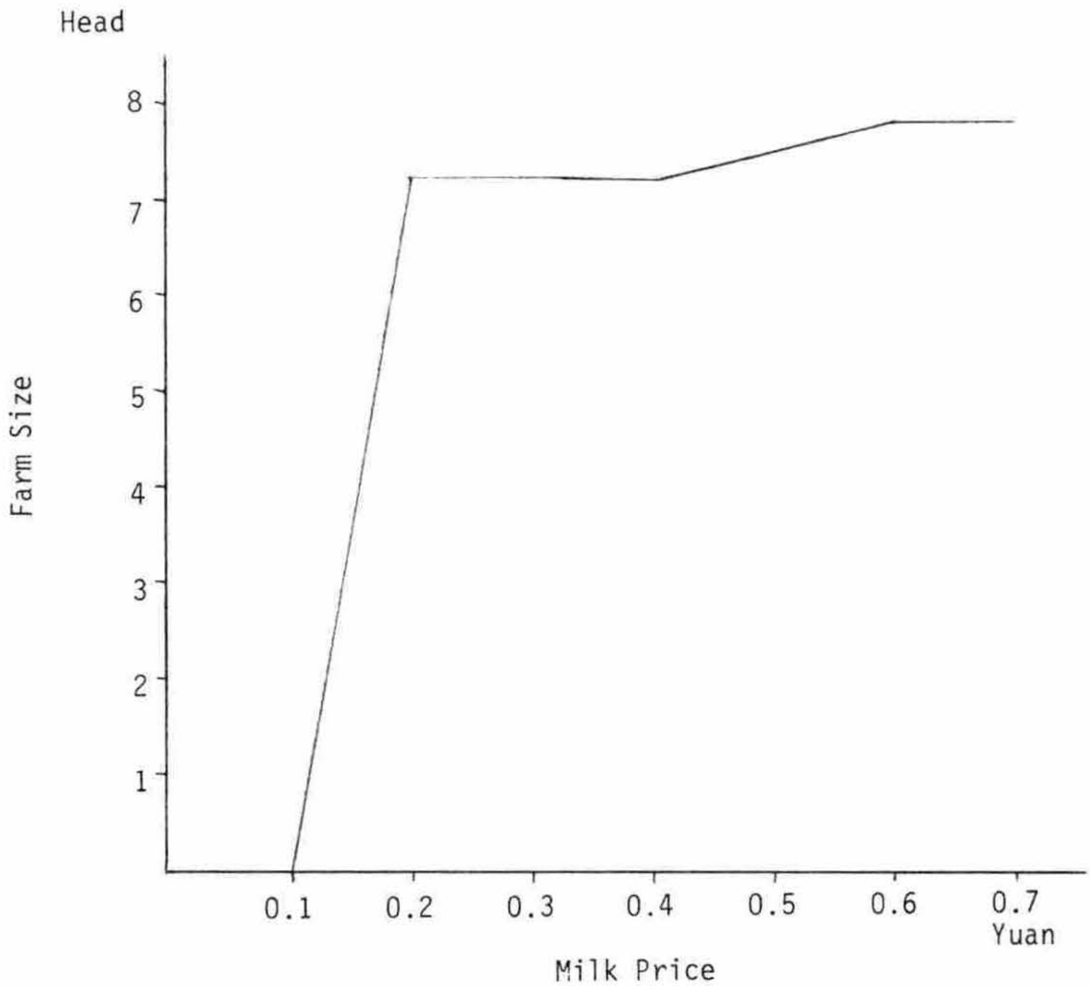

Figure 4.6. Milk price and herd size in the basic model with limited labor hiring for Farm E, Sichuan Province, China

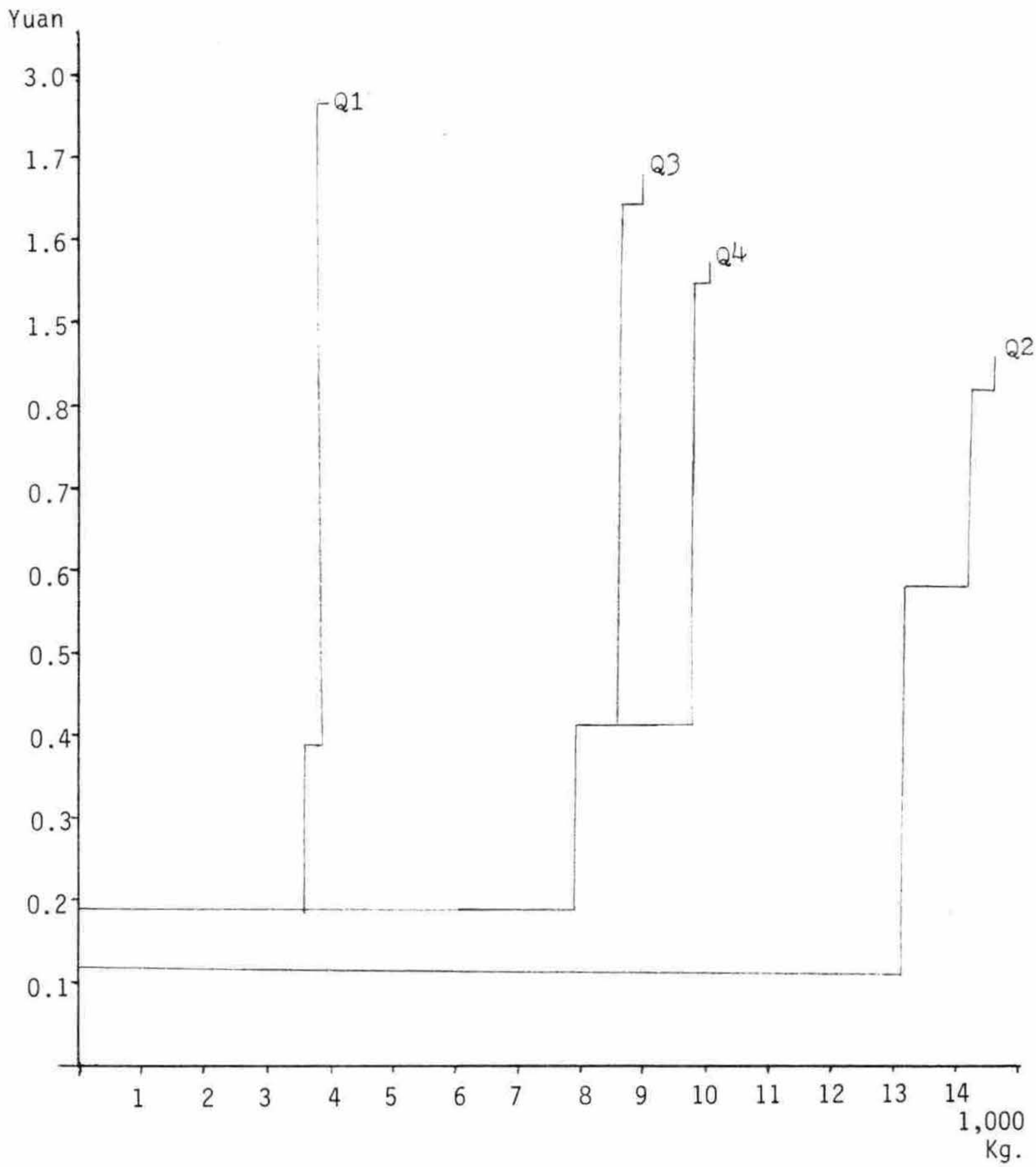

Figure 4.7. Milk supply curves in the basic model with labor hiring for Farm E, Sichuan Province, China

would cause a change more than 1% in the quantity of milk supplied. Thus, we could accept hypothesis 5 only in this price range.

4.6.3 Effects of changes in subsidy and credit

As stated, the Chinese government recently adopted agricultural policies encouraging farmers to expand animal agriculture. Subsidy and credit terms were two such policies. We will analyze the effects of changes of the two policies in this section.

The programming results indicated that all corn subsidized by the government was not used to feed cattle. Farmers made a great profit by selling the corn at free market prices. If the subsidy activities were removed from the model, nothing would change except that net farm income would decrease by an amount determined by multiplying the quantity of corn subsidized by the free market prices of corn. Thus, point of hypothesis 6 is rejected because farmers did not respond to changes in the subsidy policy. This result suggests to the government that the subsidy policy will not work as expected, or that it is not necessary for the government to spend so much money on the corn subsidy. Dairy cattle production is so profitable that farmers will stay in production even without a subsidy given that all resources, price systems, and farm skill remain unchanged.

Nor did farmers take advantage of government credit in their optimal production plans. The reason for this was that they could get daily cash inflow from selling milk. Therefore, we reject the hypothesis that farmers will respond to change in the improved credit terms. This result suggests the government that the policy of preferential credit for specialized dairy households is not necessary.

5. SUMMARY AND CONCLUSION

The major objectives of this study were to develop optimal plans, derive feed rations, determine the economic feasibility of growth, and analyze the optimal responses to government policy alternatives for a mixed crop-animal operation and a specialized dairy household.

The farms selected for this study produced in 1981 on plots of land contracted from collective teams in the Sichuan Basin, the People's Republic of China. The crops grown on the farm included maize and sweet potatoes in the summer, and wheat, rapeseed, broadbean (H), broadbean (F), and vetch in the winter. Fresh grass was cut from the borders of fields and other nonarable land. The livestock raised on the farm comprised dairy cattle, dairy goats, meat goats, yellow cattle, and swine. The specific resources for Farm E consisted of 0.45 ha. of arable land, 1,800 hours of family labor per quarter, and ¥430.5 of capital at the beginning of the year. We assumed that the goal in all cases was to maximize net farm income.

Linear programming was employed in the analysis. The basic model contained 490 production, transfer, buying, selling, borrowing, saving, and consumption activities, and 188 resource restraint and transfer rows. The activities and rows in the expanded model were increased to 505 and 194, respectively, due to the introduction of labor hiring and higher levels of production activities. In the specialized production model, 435 activities and 143 rows were designed.

Two sorts of efficiencies were analyzed in this study, technical efficiency and allocative efficiency. Five farm alternatives and some of their responses to policy changes were analyzed in the development of this study. In the basic model, an optimal plan was developed at 2.43 head of "Simmental X Yellow" dairy cattle and 0.79 head of Hog 11 under existing resources. This optimal farm plan was compared with a simulation of current production in which dairy production was forbidden. It was found that net farm income increased by ¥2,001 if dairy production were introduced into the farm operation. This result led to the acceptance of the hypothesis that allowing private dairy production cannot only provide nutritious food for society, but make farmers richer as well. The existence of the unused resources, land, on the farm showed the potential for subcontracting to neighboring crop farms. The linear programming results indicated potential areas for the most profitable economic growth, through evaluation of the value marginal product of scarce resources. The major area of growth potential on the farm was the addition of labor. The linear programming approach also formulated the feed ration which satisfied the nutrient requirements of the dairy cattle at minimum cost. Calcium was the most critical nutrient.

The basic model with limited labor hiring pursued the possibility of improving the economic situation by acquiring additional labor. The optimal scale of production increased from 2.43 to 7.28 head of dairy cattle. As a result, net farm income increased from ¥5,707 to ¥12,044. All existing resources were fully used. In addition, up to 3,000 hours of nonfamily labor were hired per quarter. The potential areas for profitable expansion in this situation were identified as land, labor, and capital. Assuming no land market, it would be more profitable to expand the farm by hiring more labor before borrowing capital.

The linear programming results showed that farm size affected net farm income positively, and average cost per head of cattle negatively. The reason was that inputs could be utilized more efficiently as farm size increased. Integer-valued cattle raising activities from 1 to 10 head were designed to analyze technical efficiency. The relationship between labor efficiency and farm size was very positive, i.e., the larger the farm size, the higher the labor efficiency. Feed efficiency, by contrast, increased sharply at the beginning of production, then gradually slowed down, and eventually becoming relatively constant at the sixth head of dairy cattle. Capital efficiency rose quickly first, then relatively slowly. Peak capital efficiency was not achieved because of the limitations on other available resources.

In the specialized dairy model with labor hiring at 9,000 hours per quarter, an optimal plan was derived. Net farm income of ¥48,779 was achieved by raising 32.47 head of dairy cattle. We concluded that specialized dairy production could be more profitable than mixed crop-animal production if more labor could be hired. The least cost feed rations formulated by the linear programming method were balanced in terms of nutritive values.

The combinations of all feed rations were almost the same because the farmer purchased all feedstuffs from the markets. Once again, calcium was the most critical nutrient. The idle resource, land, in the specialized operation illustrated great potential for shifting land from specialized to regular crop-livestock households. The analysis of allocative efficiency identified that labor was the most limiting factor, with a shadow price of up to ¥6.04. Therefore, hiring additional labor would be the most profitable area for farm expansion.

The integer cattle raising activities, measuring from 5 to 35 head, were built to analyze technical efficiency. It was found that net farm income was affected by herd size positively. The average cost per head of dairy cattle decreased as herd size grew. Minimum cost was not reached because of the limitation on labor hire. The results showed that labor could be used more efficiently at higher production levels than at lower. There was no significant relationship between feed efficiency and herd size in this specialized production because all feeds needed were bought from markets. Capital efficiency rose quickly at the beginning stages of production; then, the rate slowed and eventually became relatively constant. However, the most economic point was not gained because of resource limitation. Technical efficiencies were compared at the same level of production between the specialized production and the mixed crop-animal production.

In the specialized dairy production model with no limitation on labor hiring, we analyzed the possibility of expanding dairy production by relaxing constraints on labor hiring even further. The linear programming results showed that the number of dairy cattle increased from 32.47 head to 321.43 head and net farm income rose consequently up to ¥497,429. In this case, 28.78 days of nonfamily labor were hired per quarter. This result supported our hypothesis that labor usage in dairy production is so intensive that net farm income will be substantially increased through additional labor hiring. (The feed ration was relatively fixed and the most critical nutrient was still calcium.) In this optimal plan, all resources were fully utilized. The value marginal product of the resources indicated that additional land, labor, and capital were potential areas for profitable farm growth. Here, however, capital held more potential areas for profitable farm growth.

The linear programming results also indicated that average cost per head of cattle decreased as the production scale was enlarged. Labor efficiency and capital efficiency improved. However, no significant improvement could be found in feed efficiency.

The result that calcium was the most critical nutrient in all cases suggests three policy and research direction. First, the government could provide calcium-rich feedstuffs to farmers at a subsidized price. Second, it could encourage agronomists to develop new feedstuffs which are rich in calcium. Third, the government could make available research funds to animal nutritionists for verifying the true requirements for calcium in dairy animals. Any result that suggested lower requirements could significantly reduce feed costs.

In the parametric programming sector, we evaluated the optimal response to different policy alternatives by both mixed and specialized operations. First, we performed parametric analysis of the price of rice bran, which was regarded as the key feed input in all models. The results showed that net farm income declined with the progressive increase in the price of rice bran. Farm size remained constant at all levels of the price of rice bran. The price changes did have a negative effect on the feed ration, in terms of the proportion of rice bran included and, therefore, the demand for rice bran. All of our models followed the law of demand that the quantity of rice bran demanded by the farm tended to increase as the price of rice bran dropped and tended to decrease as the price of rice bran raised, other things being equal. The elasticity of demand was greater than unity on some price range. However, the elasticity of demand was less than unity in others.

On the output side we examined the effects of change in the price of milk. The programming results indicated that changes in the price of milk had a positive effect on net farm income and the number of cattle raised. The feed ration stayed the same at every level of milk price. The changes in milk price had a significant impact on the quantity of milk suggested. The results obeyed the law of supply, i.e., the quantity of milk supplied by the farmer tended to increase as the price of milk went up and tended to decrease as the milk price dropped. The elasticities of supply varied with the change in the milk price.

We also studied the farmer's optimal response to changes in government subsidies. It was found that the subsidy was significant only to the net farm income. Nothing else was affected.

Finally, the function of government credit terms was evaluated. We found that no borrowing from the government was involved in these optimal plans. This led to the conclusion that dairy production was so profitable that no governmental financial support was needed, given the current price system and the levels of farmers' skill.

All of these results augur well for expanding dairy production in Sichuan Province. Our results suggest that the government should continue to shift its attention from price control, subsidies and special credit terms to liberalizing the hiring of labor, releasing control of prices further, and the exchange of contractual rights to farm land. Labor exploitation could be prevented by promising hired labor the going market wage plus 50% of the difference between the value marginal product and the market wage. Specialized households would then be willing to trade in some of their land, so that it could be contracted to farms emphasizing crop production.

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7. ACKNOWLEDGMENTS

The many persons who have contributed their friendship, guidance, inspiration and leadership throughout my first two years at Iowa State University are too numerous to mention individually, but some have given so generously of their time that I cannot simply include them in a blanket acknowledgment.

Special thanks and appreciation go to my major professor, Dr. Peter H. Calkins. I have benefitted greatly from his patient counseling, expert prodding and deep concern for the many real problems facing developing countries. My appreciation and thanks go also to other members of my committee, Dr. Raymond Beneke and Dr. Roy Hickman for their individual contributions to the completion of my master's program.

Special appreciation and thanks must also be extended to Dr. A. J. De Boer and Dr. J. A. Yazman, both of Winrock International, for their invaluable assistance during the process of data collection and design of the mathematical model.

I must also thank all my friends at Iowa State University, like LeRoy Hansen and Misty Hasmen Macfie, who provided a continuous environment for discussion and advice.

I thank also my typist, Susan Danks, for typing the final draft.

Finally, I must express my deepest gratitude to Professors An Xiji at Beijing Agricultural University and Earl O. Heady at Iowa State University who served as my major professors during previous periods in my education. I could not have gotten by without help from them.

8. APPENDIX

Table 8.1. Input-output coefficients used in this model for the selected farms, Sichuan Province, China[a]

Pattern and Crop	Output[b] (kg)	State Tax (kg)	State Quota (kg)	Above Quota (kg)	Collective Retain (kg)	Total Labor Requirement (hr) Q1	Q2	Q3	Q4
A. (Annual C-row cost = ¥473.61)						584	2,823	1,554	1,029
Rice	1,620	129.6	113.4	162	48.6				
Wheat	801.9	64.15	56.1	80.2	24.06				
Broadbean H	7.3	0.6			0.22				
Broadbean F	1,125								
Rapeseed	8.1	0.65	0.57	0.81	0.24				
Vetch	4,200								
Grass	1,350								
B. (Annual C-row cost = ¥473.61)						584	2,823	1,554	1,029
Rice	2,047.5	163.8	143.32	204.8	61.43				
Wheat	900.9	72.1	63.06	90.1	27.03				
Broadbean H	10.55	0.84			0.32				
Rapeseed	0.55	0.84	0.74	1.1	0.32				
Broadbean F	1,125								
Vetch	3,780								
Grass	1,950								
C. (Annual C-row cost = ¥676.89)						588	2,824	3,414	2,428
Early rice	2,047.5	163.8	143.3	204.75	61.43				
Late rice	731.3	58.5	51.9	73.13	21.94				
Wheat	952.1	76.2	66.6	95.2	28.56				
Rapeseed	15.8	1.3	1.1	1.58	0.47				
Broadbean H	10.55	0.8			0.32				
Broadbean F	2,250								
Grass	1,950								

D. (Annual C-row cost = ¥379.48)						584	1,897	1,054	1,592
Maize	396	31.7	27.7	39.6	11.88				
Sweet Potato	4,455	356.4							
Wheat	980.1	18.4	68.6	98	29.4				
Rapeseed	9.9	0.8	0.7	1.0	0.3				
Broadbean H	8.9	0.7			0.27				
Broadbean F	1,125								
Vetch	4,200								
Grass	1,650								
E. (Annual C-row cost = ¥379.48)						584	1,897	1,054	1,592
Maize	540	43.2	37.8	54	16.2				
Sweet Potato	6,075	486			182.25				
Wheat	1,336.5	106.92	93.56	133.65	40.10				
Rapeseed	13.5	1	0.9	1.35	0.41				
Broadbean H	12.15	1			0.36				
Broadbean F	1,125								
Vetch	4,200								
Grass	2,250								
F. (Annual C-row cost = ¥412.28)						585	2,005	1,685	1,469
Maize	675	54	47.25	67.5	20.25				
Sweet Potato	5,062.5	405			151.87				
Irish Potato	2,362.5	189			70.87				
Wheat	759.4	60.8	53.2	75.94	22.78				
Broadbean F	56,250								
Grass	2,250								

[a]Source: (8, pp. 667, 669, 842).

[b]Source: (2, pp. 27-29).

Table 8.2. Land[a], labor[b] and nutrient[c] requirements of dairy cattle

Species and Seasons	Description	Milk[d] Level (kg)	Body[d] Weight (kg)	Land (ha)	Labor (hr)	ME (Mcal)	TP (kg)	DM (kg)	CA (kg)	PH (kg)
Holstein	3.5% milk fat	3,000								
Q1	31 days lactation									
	60 days gestation	310	450	0.0014	546	1,452.65	60.815	828.10	2.348	1.688
Q2	91 days lactation	1,275	400	0.0014	546	1,188.46	41.405	782.60	1.601	1.342
Q3	91 days lactation	910	450	0.0014	546	1,287.65	44.135	828.10	1.784	1.433
Q4	91 days lactation	505	500	0.0014	546	1,383.20	46.774	864.50	1.875	1.524
Holstein X Yellow	3.7% milk fat	1,500								
Q1	31 days lactation									
	60 days gestation	217	400	0.0014	546	1,334.30	56.287	782.60	2,107	1.569
Q2	91 days lactation	728	450	0.0014	546	1,291.29	44.317	828.10	1.787	1.435
Q3	91 days lactation	500	450	0.0014	546	1,291.29	44.317	878.10	1.787	1.435
Q4	91 days lactation	65	450	0.0014	546	1,225.29	39.697	828.10	1.642	1.337
Simmental X Yellow	4% milk level	4,575								
Q1	31 days lactation									
	60 days gestation	480	600	0.0014	546	1,796.36	73.716	871.78	2.954	2.143
Q2	91 days lactation	1,800	550	0.0014	546	1,487.85	49.868	871.78	2.066	1.62
Q3	91 days lactation	1,080	600	0.0014	546	1,579.76	52.461	910.00	2.157	1.711
Q4	91 days lactation	1,215	600	0.0014	546	1,579.76	52.416	910.00	2.157	1.711

[a]Source: (8, p. 629).

[b]Source: (2, p. 116).

[c]Source: (9, pp. 33, 35).

[d]Personal communication. J.A. Yazman, Winrock Int'l, Petit Jean Mountain, Morrilton, Ark., 1984.

Table 8.3. Annual C-row cost[a], land[b], labor[c] and nutrient[d] requirements of draft animals

	Yellow Cattle	Buffalo
C-row cost/year (¥)	26.46	20.91
Land req./year (ha)	0.0013	0.0013
Labor req./quarter (hrs)	182	182
Body weight[e] (kg)	450	550
Metabolizable energy req./quarter (Mcal)	979.16	1,410.32
Total protein req./quarter (kg)	31.031	36.117
Dry matter req./quarter (kg)	728	939.07
Calcium req./quarter (kg)	1.274	1.274
Phosphorus req./quarter (kg)	1.001	1.001

[a]Source (2, pp. 114-115).

[b]Source (8, p. 629).

[c]Source (2, pp. 114-115).

[d]Source (9, pp. 33-35).

[e]Source (2, pp. 83, 104).

Table 8.4. Land[a], labor[b] and nutrient[c] requirements of goats

Species and Seasons	Description	Milk[d] Level (kg)	Body[d] Weight (kg)	Land (ha)	Labor (hr)	ME (Mcal)	TP (kg)	DM (kg)	CA (kg)	PH (kg)
Sannen	3.5% milk fat	750								
Q1	31 days lactation									
	60 days gestation	90	60	0.0003	200	365.01	15.214	163.44	0.557	0.390
Q2	91 days lactation	360	55	0.0003	200	391.30	16.924	140.14	0.592	0.419
Q3	91 days lactation	225	60	0.0003	200	410.41	17.654	149.24	0.367	0.449
Q4	40 days lactation									
	51 dry days	75	60	0.0003	200	347.66	14.186	149.24	0.535	0.375
Sannen X Native	4.5% milk fat	400								
Q1	31 days lactation	30	55	0.0003	200	346.83	14.765	154.34	0.543	0.384
Q2	91 days lactatoin	225	50	0.0003	200	374.82	17.017	130.13	0.637	0.446
Q3	61 days lactation									
	30 days dry	90	55	0.0003	200	356.23	15.435	140.14	0.593	0.491
Q4	91 days lactation	75	60	0.0003	200	413.14	18.473	149.24	0.728	0.510
Native	4% milk fat	300								
Q1	31 days lactation									
	60 days gestation	30	33	0.0003	200	257.34	11.125	109.66	0.433	0.303
Q2	31 days lactation									
	60 days dry	35	33	0.0003	200	228.94	9.485	95.46	0.393	0.275
Q3	31 days lactation	130	30	0.0003	200	291.20	13.286	89.018	0.546	0.382
Q4	91 days lactation	105	33	0.0003	200	303.94	13.805	95.46	0.573	0.401

Meat Goat	Annual cost = 3.28 Yuan								
Q2	Purchase weaned kid								
	Daily gain at 150g	10	0.0003	15	150.15	4.186	74.62	0.273	0.191
Q3	Daily gain at 100g	20	0.0003	15	152.88	6.006	76.44	0.182	0.127
Q4	Daily gain at 50g	25	0.0003	15	135.59	5.324	67.80	0.228	0.559

[a]Source: (8, p. 629).

[b]Source: (2, pp. 118-119).

[c]Source: (10, p. 11).

[d]Personal communication, J.A. Yazman. Winrock Int'l., Petit Jean Mountain, Morrilton, Ark., 1984.

Table 8.5. Annual C-row cost[a], land[b], labor[c] and nutrient[d] requirements of hog raising

Species and seasons				Annual C-row cost (Yuan)	Land (ha)	Labor (hr)	ME (Mcal)	TP (kg)	DM (kg)	CA (kg)	PH (kg)
Hog 1	Hog 2	Hog 3	Hog 4	216.08							
Q1	Q4	Q3	Q2		0.00175	319.53	860.15	31.716	252.30	1.900	1.373
Q2	Q1	Q4	Q3		0.00375	846.57	909.00	39.126	284.55	2.048	1.591
Q3	Q2	Q1	Q4		0.00375	846.57	1097.70	45.546	318.30	2.228	1.801
Q4	Q3	Q2	Q1		0.00375	319.53	666.36	25.506	181.80	1.454	1.163
Hog 5	Hog 6	Hog 7	Hog 8	126.52							
Q1	Q4	Q3	Q2		0.00175	319.53	860.15	31.716	252.30	1.90	1.373
Q2	Q1	Q4	Q3		0.00175	319.53	691.16	27.186	215.55	1.62	1.223
Q3	Q2	Q1	Q4		0.00175	319.53	860.15	31.716	252.30	1.90	1.373
Q4	Q3	Q2	Q1		0.00175	319.53	691.16	27.186	215.55	1.62	1.223
Hog 9	Hog10	Hog11	Hog12	41.98							
Q1	Q2	Q3	Q4		0.0004	48.6	142.20	8.10	45	0.293	0.248
Q2	Q3	Q4	Q1		0.0004	97.2	504.02	23.68	159.5	0.911	0.752
Q3	Q4	Q1	Q2		0.0004	48.6	426.6	17.55	135	0.675	0.540

[a]Source (8, pp. 594-595).

[b]Source (8, p. 629).

[c]Source (2, p. 113).

[d]Source (11, pp. 23, 25).

Table 8.6. Nutritive values of selected feeds used in this study[a]

Feed	ME Mcal/kg	TP %	DM %	CA %	PH %
Maize	3.325	9.6	89	0.02	0.27
Broadbean (F)[b]	.1189	0.55	22	NA	NA
Sweet Potato	.574	2	23	0.01	0.06
Vetch	.31	2.97	15	0.18	0.05
Vetch hay	1.86	17.8	89	1.05	0.29
Grass	.2768	1.5	15	0.48	0.07
Grass hay	1.62	20.7	91	1.64	0.22
Soybean meal	3.54	42.9	92	0.26	0.6
Rice straw	1.48	4	91	NA	NA
Rice bran	2.58	13	87	0.07	1.54
Wheat straw	1.5347	3.18	89	0.16	0.04
Wheat bran	2.32	15	82	0.11	1.22
Maize stover	1.85	6.6	85	0.12	0.09
Broadbean (H) dry stem	1.53	6	86	NA	NA
Rapeseed oil cake	2.27	35.6	92	0.66	1.04
Sweet potato vine	.36	2	16	0.31	0.03
Cotton cake	2.06	37.9	93	0.2	0.9
Bashan bean	3.08	22.6	89	0.16	0.52
Vegetable[c]	0.0024	1.83	74	NA	NA
Barley	2.87	11.9	88	0.04	0.34
Millet	2.98	11.6	90	0.03	0.3

[a]Source (12, pp. 8-128).

[b]Source (2, p. 27).

[c]Source (2, p. 31).

Table 8.7. Price estimates for selected products in Sichuan, 1981[a,b] (yuan)

Product	Price	Product	Price
Rice (quota)	1.23/kg	Sweet potato vine	0.02/kg
Rice (above quota)	0.35/kg	Barley	0.2/kg
Rice	0.55-0.65/kg	Millet	0.32/kg
Maize (subsidized)	0.23/kg	Bashan bean	0.28/kg
Maize (above quota)	0.32/kg	Culled vegetable	0.016/kg
Maize	0.38-0.4/kg	Vetch	0.03/kg
Wheat (quota)	0.31/kg	Vetch hay	0.1/kg
Wheat (above quota)	0.47/kg	Draft cattle	450/hd
Rapeseed (quota)	0.71/kg	Draft buffalo	500/hd
Rapeseed (above quota)	1.07/kg	Cattle milk	0.4/kg
Broadbean (H)	0.4-0.5/kg	Goat milk	0.3/kg
Broadbean (F)	0.03/kg	Pork	1.24/kg
Sweet potato	0.16/kg	Weaned piglet	25/hd
Broadbean stem (H)	0.05/kg	Weaned female calf	160/hd
Grass	0.016/kg	Male calf at birth	30/hd
Grass hay	0.07/kg	Heifer	2,200/hd
Soybean meal	0.25/kg	Culled cow	600/hd
Rice bran	0.024/kg	Weaned meat goat	3/hd
Rice straw	0.03/kg	Yearling goat kid	70/hd
Wheat bran	0.068/kg	Weaned dairy goat	25/hd
Wheat straw	0.04/kg	Culled goat	19.5/hd
Maize stover	0.02/kg	Cattle draft power	100.84/hd
Rapeseed oil cake	0.21/kg	Buffalo draft power	110.78/hd
Cottonseed cake	0.15/kg	Culled cattle	300/hd
		Culled buffalo	425/hd

[a]Source (2, pp. 104-107).

[b]Source (8, p. 742).

Table 8.8. Annual cost[a], land[b], and labor[c] requirements per quarter for dairy production used in the models with labor hiring

Production Level	Annual C-row cost (yuan)	Land req. (ha)	Labor req. (hr)	Production Level	Annual C-row cost (yuan)	Land req. (ha)	Labor req. (hr)
1	167.66	0.0014	546	1-5	829.96	0.007	2,304
2	166.82	0.0014	491	6-10	809.43	0.007	1,765
3	165.99	0.0014	452	11-15	789.44	0.007	1,641
4	165.16	0.0014	420	16-20	769.94	0.007	1,543
5	164.33	0.0014	395	21-25	750.92	0.007	1,466
6	163.51	0.0014	375	26-30	732.37	0.007	1,470
7	162.70	0.0014	360	31-35	14.28	0.007	1,365
8	161.88	0.0014	349	n.a.	n.a.	n.a.	n.a.
9	161.07	0.0014	342	n.a.	n.a.	n.a.	n.a.
10	160.27	0.0014	339	n.a.	n.a.	n.a.	n.a.

Note: n.a. = not applicable.

[a]Source (2, p. 116).

[b]Source (8, p. 629).