1985

The potential for expanding dairy production in intensively-cropped areas of Sichuan Province, China

Jian-chun Ma
Iowa State University

The potential for expanding dairy production in intensively-cropped areas of Sichuan Province, China

by

Jian-chun Ma

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

Iowa State University
Ames, Iowa

1985

TABLE OF CONTENTS

	Page
CHAPTER I. INTRODUCTION	1
Background to the Problem	1
Imbalance in China's agricultural economy	1
Nutrient availability for the Chinese population	2
Pressure from increasing demand for milk products in China	4
Importance of dairy production	6
Advantages and disadvantages of dairy livestock production	7
Man-animal relationships	9
Physical Resources and Animal Agriculture in Sichuan Province	9
Physical resources	9
Supply of animal products in Sichuan Province	14
Animal production systems	15
Limitations of the Present Study	16
Objectives of the Study	17
Hypotheses of the Study	18
Methods for Testing the Hypotheses	20
Organization of the Study	22
CHAPTER II. REVIEW OF LITERATURE	23
Studies of Dairy Production on a World-Wide Basis	23
Chinese Theoretical Studies	29
The significance of expanding animal production in intensively cultivated areas	33
The strategy of all-round development of agriculture	34
Identification of the major impediments affecting animal production in intensively-cropped areas	35

Empirical Study by Winrock International 35

Positive factors 37
Negative factors 37

Summary 38

CHAPTER III. DATA AVAILABILITY, DESCRIPTION OF PRODUCTION ACTIVITIES, AND SPECIFICATION OF THE LINEAR PROGRAMMING MODEL 39

Factors Influencing the Expansion of Dairy Production 40

Farm structure 40
Cropping patterns and nutrient availability 43
Labor availability 47
Marketing and transportation 49
Dairy management 51
The government's incentives to dairy production 51
Summary 52

Description of Model Activities 53

Crop production activities 53
Transfer activities 54
Dairy cattle raising activities: CATTLE 1 to CATTLE 3 54
Yellow cattle and buffalo raising activities 55
Dairy goat raising activities: DG 1 to DG 3 55
Meat goat raising activity 56
Hog raising activities 56
Purchasing and selling activities 56
Borrowing and saving activities 58
Family consumption activities 58
Government subsidies 58

Specification of the Linear Programming Model 59

CHAPTER IV. RESULTS AND DISCUSSION 61

Procedures for Empirical Use of the Model 61

Model I: The basic model 61
Model II: The basic model plus hiring labor activities 63
Model III: Introduction of dairy cattle production 63
Model IV 63
Model V: Specialization in dairy cattle production 64

Review of Findings 64

Model I 65
Model II 66
Model III 67
Model IV 72
Model V 75
Summary 77

Discussion of the Policy Implications of the Findings 77

The impacts of dairy cattle production on land utilization 77
The impacts of dairy cattle production on other animal production 81
The significance of free labor employment 93
Milk pricing 95
Government supports 99
Specialization in dairying production 102

CHAPTER V. SUMMARY AND CONCLUSIONS 105

Summary 105

Conclusions 107

BIBLIOGRAPHY 111

ACKNOWLEDGEMENTS 114

APPENDIX A. MISCELLANEOUS TABLES 115

APPENDIX B. LINEAR PROGRAMMING MATRICES 129a

LIST OF TABLES

		Page
Table 1.1.	General topography and land use of the five ecological zones of Sichuan Province	13a
Table 2.1.	Total number of hogs, sheep and goats, and large animals in Mainland China, 1950-1981	31
Table 3.1.	Farm types in intensively-cropped areas in Sichuan Province	46
Table 4.1.	The programming results of Model I	65
Table 4.2.	The programming results of Model II	66
Table 4.3.	Dairy cattle and hog feed rations in Model III	68
Table 4.4.	The programming results of Model III	70
Table 4.5.	The programming results of modified Model III	71
Table 4.6.	The programming results of Model IV	72
Table 4.7.	The programming results of modified Model IV	74
Table 4.8.	The programming results of Model V	75
Table 4.9.	Summary of optimal solutions for five models based on Farm E	78
Table 4.10.	Enterprise budget for dairy cattle production	82
Table 4.11.	Enterprise budget for dairy goat production	83
Table 4.12.	Enterprise budget for fat hog production	84
Table 4.13.	The comparisons of average net returns of animal enterprises per unit of labor input	85
Table 4.14.	The results of parametic programming of price changes	97
Table 4.15.	Effect of government grain subsidy on cattle production	100
Table A.1.	Adequacy of per capita dairy energy and protein availability	115

Table A.2.	Per capita grain production and daily nutrient availability	117
Table A.3.	Per capita availability of meats and other animal products	118
Table A.4.	Levels of consumption of animal products per capita in selected countries, 1981	119
Table A.5.	Animal numbers in Sichuan Province, China, in millions	120
Table A.6.	Meat and milk production in Sichuan Province (1000 m.t.)	121
Table A.7.	Production cost and labor requirements for crop production for the selected farms in Sichuan Province	122
Table A.8.	Uses of crop products for selected farms in Sichuan Province	124
Table A.9.	Selected animal and animal product prices and entitlement formula of government subsidy	125
Table A.10.	Production cost, land, and labor requirements for dairy production	126
Table A.11.	Price estimates for selected products in Sichuan, 1981 (yuan)	127
Table A.12.	Selected feed rations and feed costs for dairy cattle, dairy goat and swine	128
Table B.1.	Matrix diagram of the LP model	129b

LIST OF FIGURES

		Page
Figure 1.1.	Human-animal relationships	10
Figure 1.2.	Major ecological zones of Sichuan Province	12
Figure 2.1.	Output value by sector of China's agriculture	32
Figure 2.2.	Growth in total animal population (ten million heads)	32
Figure 3.1.	Farm structure in Sichuan Province	41
Figure 4.1.	The procedure for the linear programming operations	62
Figure 4.2.	The relationship between labor employment and milk supply	74
Figure 4.3.	Supply curve of cattle milk of Model IV	97

CHAPTER I. INTRODUCTION

Background to the Problem

Imbalance in China's agricultural economy

Despite significant growth and overall improvements in China's agricultural production over the last three decades, growth has been highly imbalanced because of an over-emphasis upon grain production. Consequently, the use of many agricultural resources has been irrational. Forests and grasslands that were marginal or unsuitable for cultivation were shifted to the production of grain, causing serious soil erosion and damage to the ecosystem.

Since 1979, the Chinese government has adopted a series of new policies to stimulate all-round development of the agricultural economy and to improve the farmers' standard of living. These policies include:

--Raising purchasing prices of major agricultural and sideline products with the aim of boosting production and increasing rural incomes;

--Importing several million tons of grain annually to reduce the state procurement of farm products;

--Shifting away from the one-side emphasis on grain production by encouraging household sideline occupations and rural trade fairs and

--Establishing various forms of the production responsibility system[1] suited to rural conditions (10, p. 14).

Key among these policies is the shift from the former policy of self-sufficiency in grain production, under which all other agricultural activities were subordinated. By contrast, the new policy seeks to make use of resources based upon the principle of comparative advantage, while maintaining the ecological balance.

All-round development policy relaxes the constraints upon farmers' decisions, while the responsibility system gives greater latitude to individual farmers to engage in such sideline enterprises as fisheries and animal production. Since individual rural households have become the basic farming units and are free to diversify their economic activities, it is meaningful to investigate the potential for expanding dairy production based upon individual farmer households.

Nutrient availability for the Chinese population

Average daily per capita nutrient availability grew rapidly after 1949, and by 1958 roughly equaled requirements (Table A.1). Subsequently, however, agricultural production declined sharply because of the sudden implementation of the People's Commune System, widespread

---

[1]The production responsibility system is based upon a two-party contract between the collective and the farm household. Under the contract, the farm household pays agricultural taxes and sells a required quota of products to the state. The collective retains a share of farmers' products for its own use. The remaining portion is kept by the farm households.

unfavorable weather patterns, and the withdrawal of Russian economic assistance. The food crisis of 1959-1963, when per capita nutrient availability fell to fellow the 1950 level, involved a great deal of human suffering. By the mid-1970s, thanks to the gradual improvement of agricultural production, per capita nutrient availability had recovered to the levels achieved in 1958 (15, pp. 8-13).

Beginning with the harvest of 1978, average per capita nutrient availability has reached record highs. Both energy and protein availability have exceeded requirements (15, p. 13). However, the proportion of total protein availability coming from animal sources still compares unfavorably with that in developed countries and other middle-income countries.

According to nutritionists, the average protein supply from animal sources should be about 18 grams per day (Liu, 9), but animal protein availability in China had reached only 6.33 grams by 1981 (Table A.2). The share of total calories and protein supplied by animals was dwarfed by the share derived from vegetable source--94 percent and 90 percent respectively. China's per capita meat availability averaged 13.08 kilograms per year (35.8 grams/day) in 1981, only about 41 percent of the world average. Per capita milk availability, 1.49 kilograms per year (4.1 grams/day) in 1981, was only about one sixty-fifth of the world average and well below the levels in many developing countries (Table A.3).

Han Chinese, the dominant ethnic group in mainland China, do not have a tradition of consuming dairy products. Thus, the average availability figure may be misleading. However, at the very least the current levels of milk production are inadequate to supplement the diets of infants and the elderly and to supply the increasing needs of the several tens of millions of people living in large cities who have learned to consume milk.

For these reasons, shortages of milk and meat are still common in China today.

Pressure from increasing demand for milk products in China

Economic demand for dairy products is one of the principal driving variables determining the growth of dairy production.

The major determinants of market demand are:

Population numbers and population composition The present population of China is over a billion people, the largest potential market in the world. It is forecasted that the population will reach 1.2 billion by the end of this century. Continued high population growth rates are anticipated, especially in the rural areas, where China's one-child-per-couple family planning program is less strictly enforced.

Currently, limited amounts of milk are reserved primarily for use by children and the elderly because of the insufficiency of milk supply. China is still at the peak stage of the birthrate cycle. Over

10 million babies are born every year, even though the birth rate has decreased from 1.20 percent in 1978 to 1.15 in 1983 (26, p. 342). The one-child campaign has resulted in increasing parental attention to single offspring. It is now estimated that 80 percent of children in cities and 46 percent of children in rural areas need milk to supplement their diets (26, p. 342). Previously, only very young babies were given milk when their mother's supply was inadequate.

Amounts and trends in income Per capita annual income in China increased from ¥ 316 in 1978 to ¥ 526 in 1983 in urban areas and from ¥ 134 in 1978 to ¥ 310 in the countryside in 1983 (11, p. 19), larger quantities of milk are expected to be consumed at higher than lower incomes. For this reason, we can anticipate that continuous economic growth and income increases will create an increase in the demand for dairy products.

Consumption preferences Many Chinese people do not have a tradition of milk consumption. Most farmers do not consume any kind of dairy products even if they produce cattle. However, the preferences of the consumers are changing. Especially in the large cities, milk and other dairy products are increasingly welcomed. Urban consumers generally prefer fluid milk to other dairy products. The lack of home refrigeration and lack of fluid milk supply have also led people to consume milk powder, while few people traditionally consume butter and

cheese which are only used to make cakes by food plants. For this reason, this study focuses on the potential supply of fluid milk.

The price and income elasticities of demand People respond to changes in the prices of dairy products and incomes in terms of the quantities of dairy products they will buy. In general, income and prices elasticities tend to be lower for people with higher incomes and higher for milk than cereals.

Taking into account China's huge population, rising income, and favorable changes in consumption preference, China's milk supply is not keeping pace with rising demand, and shortages are likely to continue.

Importance of dairy production

One can evaluate the importance of dairy production in a number of ways. Two deserve emphasis at this point:

The contribution of dairy foods to the food energy and protein requirements of people Milk is a highly digestible, well-balanced nutrient source. Milk is an excellent source not only of good quality protein, but also of calcium, essential minerals and vitamin A. A liter of milk provides the average adult male with his daily requirements of fat, calcium, phosphorus, and riboflavin; one-half the protein, one-fourth the energy, one-third the vitamin A, and considerable amounts of the other required vitamins and minerals (22, p. 31).

The contribution of dairy production to the balance of the ecosystem Dairy ruminants play an important role in the human-managed ecosystem of agriculture by converting resources that otherwise could not be used into nourishing food products. Dairy production utilizes natural resources very efficiently and comprehensively, while enhancing the ecological cycle.

Advantages and disadvantages of dairy livestock production

The advantages of dairy production derive from several different aspects of the agricultural economy:

-- Transforming coarse, bulky products into more concentrated and valuable finished products. Crop by-products such as grain straw or corn stover have little value on most farms except as roughage and bedding for livestock.

-- Making use of otherwise-unproductive land. According to a recent land survey (26), cultivated land in China accounts for just 10.35 percent of total area. Land unprofitable for cultivating crops may be utilized for grazing purposes.

-- Enhancing soil fertility. In the manufacture of the finished products on the farm, dairy animals return fertility to the soil. Farmyard manure is unquestionably the most valuable byproduct of dairy animal production.

-- Contributing to raising farmers' incomes. By transforming coarse products into milk and meat, farmers can reap good profits, provided markets are available.

-- Utilizing more labor. When dairy livestock are kept, human labor is more fully employed, and at a more constant level across seasons, than with other types of farm production.

However, dairy production also has four signal disadvantages:

-- Heavy investment and rapid depreciation. As contrasted to general crop farming, the dairy interprise requires a rather heavy investment in cattle and in the buildings and facilities for carrying on the dairy enterprise in the proper manner. Depreciation in barns and dairy equipment is usually quite high.

-- Production risks. While one of the decided advantages of dairy farming is constant, steady returns, there are some heavy risks involved. Cattle are susceptible to infections which may wipe out a herd in a very short time. While most of these diseases can be prevented by the application of intelligent precautions, they nevertheless must be listed as definite risks.

-- Special skills required. The care of dairy cattle, particularly milking cows, requires special skills for optimal results, but most farmers in the intensive arable areas do not yet possess these skills.

-- Dairy ruminants are less efficient than nonruminants such as poultry and hogs in converting high quality, low fiber feedstuffs to animal products.

Man-animal relationships

The chief merit of dairy livestock to mankind lies in the fact that these animals can obtain their nourishment from grasses and other fibrous forage which people cannot consume directly. In turn, the animals provide humans with an adequate supply and proper balance of energy, minerals, vitamins and essential amino acids which human metabolism cannot do without. The nonfood contributions of these livestock, such as hides and manure, are also substantial. Therefore, the human-livestock relationship is symbiotic.

This relationship is represented by Figure 1.1. This figure is also useful in analyzing the feed sources for dairy animals and the relationships between crop production and animal production to be discussed in Chapter III.

Physical Resources and Animal Agriculture in Sichuan Province

Physical resources

Sichuan, called "the Land of Abundance" in history, is China's most populous province. More than 100 million people make their homes

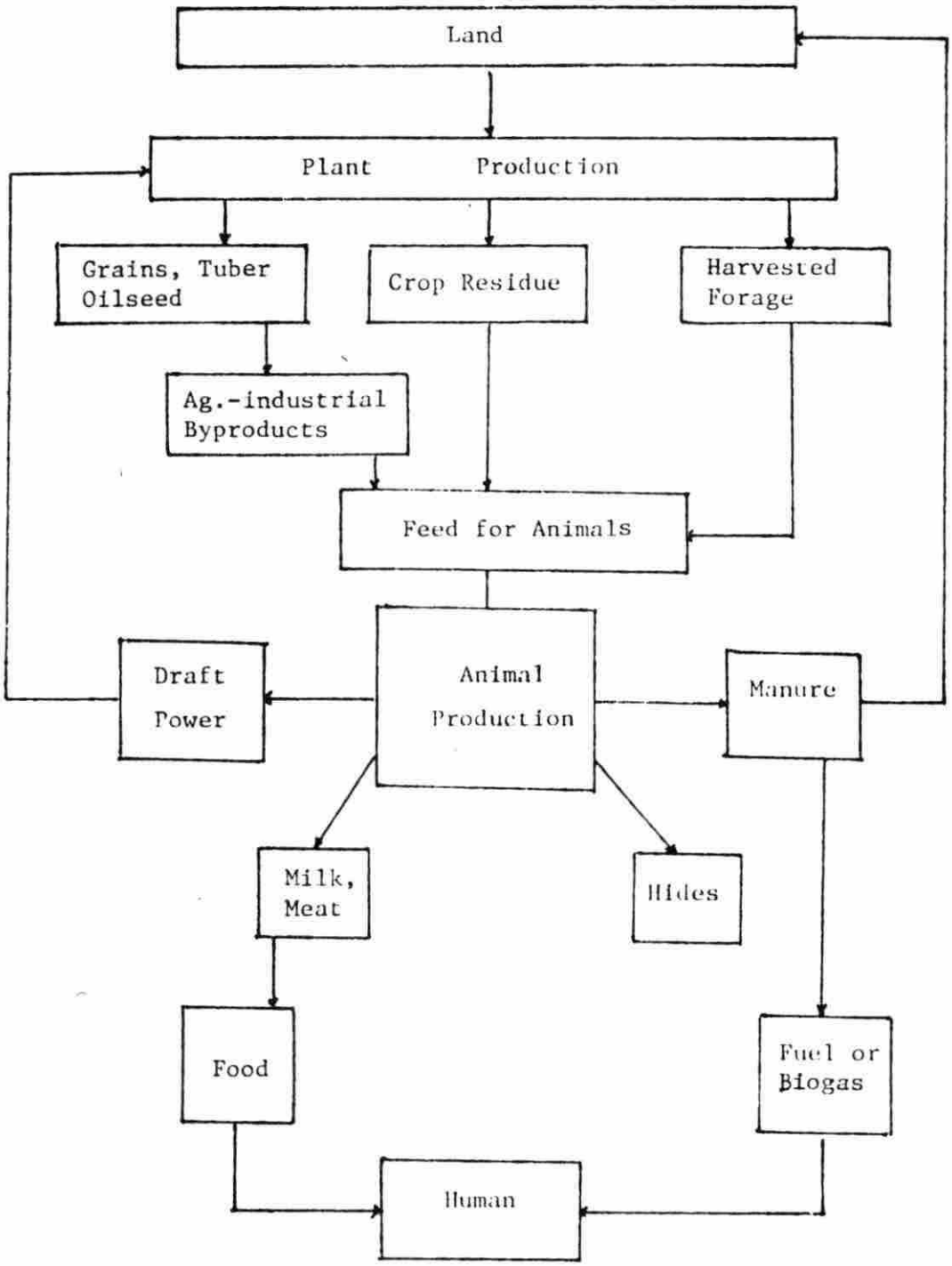

Figure 1.1. Human-animal relationships

in the province's 570,000 square kilometers. The province is dominated in the west and northwest by the massive Tibetan Plateau with elevations varying from 3,000 to 5,000 meters. In addition to mountains and hills, Sichuan has a vast expanse of grassland and a wealth of fertile land. Compared with most of the rest of China it abounds in resources and has favorable natural conditions.

However, development of the resources has been uneven. Ninety-four percent of the population and ninety percent of the cultivated land are concentrated in the eastern part of the province, which includes Sichuan Basin and the surrounding hilly regions (21, p. 22).

Sichuan may be partitioned into five major ecological zones (Figure 1.2) according to the geographical characteristics of each region (21, p. 9). Region V, the focus of the present study, is intensively farmed and only the steepest and thinnest soils are left in grasslands or scrub forest (Table 1.1). Region V could be divided into several subregions, but in this study, we concentrate on two parts: the Chengdu Plain the west and the eastern part of Sichuan Basin.

Chengdu Plain, also called the Western Basin Plain and centered in Chengdu City in the western part of the basin, bases its farming on grain and oilseed production. Rice is a major crop, occupying 39.1 percent of cultivated land area. Wheat is a second major crop, accounting for 16.6 percent of the cultivated land. The output of rice

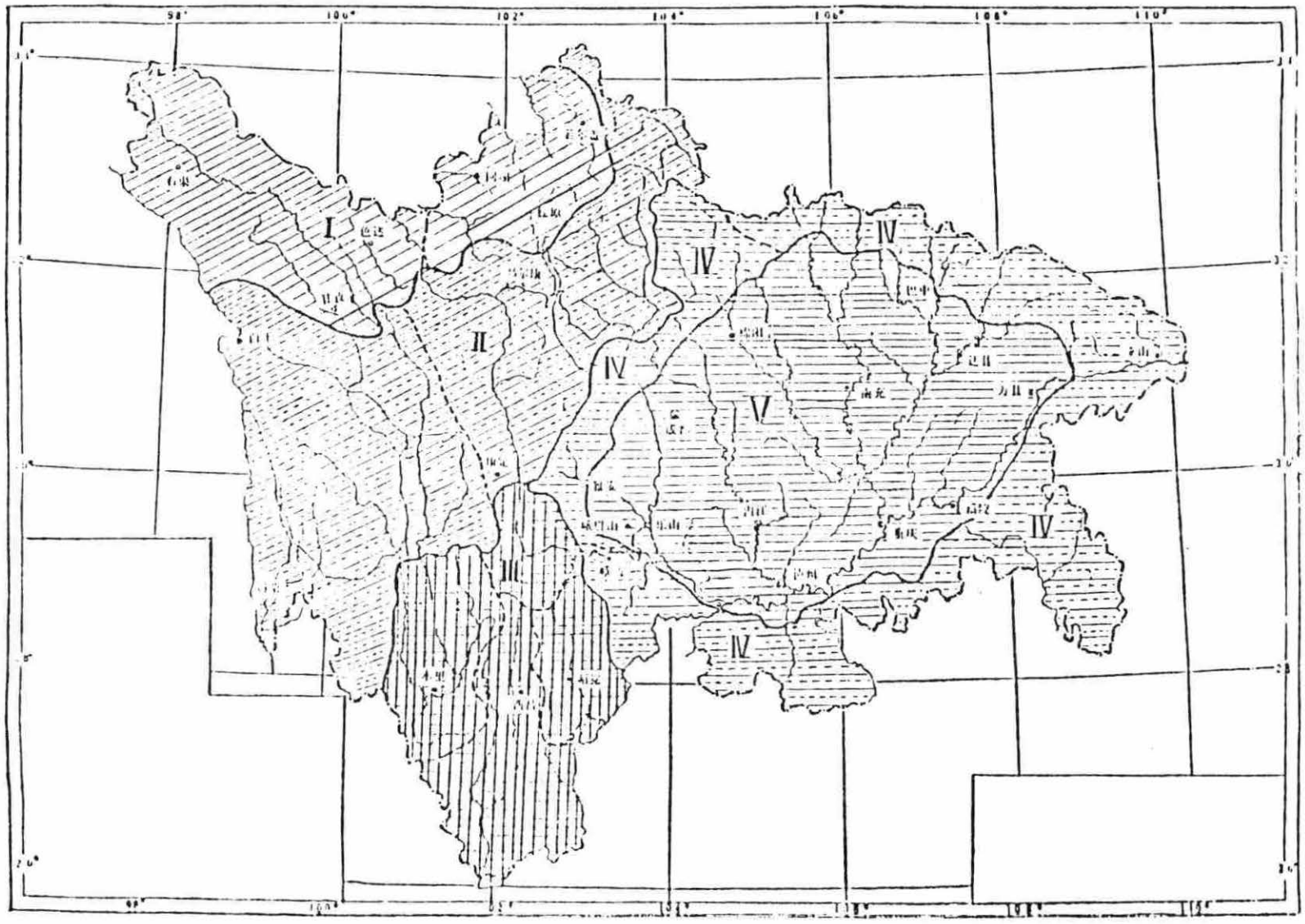

Figure 1.2. Major ecological zones of Sichuan Province (21)

Table 1.1. General topography and land use of the five ecological zones of Sichuan Province (21)

Region	General Topography	Elevation Range (meters)	Cropland			Grass Land	Forestry, water, beersem, and others	% total
			Paddy	Upland	Total			
I	Rolling, high plateau with occasional high peaks	3300 - 5000	---	87	87	7.600	3.953	20.5
II	Steep, high mountains, narrow gorges	2000 - 4000	---	107	107	3.187	9.206	22.0
III	Steep to precipitous intermediate mountains; deep, usually narrow valleys	800 - 3000	67	227	294	1.097	4.809	10.9

IV	Heavily dissected foothills to steep, low mountains	600 - 2000	413	740	1.153	2.972	6.175	18.2
V	Level (Chengdu Plain) to rolling and steep hills and mountain foothills	400 - 900	2,800	2.200	5.000	1.520	9.580	28.4
Total			3.361	3.280	6.641	16,373	33.686	100 56.700

and wheat makes up 83 percentage of total grain output (5, pp. 141-142).

The eastern part of Sichuan Basin, usually called the "Eastern Basin," is more mountainous with an elevation varying from 800 to 1,000 meters. The average temperature is 17-18.5° C and the frost-free period is 270 to 330 days. Therefore, double cropping of rice is commonly practiced. The average cropping index, 190 percent, is higher than in other parts of the Sichuan Basin, but per hectare yields fall below the provincial average by 15 to 30 percent because of summer drought and poor soil conditions (5, 17).

Supply of animal products in Sichuan Province

The direct contributions of animal agriculture to food supply include high-quality protein foods (meat, milk and eggs), the indirect contributions include draft power for cultivation and transport, and animal manures for fertilizer.

In 1981, meat and milk production statistics (Table A.6) indicated per capita availability of 18.91 kg. meat (predominantly pork) and 1.44 kg. of milk (including goat milk). These statistics were based upon a human population of 100 million. Per capita milk consumption in the major cities of Chongqing and Chengdu was estimated at less than 10 kg. per annum in 1981 (21, p. 142). In most urban areas, milk was rationed to babies and older adults with special dietary needs. It is generally accepted that demand exceeds supply.

The 1980 total value of animal output in Sichuan province was 4.33 million yuan (excluding poultry), 21.6 percent of Sichuan's agricultural output. The tentative target of Sichuan local government is to raise the total production value of animal output to 10.44 billion yuan. The goal for milk supply is the doubling of milk production from the current levels of 142,400 m.t. by the year 1990 (21, p. 65). The emphasis on dairy production is intended to increase milk supplies to large and medium sized cities as well as farm incomes.

Animal production systems

Animal production systems in Sichuan Province may be roughly partitioned along agro-ecological boundaries into the pastoral system of the western mountains and plateaus, and the mixed crop-animal systems of central and eastern Sichuan (21, p. 71).

Pastoral system Western Sichuan, characterized by the Aba and Ganzi regions, consists primarily of rangelands, where rough topography, limited rainfall, and low temperatures combine to limit opportunities for cropping. Livestock grazing is the principal agricultural activity.

Mixed crop-animal system Intensive cropping is practiced on approximately 12 percent of the total land area of Sichuan Province and is concentrated in the central and eastern counties, where sufficient irrigation water is available, and the land is cropped throughout the year.

The cropping pattern largely determines the type of animal production: normal or sedentary. In the intensively cultivated Chengdu Plain and Eastern Sichuan, animals are confined all or most of the year and are fed green feed, crop residues and concentrate feeds. But in some regions of these areas, village herding is a common practice. Cattle, sheep or goats are taken to grazing grounds outside the village along roadsides or riversides.

Limitations of the Present Study

This study is confined to the intensive agricultural area of Sichuan Province and focuses on dairy cattle and dairy goat production. Sichuan Province was selected not only because we have handy data on the animal agricultural of Sichuan Province, but also because Sichuan, especially Region V, epitomizes the demand and supply situation of dairy productions, mixed crop-animal system, and the characteristics of dairy production in the whole intensively-cropped areas in China.

The study is limited to dairy ruminant production because:

1) Virtually all of the buffalo, 99 percent of the swine, 86 percent of the cattle and 88 percent of the goats in Sichuan Province are found in these intensive farming regions (21, p. 72).

2) A major policy objective of the Sichuan local government is to increase urban milk supplies. These large urban centers are located in the intensive farming areas.

3) Swine production is used here only as a basis for analysis of resource competition and comparative budgets. Buffalo are used for draft power and have only limited potential for making a large contribution to commercial milk supplies.

Objectives of the Study

The study deals with the development potential of dairy production in the intensive agricultural areas of Sichuan Province.

The specific overall objectives of the study are to:

1) Identify the constraints which may limit expanded production of dairy cattle and dairy goats.

2) Examine the impacts on crop production and other animal production, and farmers' income of introducing dairy cattle activities.

3) Conduct basic research on farm-household resource allocation under mixed crop-animal systems.

4) Examine the impacts of labor hiring on the expansion of dairy production and specialization in dairy production.

5) Investigate the effects of the concentration of farm production and livestock specialization upon the social division of labor.

6) Conduct supplementary policy analysis essential to identifying which types of support from the government could best help farm households expand dairy production.

Hypotheses of the Study

In the process of inquiry, hypotheses serve as guides for the study. Six hypotheses are developed for testing, some of which have two or three sub-hypotheses. The specific hypotheses of the study are:

1. The introduction of dairy cattle production to the farm has positive impacts on family labor utilization and farm income.

a) The introduction of dairy cattle has a negative effect on the scale of grain production because of the limited availability of labor.

b) The introduction of dairy livestock has negative effects on dairy goat production and other animal production.

2. There is a positive relationship between the abandonment of legal limitations on the hiring of labor and grain and animal production.

a) The relaxation of constraints on labor hiring will lead to the expansion of dairy livestock production in the intensively cropped areas.

b) The relaxation of the constraints on labor employment will promote complete specialization in dairy production in some households.

3. Specialization in dairy cattle production will improve significantly the milk supply and help raise farmers' income.

a) Specialization in dairy production will lead to the possible transfer of farming land to neighboring grain farmers.

b) Specialization in dairy farming will enhance productivity and improve dairying efficiency.

4. A slight increase in milk purchasing price will lead to a great increase in milk supply.

5. There is a significant relationship between the state feed-bonus system and dairy ruminant production.

a) State subsidized concentrates are an important feed in least-cost cattle rations.

b) Cancellation of the state's premium concentrate program would bring about a decline in dairy production.

6. The government's credit supply has an important driving effect on dairy production.

a) Farmers involved in dairy production require state-supplied credit to buy feedstuffs and other inputs to expand the output of dairy products.

b) One of the deterrents to wider use of credit is the high interest rates that farmers are forced to pay.

Methods for Testing the Hypotheses

Linear programming (LP) techniques will be used in an attempt to meet the above objectives.

The linear programming model may be stated as

$$\text{optimize } z = f(x_1,x_2,\ldots,x_n) = c_1x_1 + c_2x_2 + c_nx_n$$

subject to

$$g_1(x_1,x_2,\ldots,x_n) = a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n \; [\leq = \geq] \; b_1$$

$$g_2(x_1,x_2,\ldots,x_n) = a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n \; [\leq = \geq] \; b_2$$

$$\vdots \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad \vdots$$

$$g_m(x_1,x_2,\ldots,x_n) = a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n \; [\leq = \geq] \; b_m$$

$$x_1,x_2,\ldots,x_n \geq 0$$

The variables x_1, x_2,...x_n are called decision variables. The function z to be optimized is called the objective function. x_1, x_2,..., $x_n > 0$ are referred to as nonnegativity restrictions. The optimization of the objective function z is carried out so that the m constraints g_1, g_2,...,g_m are satisfied.

Some limiting assumptions have to be imposed before one can use linear programming. To reduce computational difficulties, we have assumed that all of these limitations apply in the current research:

1) The function $f(x_1,x_2,\ldots,x_n)$ and $g_i(x_1,x_2,\ldots x_n)$, $i = 1, 2, \ldots, m$, must be linear in the decision variables x_1, x_2,...,x_n.

2) Decision variables may enter the model only in an additive way.

3) The optimization of the objective function $f(x_1, x_2, \ldots, x_n)$ takes place at a fixed point in time (static).

4) The functions are continuously differentiable.

5) The LP model is deterministic. Coefficients in the objective function and in the constraints are considered to be constants. If the coefficients are allowed to be random variables, or if the constraint inequalities need only be satisfied probabilistically, the LP model does not apply.

The application of linear programming in economics can be considered as a way to delineate a problem where limited resources are to be allocated among competing activities in an optimal manner. In this study, LP techniques allow the farm analyst to consider simultaneously a large number of different alternatives and to attempt to discover the optimal use of farm resources and the best enterprise mix.

Before building LP models, enterprise budgets for crop and animal production, which can be regarded as building blocks for LP models, will be developed. In Chapter III, further analysis will be made to compare the economic returns of dairy ruminants and other animal production to labor input.

Sensitivity analysis will be performed with linear programming in Chapter IV to examine the effects of milk price changes on the dairy production, land use, and labor demand.

Organization of the Study

This study is organized into five chapters. Chapter I is an introduction which consists of sections describing the current status of animal agriculture in China; dairy product availability; the importance and need for expansion of dairy production; advantages and disadvantages of dairy livestock production; topographical features, factor endowments and ecological zones of Sichuan Province; animal production systems in Sichuan Province; limitations and objectives of the study; hypotheses of the study; and methods for testing hypotheses.

Chapter II reviews past theoretical and empirical studies on the development of dairy ruminant production.

Chapter III outlines the major factors influencing the expansion of dairy production in Sichuan Province, available data, and the specification of the linear programming model.

Chapter IV presents the empirical findings of the linear programming and tests of the hypotheses stated in Chapter I.

Chapter V includes a summary of the study, a discussion of policy implications of the results, and recommendations for further research.

CHAPTER II. REVIEW OF LITERATURE

This chapter attempts to present a review of the empirical and nonempirical studies of dairy production in China and other countries. Unfortunately, although technical studies of animal husbandry have a wide variety of content, the study of dairy production in intensive arable areas in particular is limited.

The review of theoretical and empirical studies of dairy production will focus on the recent dairy animal production literature, especially on the literature dealing with socio-economic aspects of dairy production.

Studies of Dairy Production on a World-Wide Basis

Bogart and Taylor (4) estimated that about 30 percent of the world's human population and 32 percent of the ruminant animal population live in developed regions, but ruminants of these same regions produce two-thirds of the world's meat and 80 percent of the world's milk.

The increases in the efficiency of dairy production in the United States and Europe have been remarkable during the past four decades. Dairy production is generally sufficient, and occasionally consumption of dairy products may be considered to have reached superfluous levels. The achievements were generally ascribed to the tremendous increases in

productivity of dairy animal agriculture under free enterprise systems in which people had an incentive to promote dairy production (4, 16).

The improvement in the productivity of milk enterprises, Allen (16) maintained, resulted in large part from genetic improvement programs, breed substitution, better grassland management, the breeding of early-maturing varieties of forage maize, and favorable concentrate and fertilizer prices (16, p. 89).

Winrock International (22) held out possibility that many so-called developing regions of the world can achieve levels of dairy productivity similar to those of developed regions. In the first place, the productivity of dairy livestock depends heavily on the quantity and quality of the feed they receive. If the feed supply is ample and the digestible energy content is satisfactory, the rates of gain and the fertility levels of the animals will in turn favorably affect herd productivity. Although genetic capacity, animal health and the quality of herd management can also affect productivity, feed supply remains the single most important factor among the physical variables in dairy livestock production (22, p. 41).

Fortunately, Winrock estimated that most developing countries have abundant supplies of animal feed resources that do not compete with production of food for people and could be used to support expansion of dariy populations and production (22, p. 41). In arable areas in particular, Winrock identified a very wide array of plant materials

produced on arable land which can be utilized by dairy ruminants. These materials include forages--hay, silage, soilate, and pasture; cereal crops, tuber crops--potatoes, sweet potatoes, beets, cassavas and others; oilseed, sugar and other crops; crop residues; byproduct feeds from processing of crops and animals for human food; and other miscellaneous products.

However, De Boer maintained that changes in the animal production resource base in arable areas may impose unfavorable effects on dairy production (1, 18). In mixed farming system in the tropics, where food and cash crop production has been emphasized, shortages of feed produced from limited land have constrained the expansion of dairy goat enterprises on small-scale farms (18, p. 335). In Asia, the increase of planted area led to the gradual encroachment of cropland into more productive pasture areas. The increase in cropping normally provided some crop by-products, but the net effect was invariably to reduce annual animal feed supplies. Population increases have led to increased demands for food crops and livestock products but the competition for the land resource meant that livestock usually have to exist on fewer and fewer domestically produced feedstuffs (1, p. 87).

Furthermore, even if feed and other biological constraints are removed or diminished, actual progress in expanding dairy production is likely to be slow, according to Winrock. The reason is that a number of nonbiological factors can impede expansion of dairy production

unless they receive serious attention. Some of the most important of these constraints are:

Land Tenure Tenure problems arise because of the separation of decision-making powers of livestock owners and land owners. This is especially prevalent in the Middle East and Africa, wherever the pastures are publicly owned, and common lands and herds are privately owned. Similar conditions are reported for Latin America, where areas of pasture are held in large estates by absentee landlords who show little interest in animal or forage improvement (21, pp. 85,86). In China, decision-making powers of livestock owners and land ownership are also separated. Under the current responsibility system, farmers have the right to use the farmland for a contracted period, but land is still owned collectively. This study will investigate the possibility and significance of the transfer of contracted farmland under the current government policies of land control.

Markets and Transportation Despite the importance of markets, some governments and financial institutions continue to maintain policies that are often unfavorable to the marketing system. Many governments in developing countries attempt to control milk prices, especially in urban areas. This policy has often discouraged producers from marketing their dairy output through established channels to urban markets, thus often dampening internal production and leading to the major increase in developing countries of outlays of foreign exchanges

for condensed and powdered milk imports (22, p. 86). China has the same problem. So far, China has not completely gotten rid of the Soviet-style marketing system. The inefficiency of price system, the inadequacy of transportation facilities and marketing facilities are listed as major obstacles to the expansion of dairy production. We will investigate this problem in Chapter III.

Credit To expand and improve the output of dairy ruminant products requires large investments in livestock, processing and handing facilities, and forage resources. Unfortunately, sources of agricultural credit are poor in most developing countries. An especially important problem is that of the credit needs of smallholder dairy producers, but most institutions are reluctant to make loans to them because administrative costs of small loans are high. As a result, in many developing countries, 70 to 80 percent of small farmers do not have access to institutional credit (22, p. 90). The Chinese government did not provide credit to private farmers until the adoption of the responsibility system. Since 1981, the government changed its credit policy by relaxing the restrictions on the credit supply to individual farmers with the aim of encouraging the expansion of agricultural production.

Shortages of adequately trained and motivated people This lack of skilled manpower includes producers, processors, distributors and the network of extension advisors and technicians required for

teaching, directing and organizing program operations. In China, because farmers lack good educational background as well as experience in raising dairy cattle, not many people are possessed of the ability to manage dairy production properly.

Socio-cultural constraints Mores and prejudices against some animal products occur in some developing countries. Their basis may be mystical, whimsical or trivial. In addition, socio-cultural traits that have a have a bearing on dairy development also include the customs and folkways of tenure, family labor utilization, and community organization.

Winrock predicted that increased world population and increased consumer buying power will create a demand for 74 percent more milk (22, p. 111) by the year 2000 than was consumed in 1970. The demand can be met by implementation of the proper - and workable - strategies of action for producers, marketers and policy-makers in both governmental and private sectors.

Two options are open for increasing the supply of dairy products: (1) increase the number of dairy animals without appreciably increasing per-animal productivity, and (2) improve the fertility, health, nutrition and genotype of dairy livestock without appreciably increasing numbers. In all likelihood, a combination of these two strategies will be followed; the degree of mix will vary from regions (22, p. 111). This study focuses upon the development potential of

dairy production based upon the first option, that is, how can Sichuan Province expand milk supply by increasing the numbers of dairy cattle and dairy goats, given current levels of technology, genetic make-up, and nutrient quality of feed?

Chinese Theoretical Studies

Before the widespread adoption of the responsibility system in 1982, three distinct systems of animal production were found in China: (1) large scale production of cattle, horses, hogs, and sheep managed by state farms. Over 95 percent of the milk supplied to the major urban areas came from state farms (21, p. 38); (2) medium-scale animal production systems run by collectives at three different levels--communes, brigades and production teams; and (3) small-scale animal production by individual collective members on their private plots.

The two former types of animal production were predominant, while the animal raising by individual commune members was harshly limited, in terms of not only the number raised, but also animal species. Large animals such as horses and dairy cattle, were not allowed to be kept by individual farmers. For these reasons, the study of individual animal enterprises, particularly large animal production, was a "forbidden zone." Only after the introduction of the responsibility system, when farm households became recognized production units free to engage in

animal production, did economic studies begin to address individual animal enterprises.

Since 1979, the Agricultural Economics Research Institute of the Chinese Academy of Social Sciences has sponsored five annual meetings on the economics of animal husbandry. The literature continued to focus on the justification of current liberal government policies, reidentification of the interrelations between crop farming and animal production, and a rational structure for animal production.

China's agricultural structure has been highly imbalanced, because of both an over-emphasis on grain production and an over-emphasis on hog production within livestock. Figure 2.1, Table 2.1, and Figure 2.2 show the structure of agricultural output value by sector, and the changes in the structure of animal production since 1950.

Figure 2.1 indicates that the animal husbandry increased from 11.5 percent in 1952 to 15.5 percent in 1983, only increasing 4 percent over 31 years. The low proportion of animal husbandry in agricultural economy was dwarfed by the that of the United States and a lot of other developed countries (40 to 55 percent) (12, pp. 957-958). Figure 2.2 and Table 2.1 indicate that the number of large animals (including dairy cattle) was greater than that of hogs in 1950, but hog production increased very rapidly, though rather unstably, while the development of large animals was very slow. The number of hogs was 4.3 times

Table 2.1. Total number of hogs, sheep and goats, and large animals in Mainland China, 1950-1981 (15)

(Figures are million head year end inventory)

Year	Swine	Goat and Sheep	Large Animals[a]
1950	57.75	42.35	60.02
1951	64.01	46.73	65.38
1952	74.40	52.87	70.41
1953	89.77	61.78	76.46
1954	96.13	72.02	80.76
1955	101.72	81.30	85.30
1956	87.92	84.22	87.75
1957	84.03	91.65	87.73
1958	145.90	98.58	83.82
1959	138.29	95.68	77.68
1960	120.42	111.65	79.12
1961	82.27	112.81	73.36
1962	75.52	123.87	69.49
1963	99.97	134.65	70.20
1964	131.80	137.47	75.05
1965	152.47	136.69	79.43
1966	166.93	139.03	84.21
1967	193.36	138.08	87.40
1968	190.06	144.33	89.82
1969	178.63	144.21	91.79
1970	172.51	140.21	92.28
1971	206.10	147.04	94.36
1972	250.35	150.11	95.37
1973	263.68	149.32	95.76
1974	257.94	157.28	97.18
1975	260.78	160.87	97.53
1976	281.17	163.37	96.86
1977	287.17	158.17	94.98
1978	291.78	161.36	93.75
1979	301.29	169.44	93.89
1980	319.71	183.14	94.59
1981	305.43	187.31	95.25

[a]Large animals include cattle, horses, donkeys, camels, and other large animals.

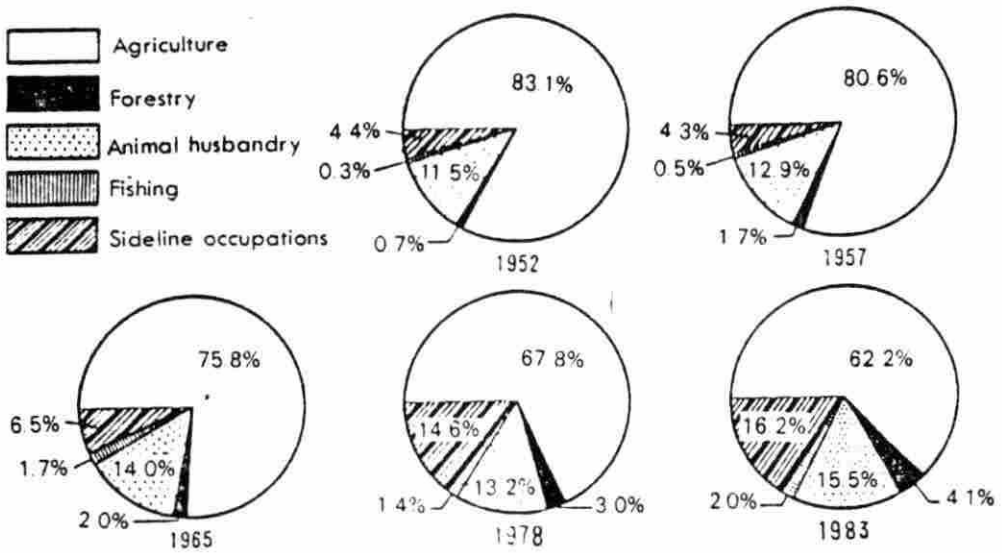

Figure 2.1. Output value by sector of China's agriculture (11)

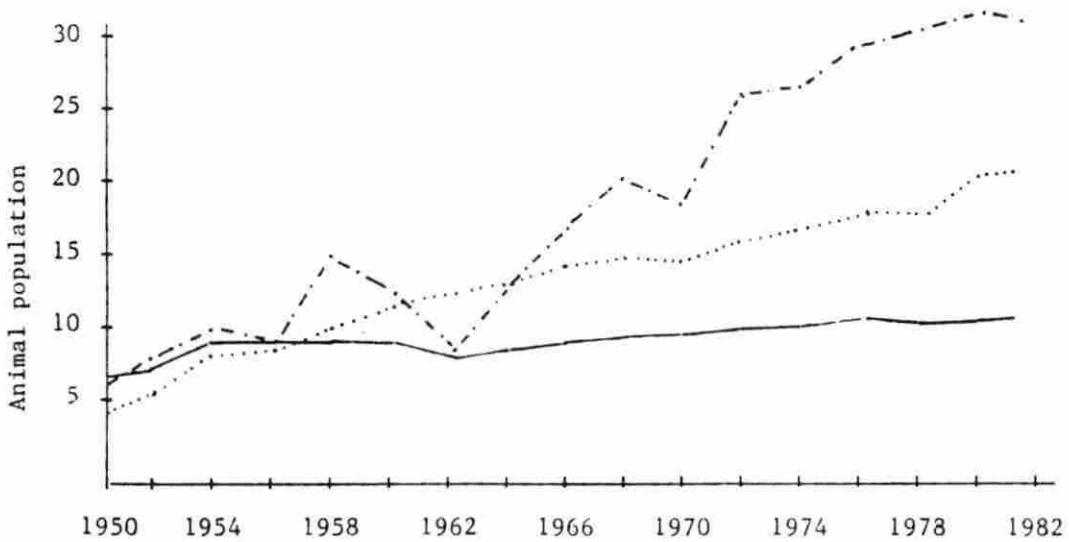

Figure 2.2. Growth in total animal population (ten million heads) (15)

greater than that of 1950, while the number of large animals was only 58.7 percent higher than that of 1950.

These policies have had two adverse effects. On the one hand, farmers have had difficulty selling hogs either to the state's purchasing station or on the free market. On the other hand, consumers have had difficulty buying beef and such dairy products as fluid milk and milk powder.

China's agricultural economists have proposed the following principles for restructuring the structure of animal production:

1) Reorganize the livestock economy along the lines of comparative advantage, giving full play to local resources.

2) Promote favorable interrelations between animal and crop farming, and coordinate animal production with the aim of enhancing the ecosystem.

3) Meet the people's consumption demand as much as possible, while increasing farmers' incomes (17, pp. 46-49).

The significance of expanding animal production in intensively cultivated areas

These economists have outlined three major advantages of a mixed crop-animal economy (17, pp. 78-94).

1) The combination of crop and animal production in intensively areas represents a trend in Chinese style agricultural development,

given the fact that one billion people rely on the limited land resource.

2) Mixed-crop animal production is a good way to promote the favorable interaction between crop farming and animal husbandry.

3) Combining crop and animal production will make better use of the surplus labor in intensively-cropped areas.

4) The mixture of crop and livestock enterprises will help raise farmers' income significantly.

Therefore, it is argued, the mixed crop-animal economy will play an important role in future agricultural development.

The strategy of all-round development of agriculture

The strategy of all-round development of agriculture is comprised of these goals (17, pp. 86-94).

1) Establishing a proper ratio between crop and animal production. An economic measure commonly used is the proportion of animal husbandry output value to total output value in the agricultural economy. It is generally accepted that the proportion of animal husbandry output should be more than 30 percent (17, p. 36).

2) Establishing a proper balance within animal agriculture. First of all, the ratio between ruminants and nonruminants should be appropriate. It has been suggested that favorable proportions should include: 50 percent hogs, 30 percent goats, and 20 percent large

animals (17, p. 92). However, the proper ratio should be based upon local natural conditions. In areas with abundant grain, a large portion of hogs and chickens, which are very efficient in converting concentrates into animal products, could be maintained. In areas where farmers do not have much surplus grain but have rich surpluses of grass and other forages, large animals, including dairy cattle, could be profitable.

3) Encouraging skillful farmers to become specialized in large-scale dairy cattle and chicken production around big cities. This is because such farmers have good access to urban markets and technical services (17, p. 94).

Identification of the major impediments affecting animal production in intensively-cropped areas

Government ideological constraints, the inefficiency of the marketing system, shortages of feedstuffs, and an irrational price system were listed as the major problems facing Chinese farmers (9, 17). The models in this study will relax these constraints to measure dairy supply response under feasible alternative policies.

Empirical Study by Winrock International

In August, 1982, the Winrock International Livestock Research and Training Center sent a study team to China to investigate ruminant livestock production in Sichuan Province. The overall goal of the

study team was to formulate a set of recommendations to promote the development of ruminant animal production in Sichuan Province.

The team found a wide variety of ruminant animal production systems being practiced in the farming areas of Sichuan. Producing units included state farms, centrally-managed communal farms, production teams and individual households. Feeding systems included pasture-based systems, the use of crop-based farms, and full confinement large-scale enterprises relying exclusively on purchased feed (17, p. 184).

The study report included a description and assessment of the natural resource base for animal production; a description of the institutional framework under which government support is provided; an outline of the structure of production, including the role of communes, state farm sector, and the economic responsibility system; economic analysis of livestock production opportunities open to commune members; identification of production, processing, distribution and market constraints limiting possible development programs; estimation of production traits of Sichuan livestock; assessment of the feed resource base on small farming units; and the formulation of rations needed to support higher levels of milk production.

Winrock considered a number of factors in evaluating the feasibility of expanding ruminant production in Sichuan Province:

Positive factors

1) Strong demand for milk.

2) Adaptability of European breeds.

3) The technical support network, extending from the provincial level to commune level technicians.

4) Support from administrative agencies. At all levels of administration (provincial, district, county, and commune) strong commitment to the goal of producing more milk for the urban population and improving the production of meat and hides is a common theme.

5) Feed resources. Ruminant producers appeared to have adequate access to feed resources in the form of cut grass and byproducts.

6) Absence of serious animal health problems.

Negative factors

1) Lack of space in intensively cropped areas.

2) Inefficiencies of collecting small amounts of milk from individual households.

3) Need for farmer training.

4) Low productivity of dairy ruminants.

In addition, the Winrock study maintained that the true development of ruminant production would require breeding improvements, capital investments, the development of feed resources, and changes in government support services.

With the permission and financial support of Winrock International, this study tries to make use of the observations of the Winrock study team to make a more concrete economic analysis of potential of diary development in Sichuan Province, especially on the aspects of economic policy. No attempt is made to examine the biological aspects of dairy production in Sichuan Province such as breeding improvements, veterinary system and improvement of feed rations. Research on the dairy production based upon the pastoral system in nonarable areas is also excluded from this study.

Summary

This chapter has attempted to present a review of the theoretical and empirical studies of dairy livestock production, especially on socio-economic aspects of dairy production. The studies were reviewed in the context of the studies of dairy production on a world-wide basis, Chinese literature on mixed crop-animal agriculture since 1978, and in the context of the special study by Winrock International.

CHAPTER III. DATA AVAILABILITY, DESCRIPTION OF PRODUCTION ACTIVITIES, AND SPECIFICATION OF THE LINEAR PROGRAMMING MODEL

Dairy production development involves a complex interaction among technical, biological and socio-economic factors. The degree of progress that dairy livestock producers in Sichuan Province will make will depend to a large extent upon their success in overcoming the constraints that inevitably face farmers--technical and economic problems that can impede the expansion of dairy production.

A number of factors will be identified as influencing the development of dairy production. These factors are associated with farm structure, cropping patterns and feed availability, labor availability, market demand for milk products, marketing and transportation problems, animal genetic improvement, dairy management, and government support policies. The effects of these factors on dairy production will be specified in the next section.

This chapter will describe the LP model, the goal to be optimized, the decision variables, and the restrictions incorporated to reflect the resource and policy constraints upon dairy development that have been discussed in Chapters I and II.

Factors Influencing the Expansion of Dairy Production

Farm structure

The growth of the production responsibility system in the Chinese countryside since 1979 has brought about fundamental changes in the operation of the rural economy and the institutional structure. Initially conceived as a reform in the methods of labor management, the system has reduced collective organization to its most skeletal form and decentralized most farming activities to the family unit. Figure 3.1. is a schematic representation of a typical small farm in Sichuan province with an average of 1.5 mu (0.073 ha) per capita.

The "household" is the core of the family farm. Labor use, human food and animal feed are identified, as are interactions between the crop and livestock subsystems. The box labeled "market" represents off-farm activities involving the purchase of such nonland inputs as fertilizer, household items and labor; and the sale of free-market output.

The major crops are rice, wheat and maize. Minor crops include sweet potatoes, broadbeans, and vetch. The most important interaction between crop and animal components is the feeding of crop residues to livestock, while manure goes to crop production in turn.

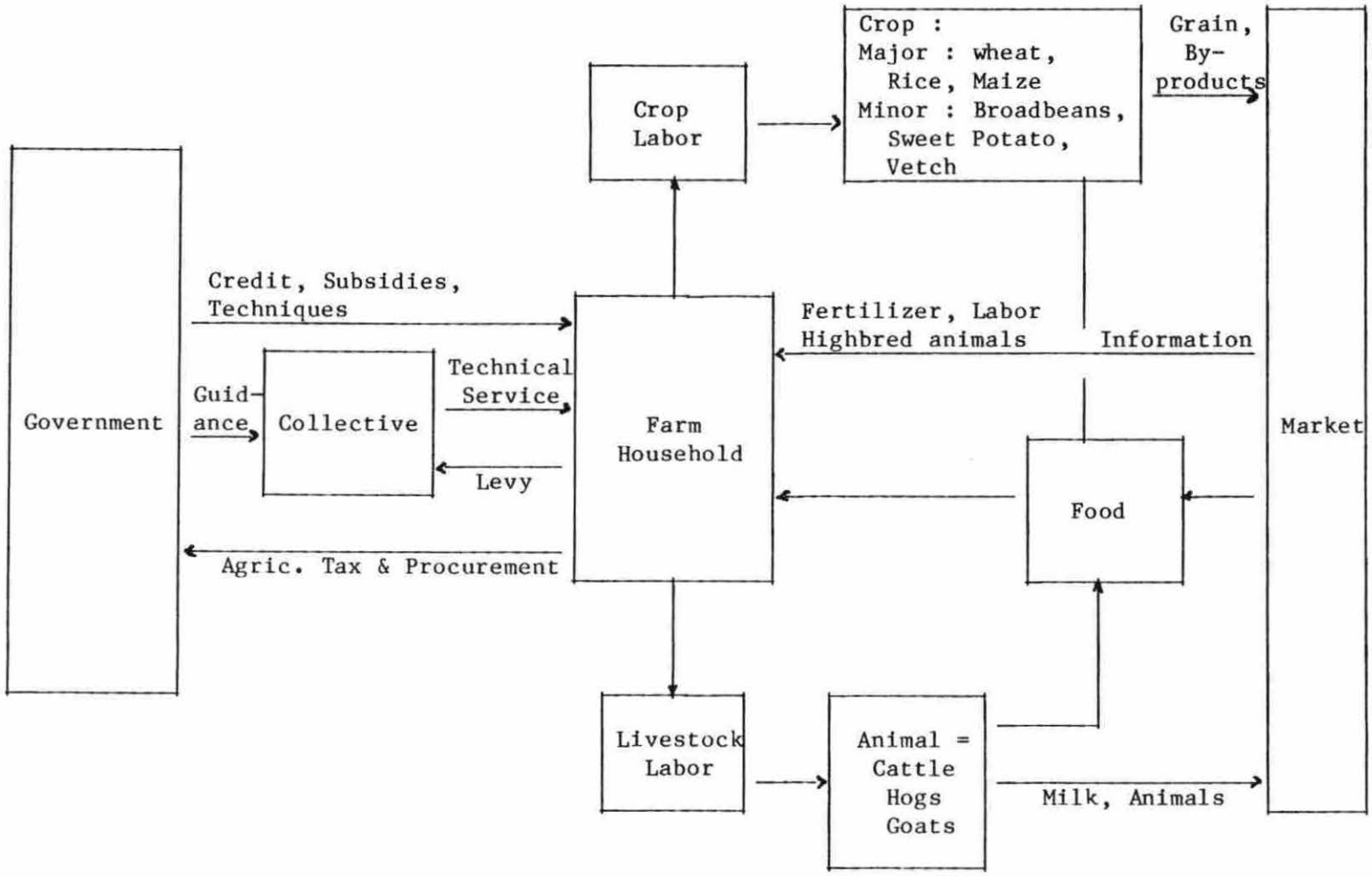

Figure 3.1. Farm structure in Sichuan Province

Under the production responsibility system, collective resources such as land and farming equipment are contracted to farmers. For each unit area contracted, a standard yield is specified. Standard yields vary according to the quality of the land but are usually based on the average yield for the past three years. At harvest, 8 percent of the standard yield is paid in kind to the state as agricultural tax, and 7 percent is sold to the state as a quota of commodity grain at the state purchasing price. The collective takes a certain amount of the farmers' products towards an "accumulation fund" for the construction of farmland and water conservation and other public works projects; a "public welfare fund" for relief to impoverished families, co-operative medical service and family-planning programs; and an "administrative fund" for the administrative expenses of the collective. The remaining portion is owned by the farm household. It can be used to feed the family livestock, sold on the free market at a higher price than the state pays, or sold to the state at a premium price (about 50 percent above the state commodity purchasing price).

The government encourages farmers to seek property and has adopted measures to help farm households to develop production and increase their income. These measures include government loans on favorable terms, and technical guidance.

Although the agricultural reforms described above are still in the process of development, it is clear that the structure of the

agricultural economy has undergone fundamental changes. However, a combination of problems still prevents adequate growth of the agricultural economy. These problems include disguised unemployment, an inability to stimulate growth in animal production, inefficiency in the marketing system, and lack of technical services.

Cropping patterns and nutrient availability

Six typical cropping systems are described in Table 3.1. along with estimated total farm production of grains, tubers, fodder and byproduct feed. Farm types A, B, and C operate paddyland, while farms D, E, and F raise their crops on rainfed dryland.

Table 3.1 reveals three further characteristics:

1) Farm size in eastern Sichuan is a little larger than that in the Chengdu Plain, while average yields are lower.

2) Intercropping patterns consisting of winter wheat, rapeseed, broadbeans and vetch are common in both irrigated areas and dryland, and the intercropping of corn and sweet potatoes is popular on dryland.

3) The index of multiple cropping on the six farms is 2.0, significantly higher than the national average of 1.47 (12, p. 930). The intensification of crop cultivation implies that crop production is very labor-intensive in these areas.

A wide array of plant materials produced in these cropping patterns could be utilized by dairy ruminants.

Forage--Large quantities of hay, broadbeans and vetch are produced on the arable land of Sichuan Province. These crops figure in crop rotation plans and facilitate good soil management.

Crop residues--crop residues rank as the second most important feed source from arable land in Sichuan Basin. In the past, however, potential feed supplies from crop residues such as rice, straw, wheat straw, and maize stover were usually used as fuel. Now that farmers have access to ruminant production, people are beginning to realize the value of these residues. For this reason, we can expect that an increasing portion of these residues will be devoted to dairy livestock production.

Some crop residues may have greater value for other uses. Rice straw, for example, may be more valuable in paper-making than as feed. But stripping all residues from the crop land will adversely affect soil fertility and tilth. Manure from dairy ruminants fed on crop residues can alleviate this possible problem.

Grain--concentrated energy sources such as maize contain approximately twice the metabolizable energy per kilogram of dry matter as grass, hay or most other forages. Since daily intake of dry matter is physically limited by the animal's stomach capacity, concentrates

Table 3.1. Farm types in intensively-cropped area in Sichuan Province (21)

Crop Season	Crop	Yield (kg/ha)	Index[a]	Grain Output (kg)	Feed/Grain Ratio	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[b]	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[b]	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
	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[b]	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	4,200
	Vetch	60,000	0.07			Green Feed	5,000
	Fresh Grass[b]	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[b]	5,000				Fresh Grass	5,000

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

Summer I	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	15,00
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[b]	5,000	0.50			Fresh Grass	5,000

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

[b]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.

can supply substantially more daily energy and protein than forages. Dairy ruminants with high genetic production for growth or milk production must have concentrates as a substantial portion of their diet if they are to perform at the level of their genetic potential. The decision as to whether dairy ruminants will be fed concentrates, and how much, generally depends on the opportunity cost of feeding livestock with concentrates.

Oilseed meal--The solids remaining after extraction of vegetable oils from oilseeds--soybean, cottonseed, peanut and others--are a high energy, high protein food source for animals.

We can conclude that there are abundant feed sources to support expansion of dairy ruminant population and production in Sichuan's intensively cropped areas.

Labor availability

In China, agriculture employs an estimated 80 percent of the labor force during all or part of the year. Since 1979, the production responsibility system, while greatly increasing productivity, has also created a problem of surplus labor in rural areas. This is most prominent in such densely populated areas as the the Sichuan Basin.

One way to solve this problem is to set up rural-industrial enterprises to put the surplus labor to work. Another is to encourage

farmers to break away from crop farming to become specialized in animal breeding, the processing of farm and sideline products, and such weaving and service trades as commercial transport. The Chinese government has gradually changed the policy concerning those activities in recent years, by removing ideological trammels and encouraging people to diversify the agricultural economy.

Ironically, when farmers become specialized in grain or animal production and try to expand production scale beyond a certain level, they may well face a labor shortage. For example, in this study, farms are assumed to start with three full-time family laborers.[1] When farmers introduce dairy cattle into their production patterns while maintaining current levels of crop farming, they may run out of time during seasonal peaks. However, the Chinese government has prohibited labor employment since 1949, on the grounds that the hiring of labor implied theoretical "exploitation"; the people who hired labor were regarded as "new landlords".

The lack of a labor market may therefore hinder the development of dairy production, resulting in milk output being significantly smaller than it would be in the absence of a labor shortage. Fortunately, along with the popularization of the responsibility system, permission

---

[1]We assumed that full-time family laborer works 8 hours a day, 25 days a month, totaling 2400 man-hours a year.

to hire nonfamily labor has been granted to farmers on a controlled basis. Control is exercised by limiting the number of hired laborers to five people.

Marketing and transportation

The major marketing problems are the lack of efficient channels to urban markets and the irrationality of price policy.

There are two channels through which Chinese milk products go to the consumer. One is that milk is collected and carried to the processing plant by special collectors. The milk plant pays the collectors based on the amount of milk he or she delivers. Then the pasteurized milk and/or milk powder is delivered to consumers or sold in the markets.

The other channel involves producers selling fluid milk door-to-door. However, milk is supposed to be pasteurized before it can be sold to the consumer. This fact makes it very difficult for the small farmer to distribute his own milk, since he cannot afford a pasteurizing equipment. Therefore, by far the greater portion of the whole milk is marketed by the state's milk distributors.

Since it is expensive and bulky to transport fluid milk for long distances and milk must be fresh when delivered to the consumers, there is a great advantage in producing milk for consumption near the consuming centers. Hence, it is highly advisable that the production

of fluid milk be located near large cities. In these areas, the cost of producing milk may be higher because a considerable portion of the feed must often be shipped in and opportunity land values are higher. However, because of the great cost of transporting the milk from long distance, farmers even under these cost disadvantages are able to compete with milk producers in lower-cost areas.

Prices have been used to regulate both the quantity and quality of dairy production as well as the consumption of dairy products in China. The system bears some similarities to the open-market system but differs in many important respects.

The state fixes price for dairy products that it buys and sells. Retail prices for dairy products have been kept relatively stable and low, but prices paid to producers for dairy products have been increased periodically to encourage greater production. However, the government's price policy may create unfavorable effects on either milk production or government outlays. If the state-fixed price for purchasing milk is too low, it will deter production. If the price is too high, the government then has to bear the heavy fiscal burden of subsidies--the current situation of the Chinese government. Therefore, the government's attempt to control milk prices might be unfavorable to the marketing system.

Dairy management

Farmers in the intensive arable areas have not had much experience in raising dairy ruminants. Nor do they have good educational background in livestock production. When they introduce dairy livestock on their farms, they encounter a range of problems, including choosing cows with good dairy tendency, making up ideal feed rations by selecting suitable feedstuffs and economical grains and supplements, preventing diseases, providing medicines and vaccines, keeping feed and product records, and so forth. These problems directly affect the productivity and the value of dairy livestock production and, thus, the milk supply and economic returns to farmers.

In addition, the shortage of adequately trained extension advisors and technicians required for teaching and directing is also a serious constraint to achieving dairy production potentials.

The government's incentives to dairy production

The Sichuan provincial government has followed the principles and policies of the central government in encouraging dairy production in recent years. Multiple economic incentives are in effect to promote and expand dairy ruminant production.

First, the state attempts to encourage dairy production by providing subsidized concentrate feeds: farmers are granted one kg. of concentrate at the state subsidized price for each two kg. of milk

sold (21, p. 53). The government also subsidizes milk processing plants and the state's milk distributors, which may not make profits because of the small spread between the purchasing prices of dairy products and the prices charged to consumers.

The government also provides credit to dairy farmers. Farmers with inadequte capital to produce dairy livestock may obtain low interest (5% - 5.76%) loans from credit cooperatives belonging to the state agricultural bank (21, pp. 55,56).

Vaccination services are free. All medicines for the prevention and treatment of livestock diseases are sold to farmers by the Animal Husbandry Bureau of the local government (21, p. 56).

Government efforts also include financial support for research programs, increasing the availability of dairy breeding stock and semen from quality sires from the state farms, providing training programs for technicians and for farmers, and improving the infrastructure for delivering and processing milk (21, pp. 58,60).

Summary

The productivity of dairy livestock depends heavily on the availability of feedstuffs. Fortunately, there are abundant supplies of feed sources in the intensively-cropped areas in the Sichuan Basin.

Among the socio-economic factors labor availability and the price system may be ranked as the most important. In addition, poorly

functioning transportation, marketing, processing and preservation systems for dairy products can significantly lower productivity, increase costs to consumers and lower returns to producers.

The success of dairy production systems can be affected by the attitude and policies of both national and local governments on prices, subsidies, credit, research and extension. Broadened and enlightened understanding of these technical and socio-economic problems would help to bring about favorable changes in dairy farming development.

Description of Model Activities

Crop production activities

The crop production patterns for the six original farms were named GRAINPA, GRAINPB, GRAINPC, GRAINPD, GRAINPE, and GRAINPF. Patterns A, B, and C were practiced on paddyland, while patterns D, E, and F were for dryland.

Patterns A and D were selected from the Chengdu Plain, which is characterized by dense population and small farm size. Patterns B, C, E, and F were selected from Eastern Sichuan, where average farm size is larger than that in the Chengdu Plain, suggesting a stronger potential for livestock production. Production costs and labor requirements of crop farming based on each pattern are represented by Table A.7.

Transfer activities

Two types of transfer activities were included. The first was the transfer of grain and feedstuffs from one quarter to another quarter to satisfy the requirements of livestock feeding, family consumption and quota and above-quota grain sales to the state.

The second type of transfer conveyed nutrients from corn and nongrain feedstuffs to a variety of nutrient pools. The transfer of nutrients was separated into two channels according to the different digestive ability of the livestock. One was for the dairy cattle, water buffalo and goats, the second was for swine, as some feedstuffs such as rice straw are good for cattle, but not for hogs.

Dairy cattle raising activities: CATTLE 1 to CATTLE 3

CATTLE 1 was the raising of Holstein, which produced about 3,000 kg. of milk in a 305-day lactation period.

CATTLE 2 was "Holstein x Yellow" dual-purpose cattle weighing an average of 437 kg. Total milk yield was 1,5000 kilograms in a 305-day lactation period.

CATTLE 3 was "Simmental x Yellow" dual-purpose cattle, the most productive among the three types of cattle. Mature weight averaged 585 kg. Up to 4,575 kg. of milk were produced in a 305-day lactation period.

For all three types of cattle, the assumption was made that 0.5 male calves were slaughtered at birth and 0.5 female calves were raised and sold after weaning.

Yellow cattle and buffalo raising activities

Buffalo and yellow cattle are very important to farming because of the low degree of mechanization. Buffalo and yellow cattle are kept primarily to provide draft power, which is used mainly in field preparation for planting. Buffalo are preferred in the paddy areas, while yellow cattle are preferred for field work in hilly, dryland areas and for the transport of goods. Therefore, the yellow cattle raising activity is included in the plan in accordance with crop production activities, A, B, and C; while buffalo enter the model in accordance with crop production on irrigated land.

Dairy goat raising activities: DG 1 to DG 3

Dairy Goat 1 was the raising of Saanen goats. Body weight was estimated at from 55 to 60 kg. This breed produced around 750 kg. of milk per 230-day lactation period.

Dairy Goat 2 was a crossbred "Saanen x Native." Mature goats weighed 50 to 60 kg., and about 420 kg. of milk was produced per 230-day lactation.

Dairy Goat 3, sometimes called Chengdu Ma goat, was a meat, milk and hide triple-purpose goat. Most famous for its tasty meat, it yielded only 300 kg. of milk in a 250-day lactation.

For all three types of goats, it was assumed that the farmer sold two kids as soon as they were weaned.

Meat goat raising activity

We assumed that farmers bought weaned kids in quarter two and fed them for sale in quarter four. The estimated products were ten kg. of mutton and the hides.

Hog raising activities

There were three types of hog raising activities in this model.

a) HOG 1 -- HOG 4: farrow to finish. One sow produced eight piglets in one of four quarters. The farmer raised the piglets to a market weight of 75 kilograms.

b) HOG 5 -- HOG 8: farrow to feeder. One sow produced eight piglets in one of four quarters, and the weaned piglets were sold in the next quarter.

c) HOG 9 -- HOG 12: feeder to finish. Farmers purchased a weaned pig in one of four quarters, fed it to a body weight of 75 kilograms, and sold it after 180 days.

Purchasing and selling activities

Except for the purchase of draft power for crop farming and pork for family consumption, all purchasing activities were for livestock production. Inputs for crop production, such as seeds and chemical fertilizer, were included in the basic production cost (C-row value) of crop activities.

Farmers could buy subsidized corn when they sold animal products such as milk and hogs to the state at the state price, which was about 42 percent lower than the free market price.

As noted, farmers under the responsibility system, who contract a small plot of land with the collective, are responsible to pay 8 percent of the total farm products of grain to the state as agricultural tax. Farmers are also required to sell 7 percent of the grain output to the state at the quota price to meet the government's requisition. In addition, farmers are encouraged to sell as much grain as they want to the state at the above-quota price. The above-quota price is 50 percent higher than the quota price, and usually higher than the free market price in the harvest season, but lower than the free market price in the other seasons. It was assumed in this model that farmers sold 10 percent of total grain output to the state at the above-quota prices.

It must be pointed out that the ratio of grain sold at the above-quota price varies significantly from time to time, and from place to place, depending upon harvest volume, the farmers' storage capacity, feed requirements for livestock production, and expectations regarding free market prices in the season following the harvest. However, ten percent seems a reasonable estimate for most mixed farming operation. The portion of grain sold to the state at the above-quota price by households specialized in grain production may be much higher.

For sideline products, we assumed that milk and hogs were sold to the local purchasing station. This is because Chinese farmers commonly sell their animal products to the state rather than door-to-door.

Borrowing and saving activities

Farmers could take out a government loan of as much as ¥ 200 in a given quarter at 5 percent interest per year or 1.25 percent per quarter. Specialized households enjoyed a higher borrowing ceiling but paid the same interest rate. The saving interest rate was 2.88 percent per year. Both borrowing and saving activities were designed so that the farmer paid back or withdrew the money in the following quarter. It could then be re-borrowed or re-saved if necessary.

Family consumption activities

Family consumption was determined by the average amount of food required by family members, and the current balance among grain products consumed. In addition, we took it for granted that a farm family's consumption was strongly related to their products in kind. Pork, however, was bought from the market to take advantage of subsidies.

Government subsidies

Farmers with dairy cattle were granted one kg. of grain at the state subsidized price for each two kg. of milk sold. The state and local government also provide subsidized grain to farmers when they

sell other kinds of animal products. Since state subsidized prices are lower than that of the free market, farmers can benefit by selling premium grain on the free market.

The entitlement formula of government subsidy is presented by Table A.9.

Specification of the Linear Programming Model

In accordance with the production activities defined in the previous section, we developed a budget for each animal production enterprise (Chapter IV). These budgets were used to determine the input requirements and profit per unit of output from each production activity.

The linear programming model in this study was designed to maximize farm profits. Since the responsibility system was introduced, farmers have been able to arrange their own schedules for working their contracted land, and their ultimate aim is usually the maximization of profit within resource restraints. The current government policy of land control shuts out the possible goal of farm ownership and farm expansion through purchasing farmland. Farmers may also desire to reduce risk and/or to have an enjoyable standard of living, but we assume that these goals are in a subordinate position. Therefore, the LP model in this study was designed to maximize farmers profit over production costs within the restraints imposed.

The specific profit function is defined by:

Maximize $Z = C'Xij$

subject to $AXij \ (\leq = \geq) \ B$

$$Xj \geq 0$$

where

Xij: crop livestock production, transfer, purchase, sale, borrowing or saving, hiring labor, and consumption (see Table B.1);

C: the objective function coefficients of each activity. These include production costs for crop and animal farming, purchase prices for buying activities, prices of selling crop and animal products activities, interest rates for borrowing and saving activities, and 0 for transfer and nonpurchase-consumption activities;

B: the resource restraints;

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

There are three types of restraints: (1) maximum, (2) minimum, and (3) equality which are labeled by L, G, and E, respectively (Table B.1). 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. Farmers face a large set of combination of production alternatives. The purpose of linear programming is to find the combination of activities that maximizes the farmer's profit.

CHAPTER IV. RESULTS AND DISCUSSION

Procedures for Empirical Use of the Model

Five programming models were developed to test the hypotheses specified in Chapter III. The testing sequence is shown by Figure 4.1.

Model I: The basic model

We started with a basic model which represented a simulation of traditional small-scale farming in Sichuan Province. This model was based on Farm E.

Farm E represented a typical small-scale farm which was cultivated on dryland in eastern Sichuan. The farm had 0.45 ha of land worked by 3 workers and supported 1.5 dependents. The major crops were wheat, maize and sweet potato. Maize and sweet potato were intercropped during the spring summer seasons (April-September), while wheat was intercropped with some minor crops: rapeseed, broadbeans and vetch (October-April). Typical cropping system made Farm E a significant representative of mixed crop-animal farm for study on dairy production the arable areas.

The basic features of the model were:

1. The model contained crop production, yellow cattle, hog and goat raising activities.

2. Dairy cattle production was not included.

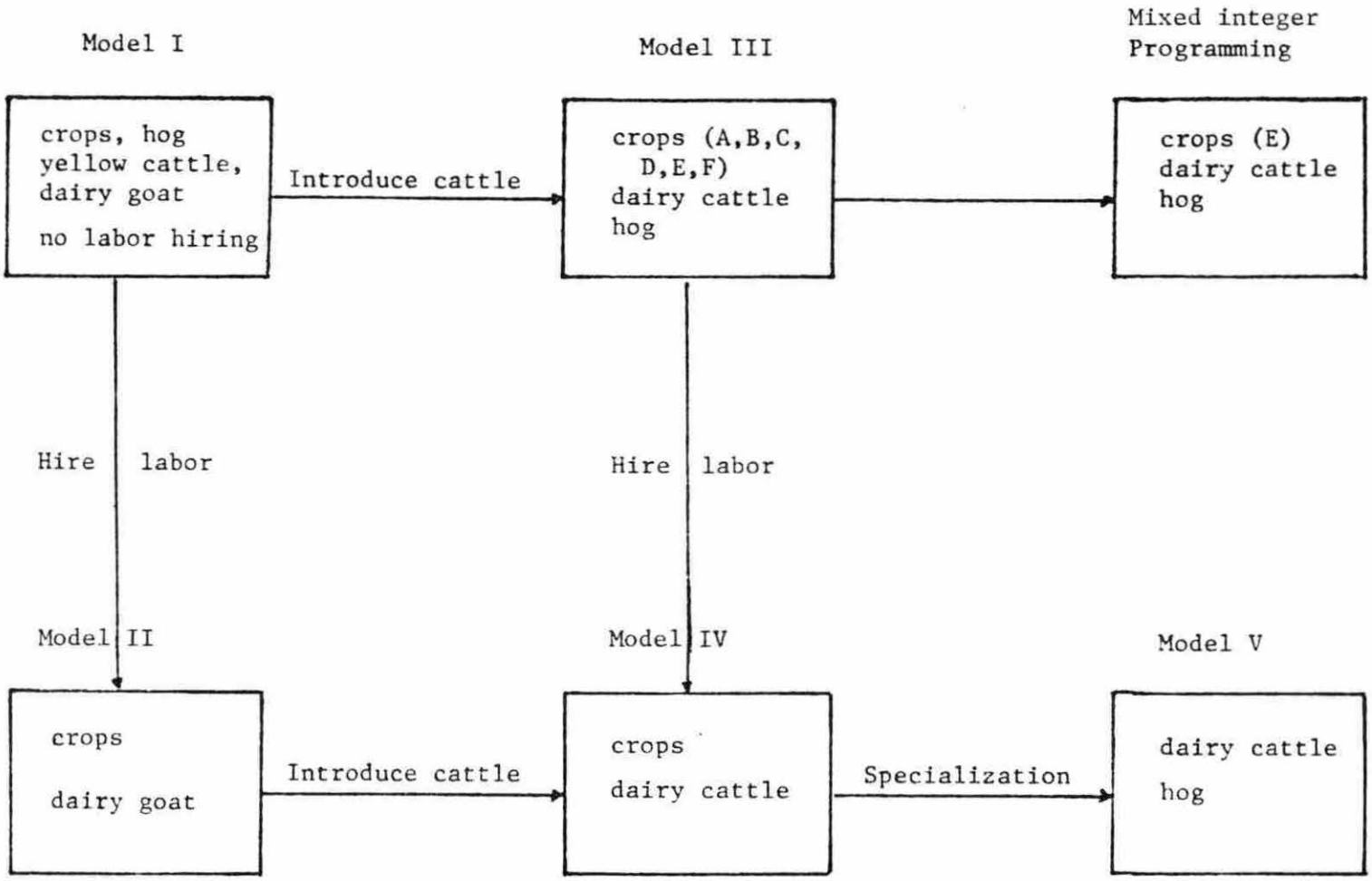

Figure 4.1. The procedure for the linear programming operations

3. No hiring of labor was involved.

4. The model was based upon the production responsibility system, representing a typical semi-self-sufficient farm with a low degree of commercialization.

Model II: The basic model plus hiring labor activities

Since labor availability was the most critical factor in the basic model, we relaxed the constraint by assuming that the farmer could hire as much labor as he wanted. Other aspects of the model remained the same as in Model I.

Model III: Introduction of dairy cattle production

We transformed Model I into Model III by introducing dairy cattle production onto the farm (see Figure 4.1). This model was designed to answer one of the most important questions: what are the impacts of introducing dairy cattle production on the farmers' optimal behavior, other animal production and farm income? This model was run six times, one for each of the six different farms.

In addition, integer programming based upon Farm E was conducted in order to find out the real optimal number of dairy cattle in Model III.

Model IV

Following Model III, we introduced labor hiring activities into the plan to test the hypothesis that there is a significant positive

relationship between the hiring of labor and the expansion of dairy cattle production. This model was based upon Farm E.

Model V: Specialization in dairy cattle production

The basic characteristics of Model V were:

1. The farmer abandoned crop production entirely to specialize in dairy cattle production.

2. The farmer could hire as much labor as he desired, to expand dairy production.

3. The farmer had no responsibility of selling quota grain to the state, but the government still offered subsidized feedstuffs to the farmer in return for selling milk to the state.

4. The other animal production activities were maintained in the model. The farmer could raise hogs or goats at the same time as he raised dairy cattle.

Review of Findings

The basic findings of the linear programming analysis are presented in order in this section. The analysis of the findings will be presented in the next section.

Model I

The results of Model I are summarized in the Table 4.1.

Table 4.1. The programming results of Model I

Farm Size (ha)	Dairy Goat (head)	Goat Milk (kg)	Hog 2 (head)	Yellow Cattle (head)	Land Use (ha)	Functional Value (yuan)
0.45	3.7	2,767	0.6	0.15	0.45	3706.43

Some basic conclusions can be drawn from the above results:

1) Farmland was fully utilized. Land used for crop production accounted for about 99.67 percent, while land for animal production accounted for 0.33 percent.

2) Family labor was fully employed in quarters two and four, the peak seasons. Shadow prices for labor in quarters two and four were ¥ 0.89 and ¥ 0.47 per hour, respectively, suggesting that the labor supply was a very critical factor in this model. These values were significantly above the going market wage of 0.4.

3) The farmer raised 3.7 dairy goats, supplying 2,767 kilograms of milk, enough to fulfill 30 people's consumption demand at the ration level of .25 kg. a day. Therefore, for farmers who could not get access to dairy cattle production for some reason, raising dairy goats

may well contribute significantly to the milk supply and farmer's income.

4) The optimal level of the yellow cattle raising activity was only 0.15, suggesting that six or seven farm households can share a yellow ox for crop farming.

Model II

Model II and Model IV were designed to test the hypothesis that there is a positive relationship between the level of labor hiring and dairy production. Farmers may not have access to dairy cattle production for some reasons such as shortage of capital or lack of large-animal dairying skills. However, if farmers are allowed to hire labor, the expansion of dairy goat production can also contribute to the supply of dairy products.

The results of Model II are presented in Table 4.2, which represents the changes in crop and animal production when the farmer may hire nonfamily labor.

Table 4.2. The programming results of Model II

Farm Size (ha)	Dairy Goat (head	Goat Milk (kg)	Hired Labor (hrs.) Q1	Q2	Q3	Q4	Functional Value (yuan)
0.45	7.7	5,774	0	582	210	448	3908.26

The major changes are as follows:

1) Dairy goat I increased from 3.7 to 7.7 head, causing goat milk supply to rise from 2,767 kilograms to 5,774 kilograms.

2) HOG 2 dropped out of the model.

3) The farmer only hired one laborer. Shadow price for labor in quarter 1 was ¥ 0.14, in quarters 2, 3, 4 were 0.41, 0.41, 0.40, respectively, very close to market wage of ¥ 0.40.

We concluded that the critical constraint upon the expansion of animal production is not the availability of feedstuffs but the supply of labor. In fact, the farmer still sold his surplus feedstuffs on the free market when he expand dairy goat production. One hired laborer enabled the farmer to raise four more dairy goats, and more than double the goat milk supply. Therefore, we tentatively accepted hypothesis one. Subsequent analysis will further evaluate this hypothesis.

Model III

When the farmer introduced dairy cattle production onto his farm, marked changes occurred:

1) Land utilization fell sharply, from 0.45 ha to 0.26 ha because of the shortage of labor. The farmer only made use of 57 percent of his land, and even then only to produce enough grain to meet the requirements of the state procurements and family consumption.

2) Dairy goat production dropped out of the plan. Obviously, dairy cattle was the most profitable type of dairy livestock (see Table 4.14). The price of cattle milk is 33.3 percent higher than goat milk, and cattle milk production is much more efficient.

3) HOG11 entered the plan, replacing HOG2. Although HOG2 was slightly more profitable, it was very labor-intensive, requiring 2032 labor-hours a year. By contrast, HOG11, only required 195 hours a year.

Hog production remained in the model because dairy cattle subsist mainly on high-fiber rations, while hogs can consume more grain, tubers and other less fibrous feedstuffs. Thus, competition between cattle and hogs is not been. Table 4.3 shows that only ricebran was consumed by both cattle and hogs.

Table 4.3. Dairy cattle and hog feed rations in the Model III

Animal	Feed Rations (kg.)					
	Maize Stover	Grass	Rice Bran	Rapeseed Oilcake	Vetch	Sweet Potato Vine
Cattle3	4,700	679	1,026	0	0	0
Hog11	0	0	279.3	93.5	25.4	257.9

4) The degree of full employment of family laborers (labor utilized/total labor supply) increased from 0.91 in Model I to 0.94 in Model III. Labor efficiency of dairy production (in terms of kg. milk/hr.) was increased from 0.93 in Model I to 2.11. Shadow prices for labor in quarter two was ¥ 3.3 per hour, or ¥ 26.4 per day (8 hrs.), indicating that the labor availability was a tremendously critical factor in Model III.

5) Farmer's income increased considerably from ¥ 3,423.09 in modified Model I to ¥ 5,706.80 in Model IV, increasing by 66.7 percent.

The programming operations were performed on the other five farms. There were several common results:

1) Farmers shifted family labor to high-profit dairy cattle until family labor were completely employed, and made much more profit than nondairy cattle farm production.

2) Farm land was not fully utilized when the farmer introduced dairy cattle to the farm. The farmer tended to concentrate on the dairy cattle production while only producing enough grain to meet the requirements of the state quota and family consumption.

3) Farmers still raised a few hogs. The farmers in irrigated areas raised two or three more hogs than farmers did in dryland areas. These results are presented by Table 4.4.

Table 4.4 The programming results of Model III

Farm	Farm Size (ha)	Land Used (ha)	HOG11 (head)	HOG12 (head)	CATTLE3 (head)	Milk Output (kg.)	Functional Value (yuan)
A	0.27	0.185	3.32	0	2.3	10,852	4,760.86
B	0.39	0.321	4.18	0	2.1	9,752	4,331.09
C	0.39	0.242	0	2.9	1.8	8,307	3,841.44
D	0.33	0.256	0.79	0	2.4	11,094	5,716.67
E	0.45	0.256	0.79	0	2.4	11,104	5,706.80
F	0.45	0.30	1.64	0	2.2	10,133	5,487.88

Table 4.4 indicated that six farms based upon different cropping systems, either paddy farms or dryland farms, could raise one or two dairy cattle, suggesting both Chengdu Plain and more mountainous eastern Sichuan has significant potential for expanding small-scale dairy production. There were sufficient feedstuffs for farmers in intensively cultivated areas to raise one or two dairy cattle, and farm incomes could be increased considerably.

For these reasons, we accepted hypothesis 1 that the introduction of dairy cattle production to farm in intensively cropped areas in Sichuan Basin has positive impacts on family labor utilization and farmer's income. Meanwhile, dairy cattle production had a negative

effect on the scale of grain production and tends to reduce dairy goat production, but did not have much unfavorable effect on hog production.

However, it should be noted that solutions presented so far are not feasible in practice because of the impossibility of raising fractional parts of animals. For the Farmer E, for example, the question is: "Should I raise two or three cattle to maximize his profit?" The alternative combinations of dairy cattle and hog raising activities are given with their associated functional values in Table 4.5.

Table 4.5. The programming results of modified Model III

(Cattle, Hog)	Land Use (ha)	Labor Requirement (hrs.)	Functional Value (yuan)
(2, 1)	0.38	6,478	5,686.25
(3, 1)	0.257	7,185	2,362.50

There, in the area practicing cropping pattern E, it would be optimal for the farmers to raise two dairy cattle and a hog. Farmers may wish to expand the dairy production, then they have to hire laborers to expand their dairy production.

Model IV

As demonstrated, the labor supply was a most critical constraint on the expansion of dairy production. If the hiring of nonfamily were prohibited, then dairy production would always be limited to a small scale, three or four dairy goats, or two to three dairy cattle, as shown in Model I and Model III. The Chinese government has come to realize the necessity of free labor employment, and began to relax the constraints on the hiring of labor from 1982.

To reflect labor hiring as allowed under current Chinese government policy, we transformed Model III into Model IV by assuming that farmers were able to hire labor to expand dairy production.

Suppose farmers could only hire up to five people, according to the regulation laid down by the government at the end of 1983, and dairy cattle production exhibited constant returns to scale, then the additional labor availability would lead a surge in milk supply. Again, cropping pattern E was selected, and the linear programming results are presented in Table 4.6.

Table 4.6. The programming results of Model IV

Model	Farm Size (ha)	Cattle 3 (head)	Milk Supply (kg.)	land Used (ha)	Labor employed[a] (person)	Functional Value
Model III	0.45	2.4	11,104	0.26	0	5,706.80
Model IV	0.45	7.3	33,284	0.45	5	12,043.55

[a]See note of Table 4.3.

With five additional hired laborers, the milk supply was almost tripled, increasing from 11,104 kg. to 53,284 kg. Therefore, hypothesis 2 is accepted that relaxation of the constraints on labor hire will promote the expansion of dairy livestock production.

In 1984, the Chinese government modified its policies concerning labor employment in 1984 by taking further steps to a free-market economy. Now, farmers may hire more than five people. In addition, the former three models did not take into account economies of size or diminishing marginal returns to scale of dairy production. This is not consistent with observations of reality. For example, forage collection for one cow requires 2.5 man-hours (21. p. 59); if the farmer raises 3 cows the average labor imput for forage collection will decline. Hence, based upon the observations of Winrock study team (21) and general records of dairy production (12), we modified Model IV to take economies of scale into account. The Model IV was changed in the two respects: 1) the farmer could hire as such labor as he wanted, and 2) dairy production exhibited decreasing returns to scale (see Table A.10). Table 4.7 represents the results of the modified model. Figure 4.2 represents the relationships between labor employment and the supply of cattle milk for integer-valued levels of cattle.

Another important finding was that when the farmer hired extra labor, farmland became fully used, implying that dairy livestock production may not crowd out crop production if there is an adequate labor supply.

Table 4.7. The programming results of modified Model IV

Labor Employment (hrs./yr.)	Dairy Cattle (head)	Dairy Goat (head)	Milk Supply (kg)	Functional Value (yuan)
1,233	3	0.26	13,725	7,835
2,698	4	0	18,300	9,146
4,271	5	0	22,875	10.480
5,764	6	0	27,450	11,832
7,197	7	0	32,025	13,204
8,586	8	0	36,600	14,594
9,947	9	0	41,175	15,997
11,296	10	0	45,750	17,405

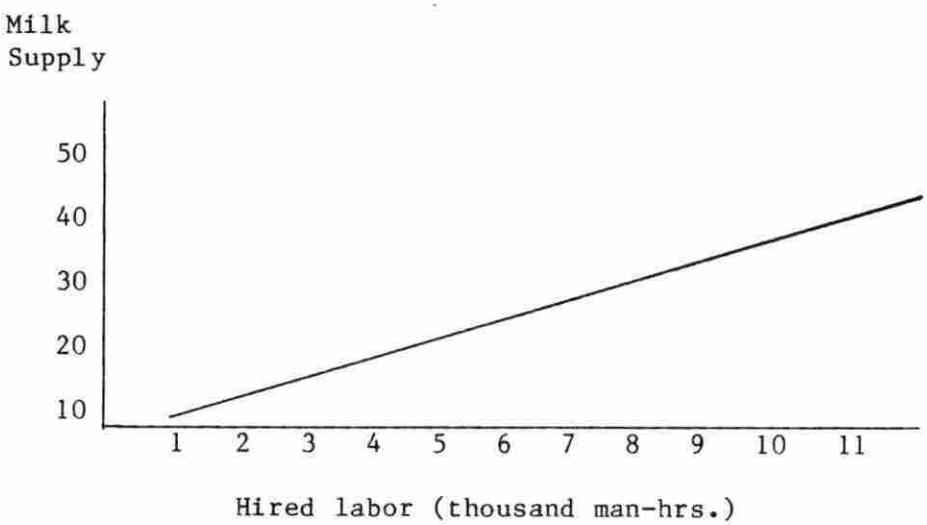

Figure 4.2. The relationship between labor employment and milk supply

Model V

This model was designed to investigate the possibility of expanding dairy production by giving up crop production entirely and specializing in dairy farming. The results of Model V are presented by Table 4.8.

Since the specialized farmer now had freedom to hire labor--the most critical factor in our model--he could expand dairy production and considerably increase milk supply. How many laborers were needed depended upon his dairy production scale. The more labor he hired, the more cows he could keep, and the larger amount of milk he could supply to urban areas.

Table 4.8. The programming results of Model V

Dairy Cattle	Hired labor (hrs/quarter)	land utilized (ha)	Milk supply (kg)	Functional Value (yuan)
5	504	0.007	22,875	8,377.26
10	2.269	0.014	45,750	15,330.42
15	3,910	0.021	68,625	22,505.95
20	5,453	0.028	91,500	29,861.00
25	6,919	0.035	114,375	37,360.89
30	8,326	0.042	137,250	44,975.79
35	9,691	0.049	160,125	52,677.56
40	11,029	0.056	183,000	60,441.30
321.4	86,339	0.450	1,470,536	497,428.85

For example, if the specialized household hired one laborer (600 work hours a quarter), it could raise five cows and supply 22,875 kilograms of milk, enough to fulfill 250 people's consumption demand (at the ration level 0.25 kg a day). If the household hired 9 laborers, then it could keep as many as 20 head and provide 91,500 kilograms to the city markets, and fulfill around one thousand people's milk consumption. If the household hired 18 laborers, it could expand dairy production to 40 head and provide 183,000 kg. milk.

Let's take Chengdu as an example. Chengdu is the capital of Sichuan Province with 2.5 million urban residents. Suppose 50 percent of the urban population have a tendency to consume milk at the current ration level 0.25 kg. a day. If some farmers in the suburban areas around Chengdu become dairy-specialized households, 1,247 dairy farms with 20 cows or 623 dairy farms with 40 cows would be able to provide milk to fulfill the demand for milk.

Sichuan's urban residents accounted for 11 percent of the provincial population of one hundred million (5, p. 1). Suppose 50 percent of urban residents, that is 5.5 million people, have a tendency to consume fluid milk, then 5,485 dairy households with 20 cows would be able to provide sufficient milk to meet the consumption demand. In other words, if 65,820 rural laborers, which only accounts for 0.2 percent of provincial rural laborers (33.4 million), engage in dairy production, they could provide enough milk to fulfill the provincial demand for milk consumption.

Meanwhile, the specialized households can make a great deal of profit when they expand dairy production. Therefore, we accept hypothesis 3, that dairy specialized households, with the help of hired labor, can considerably expand dairy production scale, and make a great contribution to the milk supply.

Summary

This section has presented a review of linear programming findings from Model I to Model V. The programming results of five models are summarized in Table 4.9. The table gives livestock production levels, land and labor input levels, milk supplies and functional values of each model.

We have already tested and accepted hypotheses 1-3. In the discussion that follows, we will evaluate hypotheses 4-6.

Discussion of the Policy Implications of the Findings

This section attempts to analyze the findings presented in the last section and to formulate some general conclusions from these results.

The impacts of dairy cattle production on land utilization

The introduction of dairy cattle production into the farm operation had significant impacts on land utilization and farm income.

When we shifted from Model I to Model III containing dairy cattle (both did not involve labor employment) the optimal solution indicated that the farmer should shift his concentration to the more profitable

Table 4.9. Summary of optimal solutions for five models based on Farm E

	Model I	Model II	Model III	Model IV	Model V (cattle=40)
Functional value (Y)	3,706.43	3,908.26	5,706.80	12,043.55	60,441.30
Land use (ha)	0.45	0.45	0.26	0.45	0.06
Labor input (hrs.)					
Quarter 1	1,217	1,800	1,510	4,288	12,829
Quarter 2	1,800	2,382	1,800	4,800	12,829
Quarter 3	1,745	2,011	1,629	4,435	12,829
Quarter 4	1,800	2,246	11,800	4,668	12,829
Livestock production					
Dairy cattle (head)	0	0	2.4	7.3	40
Dairy goats (head)	3.7	7.7	0	0	0
Hog 2 (litter)	0.6	0	0	0	0
Hog 11 (head)	0	0	0.8	0	0
Milk output (kg.)	2,762	5,774	11,104	33,284	183,000

cattle production, replacing crop production to the degree at which the farmer could still meet the requirements of the state's procurements and the family consumption.

However, since family labor was so limited, the farmer became too busy to take care of the crop production and land utilized decreased from 0.44 ha to 0.25 ha. It is evident that if the farmer attempted to complete rotation cycles while taking good care of his livestocks, family labor could not meet peak demands in quarters two and four. Either crop yields would decline, or cultivated land would decrease.

On the other hand, for populous areas like Chengdu Plain, farmland is so valuable that the result stated above is paradoxical and unrealistic. However, if farmers have the freedom to enter or exit occupations and tend to shift their attention to the more profitable enterprises, the breaking away from crop production will be inevitable. This gives rise to an important policy concern: nonmarket land transfer.

Under the responsibility system, farmers have the usufruct of contracted land, but the land cannot be let, bought or sold by farmers. Historically, land was regarded as the most critical means of production, and wealthy people had a strong inclination to accumulate land. The ownership and distribution of land, therefore, has always been at the crux of social contradiction and political struggle. This is the major reason why the Chinese government still insists on the public ownership of land in the course of promoting rural prosperity

while preventing the "antagonistic contradiction" between social production and the private ownership of land.

The land has been also regarded as a kind of social insurance. Farmers think that they may meet with natural disasters this year, but they will still reap a good harvest the next year as long as they have the land to till. The dilemma is that if the land continues to be contracted equally, and any market transfer of the contracted land is illegal, then rural sideline development will never evolve and China will never get rid of the limitations of a self-sufficient small-scale peasant economy.

Two possible solutions provide a way out of the land problem obstructing the expansion of dairy production. One is to readjust the contracted land by allowing farmers who are willing to specialize in dairy production or other sideline occupations to return their farmland to the collective, while encouraging some farmers who are good at farming to enlarge their grain and cotten production. The state's grain procurements from sideline specialized households are to be canceled simultaneously.

The second way is for dairy specialized households to transfer the concession of using contracted land to crop specialized households by signing crop-share leases privately. The dairymen may contribute the rest the cost of crop production. The cropmen are responsible for the taxes, quota sales of grain, and a levies for collective distributions; they must also provide grain for the dairymen's consumption. The dairy

specialized households are then completely free to pursue dairy production.

The impacts of dairy cattle production on other animal production

Before examining the effects of introduction of dairy cattle on the farm's production of other animals, we developed three enterprise budgets for dairy cattle, dairy goat and hog production (see Table 4.10, Table 4.11, and Table 4.12). The formation of these budgets are based upon the assumption that farmers make use of only their own family labor. Feed cost estimates are based upon Model I and Model III. These enterprise budgets represented an estimate of the actual combination of inputs and resulting output per unit of livestock enterprise.

On the basis of existing price regimes, the enterprise budgets all indicated positive net returns. The various livestock systems included in this study, therefore, are all potential sources of supplementary income for farmers in the intensively cultivated areas in Sichuan Province.

However, the introduction of dairy cattle production crowded out the other animal production. For this reason, we need to study further the economic returns of each enterprise per unit of labor input which was the most critical constraint in our LP model.

Based upon the enterprise budgets of dairy cattle, dairy goat and hog production, the comparisons of nonlabor net returns of each enterprise per unit of labor input are presented by Table 4.13.

Table 4.10. Enterprise budget for dairy cattle production

	Unit	Price or cost/unit	Quantity	Value or cost (yuan)
Gross receipts from production				
Milk	kg.	0.40	4,575.0	1,830.00
Benefit that farmers can make by selling premium maize on free market[a]		0.17	2,287.5	388.88
Male calf slaughtered at birth	head	30.00	0.5	15.00
Female calf weaned	head	160.00	0.5	80.00
Total				2,313.88
Costs				
Feed[b]	kg.			129.23
50% probability of feeding female calf with 235 kg. milk	kg.	0.40	235/2	47.00
Depreciation of cattle (purchase expenditures on a heifer over 8 years 2,200/8 - cull value of a cow over 8 years 600/8	animal	200.00	1.0	200.00
Servicing	animal	5.00	1.0	5.00
Medicine	animal	9.00	1.0	9.00
Death loss	animal	1.66	1.0	1.66
Total costs				391.89
Net returns above specified costs				1,921.99

[a]The free market price of maize is 0.40 yuan per kg. and the state subsidized price to the farmer is 0.23 yuan per kg. so the benefit is 0.17 per kg.

[b]See Table A.12.

Table 4.11. Enterprise budget for dairy goat production

	Unit	Price or cost/unit	Quantity	Value or cost (yuan)
Gross receipts from production				
Milk	kg.	0.30	750.00	225.00
Benefit that farmers make by selling premium maize on free market[a]	kg.	0.17	375.00	63.75
Kids	head	25.00	2.00	50.00
Total				338.75
Costs				
Milk for feeding two kids	kg.	0.30	150.00	45.00
Feeds[b]	kg.			32.10
Depreciation (cost of yearling kid at 70 over 7 years - cull value 18.9)	animal	7.30	1.00	7.30
Servicing, death loss	animal	1.03	1.00	1.03
Total Costs				85.43
Net returns above specified costs				253.32

[a]See note of Table 4.11.

[b]See Table A.12.

Table 4.12. Enterprise budget for fat hog production

	Unit	Price or cost/unit	Quantity	Value or cost (yuan)
Gross receipts from production				
Hog	kg.	1.24	75.00	93.00
Benefit that farmers make by selling premium maize on free market[a]	kg.	0.17	75.00	12.75
Total				105.75
Costs				
Feeds[b]	kg.			34.02
Weaned piglet	head	25.00	1.00	25.00
Monthly cost of a hog	animal	2.83	6.00	16.98
Total Costs				76.00
Net returns above specified costs				29.75

[a]See note of Table 4.11.

[b]See Table A.12.

Table 4.13. The comparisons of average net returns of animal enterprises per unit of labor input

Enterprise	Output	Quantity of output (kg.)	Net Returns (yuan)	Labor Requirements (hrs.)	Net Return per unit of labor (yuan/hr.)	Wage of hired labor (yuan/hr.)
Dairy Cattle	Milk	4,575	1,921.99	2,184.0	0.88	0.40
Dairy Goat	Milk	750	253.32	800.0	0.34	0.40
Hog	Hog	75 (liveweight)	29.75	194.4	0.15	0.40

According to these comparisons, we now can explain the impacts of introducing dairy cattle on other livestock production.

When the farmers began to introduce dairy cattle to their farms, dairy goats were crowded out because of their competition with dairy cattle for feedstuffs and labor, while hogs were kept because they were not as labor intensive as dairy goats (Table 4.11) and could take advantage of feeds not needed for the dairy cattle ration. However, when the farmer expanded dairy cattle production by hiring nonfarm labor, both goats and hogs were crowded out of the farm plan because their net returns to labor input were less than the wage rate of hired labor.

The fact that the net returns to hired labor varied substantially from one livestock enterprise to another conforms to actual farmer experience in China. Farmers have a saying that "raising hogs does not make a profit; it only makes you happy when you look back." The continuous increase of hog production (Figure 1.4) over the last three decades does not imply the high profitability of hog farming and farmers; particular interest in hog production, but rather the government's continuous administrative incentives.

The fact that dairy cattle were the most profitable livestock enterprise strongly suggests a move out of other animal production. However, other factors may also impinge on the farmers' choices of livestock activities. For this reason, further investigative step for each animal is needed.

Swine Hog production is currently the most important sector of China's livestock economy. China's 350 million swine represent over 40 percent of the world's total, while the 50 million head found in Sichuan Province represent 15 percent of the nation's total (22, p. 80). The Chinese government has never slackened its efforts to production because hogs provide China with 80 to 90 percent of the red meat consumed per capita per year. They also represent an important source of farm income and are a major contributor to the manure supply used in crop production.

The major constraint to swine production is the limited feed supply. Before the introduction of the responsibility system, farmers did not generally have much grain reserved for hog feeding. Instead, concentrate feeds used in swine production were mostly byproducts of rice or wheat milling. These were sufficient to provide only a portion of the total feed necessary to finish pigs to market weight. Therefore, the state's subsidy of concentrate feeds applies primarily to hogs.

The impact of cattle production on hogs, in this study, depends primarily on two factors: feed availability and the labor supply.

In Model III, the farmer kept raising hogs as long as cattle production was limited by the family labor supply. Evidently, if the farmer raised only two head of cattle, he still had surplus family labor and a lot of feedstuffs. He could raise a hog to utilize the feedstuffs that did not go into the cattle's rations.

By contrast, in Model IV, when the farmer expanded cattle production by hiring labor, hog production dropped out of the optimal solution. As long as the farmer faced constraints on labor employment and feed supply, he would not be willing to keep hog production, which took away labor from the more profitable dairy cattle enterprise.

We concluded that combined dairy cattle and hog production could be compatible if cattle production were limited to a small scale. For example, in Model III, the combination of two dairy cattle and one hog would be more profitable than three head of cattle (Table 4.6). However, the large-scale dairy production tended to crowd out hog production.

Dairy goat Although dairy goats were much less productive in terms of milk, several goats (3 to 5) in place of a cow would have several advantages.

Early physiological maturity Because of their early maturity, dairy goats produce returns more rapidly than cattle. The offtake of milk from goats occurs at between 9 and 15 months of age with for cattle offtake does not begin before 3 to 4 years (9).

Rapid reproduction This faster reproduction rate, ability to produce greater number of twin births, and more rapid growth enable goats to produce milk on an annual basis and to increase in numbers faster than cattle.

Small investment Initial investment per animal are small; thus, the loss of an individual animal has less impact on family

welfare than loss of a cow. Also, initial investment per animal is lower.

Low demand for concentrate feeds An additional advantage of dairy goats is their ability to withstand difficult environmental conditions and thus low demand for concentrate feeds.

Nevertheless, the critical fact that dairy goats are much less profitable forces them to give way to dairy cattle production for farmers with adequate investment capital, concentrate feed, and length of production horizon.

Summary The introduction of dairy cattle production, especially large scale cattle production tended to crowd out other livestock activities because of its significantly greater profitability. It should be borne in mind that an optimal strategy of animal production should be based upon local conditions according to the principle of comparative advantage. Although we believe that the location and resource endowments of Region V make it most suitable for dairy production, final confirmation must await further studies of optimal production patterns in the rest of Sichuan Province.

Several suggesting flow from the above discussion:

1) Because dairy cattle and dairy goats offer the higher returns to labor, farmers who have access to the necessary feed supplies, capital availability, labor supply, and techniques can be advised to undertake and/or expand dairy operations.

2) Ideally, dairy farmers should be located near urban markets or state dairies in order to gain ready sales outlets and necessary

veterinary and technical services. On the other hand, increasing nonfarm employment opportunities in urban centers may have a countervailing unfavorable impact on dairy production. Farmers near urban areas can likely make more profit by undertaking vegetable planting, commercial enterprises and small-scale industries. For this reason, it is strongly suggested that in areas near large cities, dairy goats not be kept because of uncompetitive returns. In addition, it is not advisable to keep both dairy cattle and dairy goat production because of the competition for available forage resources (see Table A.12) and labor supply.

Meanwhile, dairy goats are expected to play an important role in efforts to increase milk output in places where (a) feed resources on farms are inadequate to support a lactating cow, (b) farmers do not have enough money to purchase an expensive dairy calf, (c) farmers do not have the basic ability to manage a cow (children and women can manage goats more easily), (d) farmers do not have much time to take care of a labor-intensive cow when they engage mainly in crop production.

3) Swine and meat goats require little labor and are therefore very attractive to families with intensive cropping activities and hence limited time for livestock operations. For the farmers with a large amount of surplus grain in particular, fairly large scale hog production could be feasible and profitable.

The significance of free labor employment

The impacts of labor employment on dairy production were one of the most important results from the LP operation.

Because of the labor intensivity of Sichuan's agriculture, labor availability is always a constraint on both crop production and livestock production, no matter whether the cattle activity is int he model or not. In the basic model, the labor supply limited dairy goat and swine production. In the expanded Model III involving dairy dattle production, the labor supply constrainted the expansion of cattle production. Therefore, labor availability became an extreme critical factor in each model.

This signal shortage of labor availability in the populous Sichuan Basis seems to be illogical. The major reason is the low degree of mechanization.

Machines capable of replacing labor devoted to irrigation, plowing, transport, harvesting, milking, and so on can definitely eliminate seasonal bottlenecks that limit the performance of mixed crop-livestock production patterns. Mechanical innovation, unfortunately, is often handicapped by 1) the lack of a farm-machinery industry capable of supplying suitable equipment to the countryside, 2) the lack of refined fuels or a rural electricity supply, and 3) high purchasing costs of machinery.

A free labor market policy would be a more reasonable way of eliminating labor shortage bottlenecks. In fact, China has tremendous unemployment. The government has adopted a series of measures over the last three decades to solve this serious socio-economic problem. These measures include practices, intensification of the cropping cycle, promotion of the rural-based industry and so on. However, the free labor market system was never permitted until last year. The major ideological argument is that a free labor market will lead to exploitation of hired labor and widen the income gap between the rich and the poor, leading to further class polarization. Therefore, according to Chinese economists, the government's policy should be to encourage the people to become well-off through their own labor, the income gap will be bridged, and the social goal of common prosperity will be achieved.

These arguments were so high-sounding that nobody dared to doubt them publicly. However, with the introduction of the production responsibility system, freedom of labor employment became more and more critical. Although some people, for example the farmers in our study, are anxious to hire labor to expand their enterprises, many surplus laborers cannot find a job. The free labor market system, which lines the demand and supply of labor, becomes absolutely imperative to economic efficiency and development.

There is no denying that the free labor employment may lead to a wider income gap, but so called "labor exploitation" is far from inevitable. The free labor hiring often makes the rich richer, but it can also make the poor rich. More important, the free labor employment can enable farmers to expand milk production and make greater contributions to everyone's economic well-being. In our model, the fact that when the farmer hired labor, either goat milk supply in the Model II (Table 4.3) or the cow milk supply in the Model IV (Table 4.7) increased considerably indicates the significance of free labor employment to the expansion of dairy production.

Milk pricing

The state uses a combination of prices and subsidies to control grain and animal production, while using a combination of prices and rationing to control consumption. These are the typical characteristics of a Soviet style economy.

In order to ensure the supply of the major commodities at low prices and stabilize the people's livelihood, the state buys from the farmers at fixed purchasing prices and sells to urban residents at lower prices. In addition, China has opened rural and urban free markets for farm products where farmers can sell their surplus agricultural and sideline products directly to consumers through bargaining on the free markets.

Since December 1978, in efforts to adjust the price ratio between farm products and industrial products, the state has substantially raised the purchasing prices for farm produce. The prices were raised by 22.1 percent in 1979, 7.1 percent in 1980, 5.9 percent in 1981 and 2.2 percent in 1982 (6, p. 19).

In Sichuan Province, the prices of milk products have also been raised. The retail price of milk was increased from ¥ 0.52 in 1979 to ¥ 0.62 in 1982 per kg., with all the increase going to the producer (17, p. 56). Farmgate prices were ¥ 0.40.

The question is, would a further increase in milk purchasing price stimulate the milk supply? In other words, is the low milk purchasing price a major obstacle to the expansion of milk production? To assess the impact of price changes on dairy farming, parametric programming was conducted on Farm E in Model IV. The same parametric programming for Model III and Model V was also conducted but eliminated because the results were not significant. Table 4.14 and Figure 4.3 provide useful insight into the sensitivity of Model IV when milk purchasing price was changed.

The parametric operations revealed that milk supply was very insensitive to price changes at the farmgate. The optimal mix of crop and dairy cattle production remained unchanged within the price range between ¥ 0.2 and ¥ 0.45. This meant that even if the milk purchasing price increased by 12.5 percent or decreased by 50 percent, the dairy

Table 4.14. The results of parametric programming of price changes

Milk Price	Land Use	Cattle	Milk Supply	Functional Value
0.1	0.45	0.0	0.0	3,748.55
0.2	0.45	7.3	33,284	5,273.97
0.3	0.45	7.3	33,284	8,658.76
0.4	0.45	7.3	33,284	12,043.55
0.45	0.45	7.3	33,284	12,735.94
0.50	0.26	7.9	36,241	15,511.23
0.60	0.26	7.9	36,241	19,196.70
0.70	0.26	7.9	36,241	22,882.16

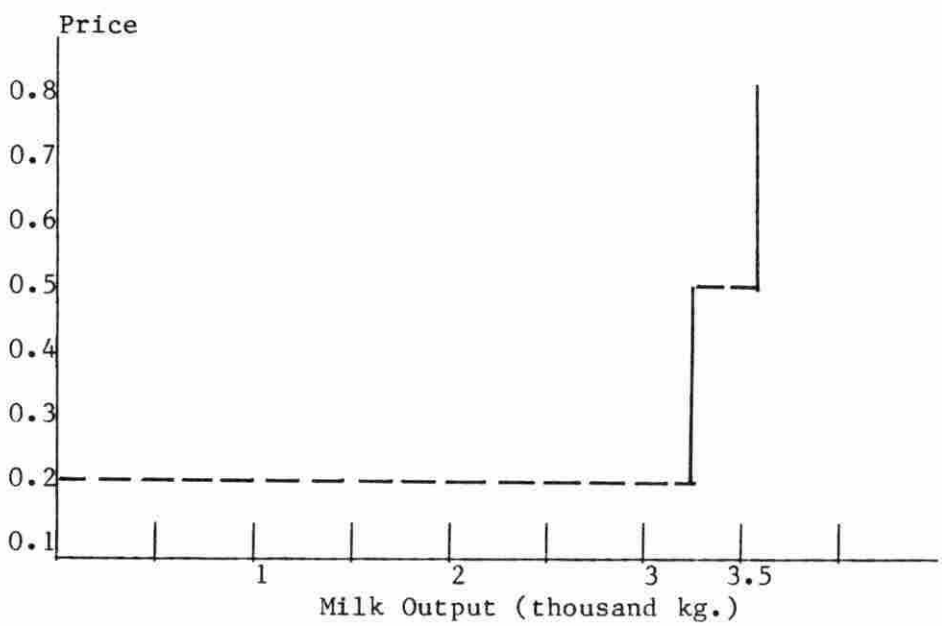

Figure 4.3 Supply curve of cattle milk of Model IV

farming scale still remained the same. Only when the dairy purchasing price increased to ¥ 0.50 per kg., would dairy production increase slightly, with a resultant huge reduction in crop area, from 0.44 ha to 0.26 ha. This result suggests that only when the milk price was increased up to ¥ 0.50, will farmers be willing to expand milk production at the cost of reduction of crop cultivation, when labor supply is limited. Therefore, we may reject hypothesis 4 that the slight increase in milk purchasing price will lead to a great jump in the milk supply.

Contrary to the decrease in milk price, Table 4.14 indicates that the increase in milk price would make it more profitable for farmers to raise dairy cattle. Given the large unsatisfied demand for milk at present, this high profitability would attract more farmers in aggregate to engage in dairy production.

But on the other hand, the increase in milk price will give rise to a more serious subsidy problem. Suppose the government tried to raise the milk purchasing price to expand milk production while keeping all retail price relatively low and stable for milk purchased. Under the ration or coupon allocation, the government had to spend more money on milk subsidy. In fact, subsidies for grain, edible oil, vegetables, meat, milk, eggs and coal for household use in 1982 exceeded 20,000 million yuan in China, close to 10 percent of the total volume of retail sales (7, p. 21). It is obvious that continued and huge

subsidies are not the basic way to stabilize prices, and the artificial pricing system may create inefficiencies in the economy by sending the wrong signals to farmers.

Therefore, the local government should not raise milk purchasing price by subsidizing the state's milk distributors. Rather, it should consider dismantling the Soviet style price system and gradually leave the prices of milk products to be determined by market demand and supply, even though not all kinds of subsidy can be abolished for the time being.

Government supports

We have shown that a freer market for labor could play a key role in the expansion of dairy farming, and the artificial price system may distort farm efficiency. But there are still other important policy implications that the present study can point out to government planners.

State feed grain subsidies To determine the effect of the government's concentrate feed subsidy on dairy farming, we modified Model IV by dropping the concentrate subsidy out of the model. The results are presented by Table 4.15.

Table 4.15. Effect of government grain subsidy on cattle production

	Land Used (ha)	Loan (yuan)	Cattle (head)	Milk Supply (kg)	Functional Value (yuan)
With Subsidy	0.45	0.00	7.3	33,284	12,043.55
Without Subsidy	0.45	0.00	7.3	33,284	9,139.33

Clearly, dropping the state subsidy system had no impacts upon cattle production except the functional value. If the government subsidy is phased out, the farmers will still keep the same scale of cattle production, because the subsidy concentrate (maize in our models) is not a key nutrient. In fact, maize did not even figure in the optimal dairy ration. Paradoxically, the state's subsidy does encourage farmers to engage in dairy production, because farmers can benefit by purchasing subsidized grain and selling it on the free market at higher price. In our models, the free market price of maize is ¥ 0.40 per kg. and the state price to the farmers is ¥ 0.23 per kg., so the benefit is ¥ 0.17 per kg. The same programming was conducted for Model III and Model V, the conclusions were the same: state subsidy of concentrate feeds was only a kind of income transfer from the government to individual farmers.

Therefore, we may reject the hypothesis 5 that there is a significant relationship between the state feed-bonus system and dairy ruminant production. Cancellation of the state's premium concentrate program would not bring about a significant decline in dairy production.

Credit It was not necessary for Farmer E to make use of government credit in any model formulation. This result may be attributed to the high profitability of, and steady seasonal returns to, dairy production. Contrary to the case of crop cultivation, farmers raising dairy ruminants can get returns immediately when they sell milk; hence, they enjoy a stable flow of income.

Nevertheless, although we rejected hypothesis 6 that the government's credit supply has important driving effects on dairy production, we need to point out that, and one of the deterrents to index use of credit is the high interest rates, in practice, some farmers may desire the government's credit to expand dairy production to a large scale or adapt some modern equipment for dairy production, and some farmers beginning in the dairy production may need to be backstopped by governmental financial supports. Therefore, the local government in Sichuan Province should take a major role in making credit available and in keeping the interest rates as low as possible without actually being subsidized.

Technical support network Since farmers in the intensively cropped areas do not have a long tradition of managing dairy cattle, substantial additional training and guidance in dairying would be very desirable. Technical information and services in China are transferred to the producer through the government support network, which extends information from provincial bureaus to township-level technicians. The strength of this network will be an important factor in efforts to increase milk production in the province.

Milk marketing Since milk consists mostly of water (up to 90 percent) and is highly perishable, improvements in milk collecting and transportation in the urban areas would free farmer's minds of the current risks of milk marketing and induce them to expand milk production. At the same time in remote areas, small-scale processing and packaging facilities should be promoted to pasteurize milk for sale to the rural population, or to make cheese and butter for sale to the urban population.

Specialization in dairying production

Following the popularization of the responsibility system, households specializing in one kind of production have emerged in the countryside. These are households which engage in a specialized trade instead of farming, such as fish, hens or cattle production, food processing, commerce and transportation.

The significance of specialization can be evaluated as follows:

1) Specialization of production permits rural labor as well as land to be utilized efficiently.

2) Specialization impels farmers to master the techniques of their field of specialization and promote productivity.

3) Specialization helps raise the farmers' income and promote the efficient division of labor.

In our study, specialization in dairy production has been shown to have the potential of boosting the milk supply and increasing considerably the income of specialized households.

The shift from farming to specialized trade poses no danger to the output of grain. While the number of specialized households have increased significantly, grain output of Sichuan Province has increased from 31.4 million tons in 1978 to 40 tons in 1983 (27, p. 28). One of the reasons is that the transfer of contracted land gives the "grain specialized households" greater latitude in grain production and enables farmers to adopt small-scale farming machinery to promote productive efficiency.

On the other hand, the dairy specialized households need more feed supply, more capital requirements, more housing and feed storage facilities, more management training, and government technical support. Despite these multiple requirements, dairy specialization will represent an important feature of the expansion of milk production.

Therefore, we accept the hypothesis three that specialization in dairy cattle production will improve significantly the milk supply and help raise farmer's income.

CHAPTER V. SUMMARY AND CONCLUSIONS

Summary

This study has been an attempt to investigate the development potential of dairy production in intensively cultivated areas of Sichuan Province. The first chapter gave a brief introduction to China's potential for livestock development, current nutrient availability to humans, the importance of dairy production, and the physical resources and dairy production systems in Sichuan Province. The scope of the study was limited to the intensively cropped areas in Sichuan Province. Pastoral dairy production was not considered.

The objectives of the study included identification of biological and nonbiological factors influencing the expansion of dairy production; basic study of optimal resource allocation of farmer households with and without dairy production; identification of the impacts of dairy production on farmers' business behavior and income; examination of the impacts of free labor employment on the expansion of dairy production; investigation of dairy specialization; and analysis of government policies with regard to the expansion of dairy production.

A series of hypotheses were developed to guide linear programming analysis:

1. The introduction of dairy cattle production to the farms has positive impacts on family labor utilization and farm income.

2. There is a positive relationship between the abandonment of legal limitations on the hiring of labor and grain and animal production.

3. Specialization in dairy cattle production will improve significantly the milk supply and help raise farmers' income.

4. A slight increase in milk purchasing price will lead to a great increase in milk supply.

5. There is a significant relationship between the state feed-bonus system and dairy ruminant production.

6. The government's credit supply has an important driving effect on dairy production.

Chapter II reviewed the literature concerning dairy production. The review mainly covered the studies of dairy production on a world-wide basis, the recent Chinese literature on animal production since 1978, and empirical study conducted by Winrock International in 1982.

Chapter III reviewed the factors affecting dairy production in intensively arable areas in Sichuan Province. Chapter III also presented the description of linear programming model, the empirical technique used to estimate the influences of factors on dairy production.

Chapter IV reported the findings of the linear programming analysis and the discussion of the policy implications of the findings. Hypotheses 1, 2, 3 were accepted, while hypotheses 4, 5, and 6 were rejected. The results of hypotheses tests indicated that the Sichuan local government needs further improvement of the policies concerning dairy production.

Conclusions

Because of an over-emphasis upon the grain production, shortages of dairy products are still common in China, and many people are on "short rations" of animal protein. The same situation applies in Sichuan Province, where milk supplies have not kept pace with rising levels of demand. Unless the dairy industry is developed, shortages are likely to continue.

Sichuan has a highly diversified environment, ranging from high mountains in the west part to plains in the east. Livestock production systems range from traditional to modern, from state farms to individual households, from extensive to intensive. This study does not attempt at comprehensive analysis, but concentrates on the intensively-cropped areas in Sichuan Basin.

Human population and land pressures necessitate the expansion of dairy livestock production in intensively-cropped areas. Dairy ruminants in these areas provide a good opportunity for expanding milk

supply because of abundant feedstuffs and labor supply. Consequently, the potential of dairy expanded production in mixed crop-animal areas needs to be more effectively exploited if the burgeoning demand for milk it to be satisified.

Dairy production has a number of advantages, such as transforming coarse, high-fiber materials into a more valuable finished products; enhancing soil fertility; helping to raise farmers' incomes and absorbing rural surplus labor. Yet, dairy production also involves expensive investment, heavy risks and special skills.

While the expansion of dairy production in intensively cropped areas is technically feasible, a number of nonbiological factors may impede sizable expansion of dairy production unless they receive serious attention. Some of the most important constraints that inhibit expansion of dairy animal production are association with labor availability, pricing system, land tenure, and government policies.

Labor availability is the most critical constraint on the expansion of dairy production. Although dairy production is very profitable, the sizable expansion is often handicapped by shortages of labor. A free labor market system could eliminate this bottleneck to dairy expansion.

Transfer of contracted land is inevitable if some farmers expand their animal production. The recent legalization of the transfer of

land concession will encourage farmers to expand dairy production and promote dairy specialization.

Despite the importance of markets and market response on production, the government maintains policies that are often unfavorable to the dairy production. The fixed price system often puts the government in a dilemma of short supply and huge subsidies. A price-efficient marketing system should be constructed in which farmers are able to readily modify their allocation of farm resources and supply of products in response to price signals.

The local government needs to adjust its development policies of dairy production. Instead of controlling the price system and labor employment, the government should pay more attention to genetic improvement of dairy ruminants, farmer training, and technical services.

Dairy specialization can significantly increase milk supply to urban areas and help raise farmers' incomes. Although it involves more capital investment, more feed supply and more technical requirements, it will represent an important trend in dairy development.

The expansion of dairy production in intensively-cultivated areas, especially in places near large cities, may have unfavorable impacts on other livestock production. This suggests rational distribution of animal production according to the local resources and marketing conditions. Ideally, dairy farmers would be located near to urban

markets or state dairies in order to gain ready access to markets and necessary veterinary and technical services.

A goal for Sichuan Province is the doubling of milk production from the level of 142,000 MT in 1981 by the year 1990. Most of this additional milk will come from cattle in the intensive farming areas. If the government continues its reform program in rural areas, modifies policies concerning dairy production, and makes continuous efforts to improve dairy technology and infrastructure, the prospects for growth in dairy production are propitious.

BIBLIOGRAPHY

1. Asian Productivity Organization. Livestock Production in Asian Context of Agricultural Diversification. Hong Kong: Nordica International Limited, 1976. 361 pp.

2. Barker, Tandolph and Radah Sinha (Eds.). The Chinese Agricultural Economy. Boulder, Colorado: Westview Press, 1982. 266 pp.

3. Beneke, Raymond R. and Ronald D. Winterboer. Linear Programming Application to Agriculture. Ames, Iowa: Iowa State University Press, 1973. 244 pp.

4. Bogart, Ralph and Robert E. Taylor. Scientific Farm Animal Production. 2nd ed. Minneapolis, Minnesota: Burgess Publishing Company, 1983. 415 pp.

5. Chengdu Institute of Geography. Agricultural Geography of Sichuan. Chengdu, Sichuan: Sichuan People's Press, 1980. 262 pp.

6. Cheng, Zhiping. "Basic Stability of Market Prices." Beijing Review, No. 35 (August 29, 1983), 21-24.

7. Dai, Yuanchen. "Different Price for Farm Products." Beijing Review, No. 35 (August 29, 1983), 21-24.

8. Hoefer, J. A. and P. J. Tsuchitani (Eds.). Animal Agriculture in China. Washington, D.C.: National Academy Press, 1980. 197 pp.

9. Liu, Yinwu. "Develop Dairy Goat Production to Solve the Protein Insufficiency Problem." Guangming Ribao, 24 February, 1984, p. 3.

10. Lu, Baifu. "Chinese-type Modernization: The Way for Agriculture." Beijing Review, No. 4 (24 January 1983), 14-21.

11. Lu, Dong. "China's Industry on the Upswing." Bejing Review, No. 35 (27 August 1984), 18-21.

12. Niu, Ruofeng and Liu Tianfu (Eds.). Handbook of Agricultural Technology Economics. Peking: Agricultural Publishing House of China, 1983. 1050 pp.

13. Maxwell, Neville and Bruce McFarlane (Eds.). China's Changed Road to Development. New York: Pergamon Press, 1984. 232 pp.

14. Pfaffengerger, Roger C. and David A. Walker. Mathematical Programming for Economics and Business. Ames, Iowa: The Iowa State University Press, 1976. 462 pp.

15. Piazza, Alan. Trends in Food and Nutrient Availability in China, 1950-1981. Washington, D.C.: The World Bank, 1983. 125 pp.

16. Politiek, R. D. and J. J. Bakker (Eds.). Livestock Production in Europe, Perspectives and Prospects. New York: Elsevier Scientific Publishing Company, 1982. 335 pp.

17. Research Institute of Agricultural Economics, The Chinese Agricultural Academy of Sciences. Selections of Economic Research Papers on Animal Husbandry. Peking: Social Science Press, 1982. 207 pp.

18. Simpson, James R. and Phylo Evangelow (Eds.). Livestock Development in Subsaharan Africa. Boulder, Colorado: Westview Press, 1984. 407 pp.

19. Tregear, T. R. An Economic Geography of China. London: Butterworth and Co. Ltd, 1970. 276 pp.

20. Wang, Qingyi and Gu Jian. "How Will China Solve Energy Problems?" Beijing Review, No. 35 (26 December 1983), 13-35.

21. Winrock International. Ruminant Livestock in Intensive Agricultural Areas of Sichuan, China: Current Status and Development Prospects. Morrilton, Arkansas: Winrock International, 1982. 199 pp.

22. Winrock International. The Role of Ruminants in Support of Man. Morrilton, Arkansas: Winrock International, 1978. 136 pp.

23. Yousef, Mohamed K. (Ed.) Animal Production in the Tropics, New York: Praeger Publishers, 1982. 376 pp.

24. Zhang, Zhongji. "China's Economy: Achievements in 1983." Beijing Review, No. 8 (20 February 1984), 14-20.

25. Zhongguo Nongye Nianjian 1981 (Agricultural Yearbook of China 1981). Peking: Agricultural Publishing House of China, 1981. 646 pp.

26. Zhongguo Nongye Nianjian 1982 (Agricultural Yearbook of China 1982). Peking: Agricultural Publishing House of China, 1982. 578 pp.

27. Zhou, Zheng. "Sichuan--Land of Abundance." Beijing Review, No. 31 (30 July 1984), 22-29.

ACKNOWLEDGEMENTS

I would like first to thank my major professor, Dr. Peter H. Calkins, for his helpful criticism and suggestions throughout this study and for his guidance during my M.S. graduate program.

I would also like to extend my appreciation to the other members of my graduate committee: Dr. Raymond R. Beneke and Dr. Roy D. Hickman for their suggestions.

Special thanks go to Dr. A. J. De Boer, agricultural economist, Winrock International Livestock Research and Training Center, for his help in formulating the LP models and for funding part of this study.

Appreciation is also extended to Dawn Baksh for typing this report and for assistance in checking it for errors.

APPENDIX A. MISCELLANEOUS TABLES

Table A.1. Adequacy of per capita daily energy and protein availability (15)

Year	Total Energy (KCal)	Energy as of % of Requirements[a]	NPU[b] (g)	NPU as of % of Requirement[c]
1950	1613.98	74.72	22.68	91.47
1951	1723.68	79.80	24.01	96.81
1952	1916.89	88.74	27.98	112.82
1953	1923.63	89.06	26.77	107.96
1954	1927.47	89.23	26.95	108.66
1955	2031.36	94.04	28.05	113.10
1956	2073.37	95.99	28.28	114.02
1957	2064.61	95.58	29.80	120.15
1958	2071.90	95.92	28.44	114.68
1959	1736.81	80.41	14.31	98.04
1960	1462.32	67.70	20.74	83.64
1961	1568.62	72.62	22.24	89.68
1962	1678.59	77.71	23.62	95.25
1963	1802.57	83.45	24.38	98.32
1964	1965.51	91.00	26.39	106.40
1965	1996.55	92.43	28.79	116.10
1966	2105.63	97.48	28.16	113.53
1967	2066.50	95.67	27.65	111.51
1968	1951.26	90.34	26.00	104.85
1969	1897.67	87.85	25.20	101.60
1970	2092.40	96.87	28.55	115.13
1971	2097.83	97.12	26.66	107.49
1972	2020.50	93.54	26.00	104.83
1973	2175.01	100.69	27.87	112.37
1974	2209.19	102.28	28.52	115.00
1975	2225.98	103.05	28.81	116.16
1976	2234.60	103.45	30.59	123.36
1977	2247.63	104.06	30.59	123.35
1978	2370.08	109.73	30.47	122.86
1979	2571.81	119.07	35.44	142.89
1980	2496.29	115.57	34.86	140.56
1981	2525.70	116.93	35.42	152.83

[a]According to an estimated 1979 energy requirement of 2,160 KCal/day.

[b]Net protein utilization (NPU) is a superior measure in that it accounts for both digestibility and amino acid profile. NPU is the product of digestibility and biological value.

[c]According to an estimated safe limit of protein intake of 24.8 g/day.

Table A.2. Per capita grain production and daily nutrient availability (15)

Year	Per Capita Grain Production KG/year	Total Energy (KCal)	Total Protein (g)	Total Fat (g)	Protein Animal Source (g)	Protein Vegetable Source (g)	Energy Animal Source (KCal)	Energy Vegetable Source (KCal)
1950	229	1613.98	42.21	19.72	2.74	40.47	58.52	1555.46
1951	245	1723.68	45.65	21.29	3.02	42.63	63.02	1660.67
1952	274	1916.89	52.03	24.44	3.48	48.55	73.45	1843.44
1953	273	1923.63	50.76	23.97	3.73	47.03	80.17	1843.46
1954	270	1927.47	50.90	24.66	3.98	46.92	84.11	1843.36
1955	288	2031.36	53.18	25.07	3.79	49.39	78.33	1953.02
1956	296	2073.37	53.59	24.75	3.66	49.92	72.61	2000.75
1957	293	2064.61	55.69	24.17	4.04	51.65	78.42	1986.19
1958	295	2071.90	54.80	25.87	4.18	50.61	92.10	1979.80
1959	248	1736.81	46.60	21.92	3.85	42.74	80.14	1656.66
1960	210	1462.32	39.70	15.75	3.16	36.54	57.92	1404.40
1961	217	1568.62	42.90	16.30	2.76	40.14	49.29	1519.32
1962	233	1678.59	45.69	16.76	2.78	42.91	49.59	1629.00
1963	243	1802.57	46.84	19.16	3.65	43.19	71.65	1730.92
1964	261	1965.51	50.66	21.86	4.09	46.57	84.98	1880.54
1965	264	1996.55	53.88	22.42	4.31	49.57	91.05	1905.50
1966	283	2105.63	54.03	23.19	4.45	49.59	95.30	2010.34
1967	281	2066.50	53.03	23.32	4.41	48.62	96.58	1969.92
1968	263	1951.26	49.84	22.23	4.16	45.68	92.50	1858.76
1969	258	1897.67	48.30	21.69	4.10	44.19	88.40	1809.27

1970	286	2092.40	52.70	22.91	4.14	48.56	86.08	2006.31
1971	291	2097.83	51.03	23.56	4.62	46.42	97.57	2000.26
1972	274	2020.50	49.49	23.84	4.92	44.57	107.31	1913.19
1973	296	2175.01	53.26	24.78	4.89	48.37	106.21	2068.80
1974	302	2209.19	54.53	24.55	4.88	49.65	104.16	2105.03
1975	308	2225.98	55.11	24.57	4.86	50.25	103.65	2122.34
1976	306	2234.60	56.54	23.97	4.76	51.78	102.62	2131.98
1977	299	2247.63	56.30	24.66	4.80	51.51	103.08	2144.55
1978	318	2370.08	58.29	25.39	4.99	53.30	109.31	2260.77
1979	343	2571.81	65.47	30.67	5.59	59.88	130.39	2441.42
1980	325	2496.29	64.05	32.54	6.10	57.96	144.35	2351.94
1981	328	2525.70	65.25	33.43	6.33	58.93	146.89	2378.81

Table A.3. Per capita availability of meats and other animal products (figures in kg per year) (15)

Year	Pork Beef & Mutton	Poultry Meats	Other Red Meats	Fish	Eggs	Milk	Animal Fats
1950	4.11	.88	.15	1.50	1.48	.92	.38
1951	4.44	.88	.15	2.15	1.43	.92	.41
1952	5.45	.88	.16	2.65	1.43	.92	.46
1953	5.97	.88	.16	2.95	1.43	.92	.54
1954	6.27	.88	.16	3.48	1.43	.92	.56
1955	5.45	.88	.17	3.75	1.43	.92	.58
1956	4.98	.88	.16	3.87	1.40	.92	.51
1957	5.66	.88	.16	4.46	1.38	.91	.48
1958	6.60	.88	.15	3.94	1.36	.91	.76
1959	5.17	.89	.15	4.29	1.44	.92	.71
1960	3.02	.91	.14	4.23	1.48	.94	.52
1961	2.57	.93	.14	3.23	1.53	.97	.38
1962	2.66	.94	.13	3.16	1.53	.98	.36
1963	5.06	.94	.13	3.54	1.52	.98	.43
1964	6.31	.93	.13	3.71	1.50	.97	.55
1965	6.88	.93	.13	3.85	1.49	.97	.59
1966	7.29.	.92	.13	3.90	1.47	.96	.63
1967	7.30	.92	.14	3.74	1.48	.96	.69
1968	7.00	.91	.14	3.24	1.47	.95	.66
1969	6.62	.91	.11	3.54	1.46	.94	.61
1970	6.72	.89	.09	3.61	1.45	.94	.49
1971	8.01	.89	.09	3.87	1.44	.93	.51
1972	8.70	.88	.08	4.16	1.45	.93	.65
1973	8.59	.88	.09	4.17	1.45	.93	.64
1974	8.29	.88	.11	4.47	1.45.	.94	.64
1975	8.16	.88	.10	4.53	1.46	.94	.65
1976	7.90	.89	.10	4.46	1.47	.96	.70
1977	7.84	.90	.10	4.62	1.48	.96	.72
1978	8.50	.89	.10	4.53	1.49	.98	.76
1979	10.46	.89	.09	4.13	1.68	1.31	.93
1980	11.64	.89	.08	4.26	1.98	1.34	1.05
1981	12.11	.90	.07	4.32	2.16	1.49	.95

Table A.4. Levels of consumption of animal products per capita in selected countries, 1981 (kg.) (12)

Country	Meat	Milk
World	31.55	104.85
Canada	99.60	331.95
China	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

Table A.5. Animal numbers in Sichuan Province, China, in millions (26)

	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 A.6. Meat and milk production in Sichuan Province (1000 m.t.) (21)

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.

Table A.7. Production cost and labor requirements for crop production for the selected farms in Sichuan Province (12, 21)

Cropping Pattern	Production Cost (yuan)	Labor Requirement (hrs.) Q1	Q2	Q3	Q4
A	473.61	584	2,823	1,554	1,029
B	473.61	584	2,823	1,554	1,029
C	676.89	588	2,824	3,414	2,428
D	379.48	584	1,897	1,054	1,592
E	379.48	584	1,897	1,054	1,592
F	412.28	585	2,005	1,685	1,469

Table A.8. Uses of crop products for selected farms in Sichuan Province (21)

Pattern and Crop	Output (kg)	State Tax (kg)	State Quota (kg)	Above Quota (kg)	Collective Retain (kg)	Family Consumption
A. (Annual C-row cost = Y473.61)						
Rice	1,620	129.6	113.4	162	48.6	675.2
Wheat	801.9	64.15	56.1	80.2	24.06	334.3
Broadbean (H)	7.3	0.6			0.22	3
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 = Y473.61)						
Rice	2,047.5	163.8	143.32	204.8	61.43	700.6
Wheat	900.9	72.1	63.06	90.1	27.03	308.3
Broadbean (H)	10.55	0.84			0.32	3.6
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 = Y676.89)						
Early rice	2,047	163.8	143.3	204.75	61.43	554.1
Late rice	731.3	58.5	51.9	73.13	21.94	197.9
Wheat	952.1	76.2	66.6	95.2	28.56	257.6
Rapeseed	15.8	1.3	1.1	1.58	0.47	
Broadbean (H)	10.55	0.8			0.32	2.87
Broadbean (F)	2,250					
Grass	1,950					

D. (Annual C-row cost = Y379.48)						
Maize	396	31.7	27.7	39.6	11.88	176.2
Sweet Potato	4,455	356.4				1982.2
Wheat	980.1	18.4	68.6	98	29.4	436.0
Rapeseed	9.9	0.8	0.7	1.0	0.3	
Broadbean (H)	8.9	0.7			0.27	4.0
Broadbean (F)	1,125					
Vetch	4,200					
Grass	1,650					
E. (Annual C-row cost = Y379.48)						
Maize	540	43.2	37.8	54	16.2	176.0
Sweet Potato	6,075	486			182.25	1982.5
Wheat	1,336.5	106.92	93.56	133.65	40.10	435.7
Rapeseed	13.5	1	0.9	1.35	0.41	
Broadbean (H)	12.15	1			0.36	4
Broadbean (F)	1,125					
Vetch	4,200					
Grass	2,250					
F. (Annual C-row cost = Y412.28)						
Maize	675	54	47.25	67.5	20.25	279.3
Sweet Potato	5,062.5	405			151.87	2094.8
Irish Potato	2,362.5	189			70.87	
Wheat	759.4	60.8	53.2	75.94	22.78	314.2
Broadbean (F)	56,250					
Grass	2,250					

Table A.9. Selected animal and animal product prices and entitlement formula of government subsidy (21)

Animal or animal product	State Price (yuan)	Free Market Price (yuan)	Entitlement Formula
Cattle milk (kg)	0.40	n.a.[a]	2 kg. milk = 1 kg. grain
Goat milk (kg)	0.30	n.a.	2 kg. milk = 1 kg. grain
Hogs (kg)	1.24	n.a.	1 kg. l w. = 1 kg. grain
Piglet (head)	n.a.	25.00	
Mutton (kg)	n.a.	1.40	

[a]n.a. = not applicable.

Table A.10. Production cost, land, and labor requirements for dairy production (12, 21)

Production Level	Production Cost yuan/year	Land req. (ha/qt)	Labor req. (hr/qt)	Production Level	Production Cost yuan/year	Land req. (ha/qt)	Labor req. (hr/qt)
1	167.66	0.0014	546	1-5	829.92	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	360	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.[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.

[a]n.a. = not applicable.

Table A.11. Price estimates for selected products in Sichuan, 1981 (yuan) (21)

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 (free market)	0.55-0.65/kg	Millet	0.32/kg
Maize (subsidized)	0.23/kg	Bashan bean	0.016/kg
Maize (above quota)	0.32/kg	Culled vegetable	0.016/kg
Maize (free market)	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

Table A.12. Selected feed rations and feed costs for dairy cattle, dairy goat and swine[a]

Animal	Maize stover	Grass	Ricebran	Rapeseed Oilcake	Vetch	Sweet Potato Vine	Feed Cost
Dairy Cattle 3	4,700.0	679.0	1,026.0	0.0	0.0	0.0	129.33
Dairy Goat 1	1,038.7	441.8	177.4	0.0	0.0	0.0	32.10
Hog 11	0.0	0.0	279.3	93.5	25.4	257.9	34.02

[a]Figures for dairy cattle and hog were based upon Model IV, while figure for dairy goat was modified Model 1.

APPENDIX B. LINEAR PROGRAMMING MATRICES

Table B.1. Matrix diagram of the LP model

	Crop Production		Livestock Raising		Grain and feed transfer	
Objective Function	$-c$ . . .	$-c$	$-c$ . . .	$-c$	. . . 0 . . .	
Resource	a_{ij}	a_{ij}	a_{ij}	a_{ij}		
Restraints	a_{ij}	a_{ij}	a_{ij}	a_{ij}		
Grain and Feed Pool	$-a_{ij}$	$-a_{ij}$			1 $-a_{ij}$	$-a_{ij}$
	$-a_{ij}$	$-a_{ij}$				1
Nutrient			a_{ij}	a_{ij}		
Pool			a_{ij}	a_{ij}		
Livestock Product Pool			$-a_{ij}$	$-a_{ij}$		
			$-a_{ij}$	$-a_{ij}$		
Subsidy						
Pool						
Bounds on						
Selling						
Lower Bounds on Consumption						
Bounds on						
and Hiring						

Nutrient Transfer	Buying Activities	Labor Hiring	Borrowing	Saving
. . 0 . .	-c . . -c	-c . . -c	-c . . -c	c . . c
		-1	-1 a_{ij}	1 $-a_{ij}$
			a_{ij}	$-a_{ij}$
		-1	-1	1
1	-1			
1	-1			
$-a_{ij}$				
$-a_{ij}$				
		1		
		1		

Table B.1 (Continued)

	Selling Grain or Feed	Grain Selling Quota or Above Quota	Selling Animal Products	Family Grain Consumption	RHS
Objective Function	c . . . c	c . . . c	c . . . c	. . 0 . .	
Resource					
					LB
Restraints					
Grain and Feed Pool	1	1		1	LO
	1	1		1	
Nutrient Pool					LO
Livestock Product Pool			1		
			1		
Subsidy Pool			$-a_{ij}$		LO
			$-a_{ij}$		
Bounds on Selling		1			GO
		1			
Lower Bounds on Consumption				1	GO
				1	
Bounds on and Hiring					EB