CHINESE-AMERICAN
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APPLICATION OF LINEAR PROGRAMMING TO CROP COMPETITION STUDY IN TAIWAN (WITH SPECIAL REFERENCE TO RICE AND SUGARCANE COMPETITION IN CENTRAL TAIWAN)

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in Central Taiwan)

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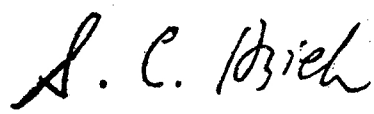
Foreword

Linear programming is a newly-developed technique by which we can determine which combination of inputs and outputs in production will yield the highest return or incur the lowest cost under certain specified assumptions and conditions. In recent years, this technique has been widely used in farm management and production economics research to deal with the problem of optimum resource allocation and regional analysis in agriculture. With the availability of the information of resource restriction, alternative productive processes and input-output coefficients, this technique can be applied effectively to solve the problems of optimum farm organization for return maximization or cost minimization through automatic mathematical calculation.

During the period from October 23, 1956 to September 20, 1957, I visited several universities and agricultural economics research institutions in the United States and Japan under the travel fellowship program of the Council on Economic and Cultural Affair at New York. I spent considerable amount of time during my stay in the American universities to study the method of linear programming, input-output studies and activity analysis as used in farm management and agricultural production economics research. The first draft of this paper was prepared in the Spring of 1957 with advice from Drs. G. A. Pond and S. A. Engene, Professors of Farm Management and Production Economics of the University of Minnesota. The present paper represents a final revision made after my return to Taiwan from the United States and Japan, and after receiving comment from Commissioners R. H. Davis and T. H. Chien of JCRR. The major purpose of this paper is to demonstrate how this modern technique of linear programming could be applied to analyze the crop competition problems in Taiwan. It is hoped that this paper will serve as a pioneer trial in the application of linear programming to agricultural economics research under Chinese agricultural conditions, and that further efforts will be made in the application and testing of this method in our agricultural economics research.

Taking this opportunity, I would like to express my sincere thanks to Drs. G. A. Pond and S. A. Engene of the University of Minnesota and Commissioners R.H. Davis and T.H. Chien of JCRR for their comments and criticisms on this paper, and to Drs. J. L. Buck and A. B. Lewis of the Council on Economic and Cultural Affairs for their arrangement and assistance in the grant of the travel fellowship program. Sin-

cere appreciation is also due Professor M. N. Soong and other Professors and senior students in the Department of Agricultural Economics of the Provincial Agricultural College at Taichung for their participation and assistance in the collection of the farm data for this analysis.



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CHAPTER I

PURPOSES OF THE STUDY

Since the use of arable land in Taiwan is approaching its maximum and too many farm families are working on the limited acreage of cultivated land, keen competition among crops has been in existance in the use of land on this island. This necessitates the rational allocation of land resource among crops on farms and the adoption of intensive cultivation. This situation is especially apparent in districts like Central Taiwan where irrigation facilities have been highly developed, the productivity of land is high, the farm villages are comparatively concentrated, and there is a surplus farm population.

There are two kinds of cultivated land used in Taiwan, paddy land and dry or unirrigated land. Normally, paddy land is used for the cultivation of rice which, supplemented by minor and winter crops, forms the basic rice cropping system. The dry land is used principally for the cultivation of sugarcane and sweet potatoes. Sugarcane cropping systems combine sugarcane with other plants as intercrops. When sugarcane is planted in the paddy land, its unit yield is substantially increased over that from dry land. Hence, if the price of sugar is favorable and if there is a positive margin between the additional return from the increased yield and the additional land and other costs, the farmers would tend to use their paddy land for sugarcane. The competition between rice and sugarcane in the use of paddy land is particularly keen in Central Taiwan, because the major portion of cultivated land in the district is paddy land.

There could be two approaches in making a study of rice and sugarcane competition. From the standpoint of public or national economy, the study would be chiefly concerned with the reasonable allocation of available paddy land for rice and sugarcane production, taking into consideration national interest in the relative contribution of the two crops. From the standpoint of the private or the farmer's economy, however, the study would be chiefly concerned with the farmer's choice of rice or sugarcane for their paddy land use in relation to the production conditions of their farms, uses of family labor and capital, their own requirements, and the relative profitableness of the two crops. This study is made entirely from the viewpoint of the individual farmer.

The nature of production of rice and sugarcane is quite different. Rice is grown mainly for farm family food and payment for land taxes in kind, while sugarcane is produced solely for sale. It is believed that aside from the factors of comparative costs and comparative returns, there are many other economic and non-economic factors and considerations influencing the farmers' choice of rice or sugarcane or combinations of the two. The objective in conducting the rice and sugarcane competition survey in Central Taiwan was, therefore, to investigate and ascertain the degree of importance of various influencing factors, such as comparative costs and comparative returns, sugar-rice price ratio*, cash expenditures in production, labor requirements and distribution, size of farm, and other economic and non-economic pressures in relation to rice and sugarcane competition in the use of paddy land in the district. The major purposes of this study are (1) to apply cost and income data as a basis for making an interpretation and analysis of the factors influencing farmers' choice of rice or sugarcane, and the possible responsiveness of farmers in the planting of rice and sugarcane which might be expected to follow changes in sugar-rice price ratios, and (2) to apply the limited input-output data and information as a basis for making an analysis of choice and cambination of rice and sugarcane cropping systems on individual farms for optimum allocation and efficient use of farmers' limited resources. The modern technique of linear programming is applied to solve the optimum farm organization problem. It is believed that this study will have value as (1) a source of practical information regarding important factors affecting the use of paddy land for rice or sugarcane, (2) an important reference in the making of production policy for efficient use of land resources, and (3) a guide to government officials and agricultural extension officials responsible for determining policy and carrying out farm extension work, especially with respect to the production of rice and sugarcane. Furthermore, this study will serve as a demonstration in the application of modern technique of linear programming to crop competition study in Taiwan and to explore the applicability of this technique under Chinese agricultural conditions.

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* Sugar-rice price ratio as used in this study is defined as the price of sugar divided by the price of rice. A sugar-rice price ratio of 1:1 means that the price of one unit of sugar equals the price of one unit of rice, while a ratio of 1:1.5 means that the price of one unit of sugar equals the price of 1.5 units of rice.

CHAPTER II

RICE AND SUGARCANE COMPETITION IN TAIWAN

Taiwan is an island geographically located on the sea southeast of Mainland China. The central and northern parts of Taiwan are in the semi-tropic zone, while its southern part is in the tropic zone. It has a total area of 35,961.2125 square kilometers and a population of 9,310,158 (excluding military) on September 16, 1956 according to a population census conducted by the Chinese government.

There were about 1,042 thousand hectares of cultivated land for agricultural use on the island in 1956 which was 29 percent of the total area. Because of the development of irrigation in Taiwan, 55 percent of cultivated land is paddy land, while the remaining 45 percent is dry land. Of the paddy land, about 60 percent is double cropping paddy land from which three crops are usually harvested in a year. Because of the improvements made in varieties and in farming practices, there has been increased use of paddy land in the winter. Many new crops like tobacco, wheat, vegetables and flax, are cultivated on paddy land in the winter, thus making full use of such land which was formerly left fallow in winter. These winter crops have increased considerably the farm income and will certainly have an important effect on the farmer's economy as well as crop competition. Some of the winter crops are planted through the "Hu-tze" planting method*, a method which is widely adopted in the Central Taiwan. As a result of this and the suitability of Taiwan's climate, the index of double cropping is quite high.

Although the cropping system in Taiwan is greatly diversified and a great variety of crops is planted on the island due to its favorable natural conditions, there are only about ten crops which are important from the viewpoint of Taiwan's economy. Of these ten, rice and sugarcane are by far the more important crops in the economy of the island.

In the pre-war years, half of the rice produced was consumed by its population of

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* The "Hu-tze" planting method, or interplanting method, is a practice of planting a crop in the field a few weeks before the harvest of the previous crop. For instance, fall-planted Hu-tze sugarcane is planted in late September before the harvest of the Fall rice crop.

about 6 millions, leaving about 700,000 metric tons for export to Japan. Only 5 percent of sugar produced was for domestic comsumption, while 900,000 metric tons was for export to Japan, the mainland of China, and other countries. Since the population in Taiwan has increased greatly after its restoration, the consumption of rice has also increased. Only about 115,000 metric tons of rice were exported annually in the period of 1954-56, which was about 6 percent of the annual rice production. Sugar has been the most important export item since Taiwan's restoration.

The main characteristic of rice production in Taiwan is the adoption of highly intensive methods of cultivation. Most of the double cropping paddy land in Taiwan produce two rice crops in a year, but in the Central Taiwan and Kaohsiung districts, a winter crop is generally planted in the double cropping paddy land in addition to the two rice crops. As the farm size in Taiwan is especially small, the only way for farmers to increase their farm income is to make intensive use of their paddy land and engage in intensive farming. Hence, the paddy land in Taiwan is not simply the land for growing rice, but rather a kind of farm land on which many other crops are added in the minor crop seasons in summer and winter.

The sugar industry in Taiwan is dependent on foreign markets. Of the sugar production, 90 to 95 percent is for export. The export of Taiwan sugar has been chiefly to Japan and the Near East. Its competitors in these markets are Java sugar and Cuba sugar. In Taiwan, the unit yield of sugarcane is lower than that in Java, while the production cost of sugar is higher than that in Cuba. Hence, Taiwan has been in an unfavorable position to compete with them in the international market.

The sugarcane acreage and sugar production have undergone great changes in the past. While the production facilities remain stable, the supply of raw sugarcane has been quite variable. This is a great weakness in Taiwan's sugar industry. The reasons for this instability are twofold. On the one hand, the supply of raw sugarcane is affected by the rise or fall of the sugar price in the international market, and on the other, by the keen competition between rice or other crops and sugarcane.

In the competition between rice and sugarcane, the active role is always played by rice, while sugarcane remains passive. This is chiefly because the growing season of sugarcane is much longer which tends to encourage farmers to cultivate crops of

shorter growing season. In Central Taiwan, almost all sugarcane farmers cultivate rice on part of their land or cultivate sugarcane and rice by rotation. Few rice farmers, however, find it desirable to include sugarcane in their corpping system.

The competition between rice and sugarcane production is quite obvious in the history of the island. When there was an increase in the production of the one, a corresponding decrease occured in the production of the other. Since Taiwan's restoration, there have been great increase in both rice acreage and ouput, while sugarcane production has been quite unstable, varying greatly from year to year. Following the influx of immigrants from the mainland of China, the population on the island increased substantially. The number of farm families also increased. This has made the size of farm even smaller and increased the difficulties of farmers in their choice of sugarcane. In addition, the production of sugarcane involves usually greater risks in production and price which results in more difficulties for sugarcane extension.

As rice and sugarcane are both of great importance to the island's economy, the competition between the two has been of particular concern to the government and the people. Various political and economic measures were carried out to adjust their competition. Two important measures to remedy the unfavorable economic conditions for sugarcane are (1) a support price program for sugar and (2) farm practice improvements.

During the Japanese occupation, sugarcane was purchased directly by sugar mills from farmers. The purchase price was pegged and adjusted in relation to the rice price, the purpose of which was to insure a supported definite price ratio between sugarcane and rice. The present practice is that farmers send their sugarcane to sugar mills for processing and that sugar thus produced is shared equally between the farmers and the Taiwan Sugar Corporation. The supported price of farmers' sugar is announced by the Corporation after reference is made to a survey of relative costs and returns of sugarcane and major competing crops. When the current purchase price of sugar calculated on the basis of international sugar price is lower than the supported price, a subsidy is granted to cover the balance.

All technical improvements made in farm practices in sugarcane production have been directed to increase the unit yield of sugarcane. The condition most unfavorable

to sugarcane plantation is the economic lag between expenditure and receipt. Among various methods to shorten its growing period, the most effective is the "Hu-tze" planting method which is widely adopted in the Central Taiwan district. By this interplanting method in paddy land, the growing period of sugarcane is shortened by two months. Moreover, the growth of "Hu-tze" sugarcane is generally good because of early planting. In the case of ratooning sugarcane, the growing period of sugarcane could be shortened by six months.

The interplanting of other crops in a sugarcane field is also widely practiced in the Central Taiwan district, which provides substantial income to sugarcane farmers. With the exception of tobacco and wheat, other winter crops such as flax, cotton, vegetables, peanuts and sweet potatoes can be interplanted with sugarcane.

CHAPTER III

FIELD SURVEY AND TABULATIONS

1. Field Survey

The survey was carried out in the prefectures of Taichung, Changhua and Nantou, and Taichung City; these were divided into seven sub-districts. A total sample of 1,000 farm families was selected, the distribution of which was worked out in consideration of the distribution of total farm families and the distribution of the acreage of paddy land in different sub-districts.

Table 1. Distribution of Samples in the Seven Sub-districts

Sub-district	Taichung Basin	Tachia Coastal Plain	Changhua Plain	Peitou Coastal Plain	Taichung Mountain Area	Puli Basin	Chushan Mountain Area	Total
Number of Samples	300	100	300	150	50	50	50	1000

Furthermore, 20 townships were selected from the seven sub-districts according to the distribution of the acreage of paddy land. For each township, 50 samples were allocated and selected.

Table 2. Distribution of Sample Farms by Farm Size

Farm Size	No. of Sample Farms
Below 0.5 ha.	308
0.51 – 1.0	352
1.01 – 2.0	261
Above 2.0	79
Total	1000

The questionnaires for the survey were drafted after consultation with the organizations concerned. A pilot test of the draft questionnaires was made before they were printed into final form for field use. The contents of the questionnaire for farm interview were:

1. Farmer's name and address
2. Farmer's type
3. Type and acreage of farm land
4. Farm houses and farm implements
5. Domestic animals
6. Family members and farm labor
7. Animal labor
8. Cropping systems on the farm
9. Production expenses of each crop
10. Yield of each crop
11. Reasons for choice of rice or sugarcane

The farm interview was carried out by 40 senior students selected from the Department of Agricultural Economics of the Taichung Agricultural College. These 40 students were divided into 20 groups, with each group of two students responsible for interviewing 50 farm families in one township.

2. Standards for Statistical Tabulation and Computation.

In this survey, besides the questionnaire designed for direct interview of farmers as mentioned above, a General Questionnaire was also designed and used to gather general and overall information of each selected township from the farmers' associations, township offices and demonstration farmers. The major items of inquiry were paddy land price, rental payment, prices of farm implements, fertilizer prices, current wages, collection of water fees, normal crop yields, prices of major farm products, timing of work for crop cultivation, damage from insects and disease and other pertinent economic information of the township. The information collected from the general questionnaire were used as reference materials for the tabulation. In some cases when sample farmers could not report data or information of certain items which were considered relatively uniform or standardized in the township, such as wages, water fees and prices of farm products sold to the local market, the data from the General Questionnaire were used instead. Items on which the Government has regulated uniform standards, such as the exchange ratio between fertilizer and rice, land rent, and land taxes, were calculated according to the uniform standards.

The following are standards used for tabulation and computation, which need explanation:

(1) Farm labor

a. The farm laborers referred to in the survey are in the age between 16 and 55. For convenience of comparison, farm workers of the sample families were converted to standard man-labor units (or man equivalents). A man-labor unit was considered as the labor of one man in the 16-55 year age group, while a woman-labor unit was calculated at 0.8 of the standard man-labor unit. Child laborers below 16 years of age were not included in the conversion in order to facilitate statistical computation. This will result in a small under-estimation of the total labor supply of the sample families. The physical input of labor for the cultivation of crops investigated was expressed in terms of standard man-labor units.

b. In computing the number of workers on farms, the part-time family laborer with outside employment was discounted according to the number of work days outside the farm. The adjustments used in terms of standard man-labor units are given in Table 3.

Table 3. Standards for Computation of Part-Time Family Labor

Number of work days outside the farm in a year	Available number of farm workers on farm (fraction of standard man-labor unit used)
Less than 50 days	1
51—100 days	2/3
101—150 days	1/2
151—200 days	1/3
201—250 days	1/4
More than 251 days	0

(2) Fertilizer

The prices of farm manures were calculated according to the prices reported by sample farmers, but if no such prices were reported by them, they were calculated

according to prices in the General Questionnaire. The prices of chemical fertilizers were calculated at their actual costs if they were purchased by farmers from the market, and at their exchange ratios if they were exchanged by farmers with paddy rice (unhulled rice).

Chemical fertilizers for sugarcane are allocated by the Taiwan Sugar Corporation, the costs of which are paid later in terms of sugar after the farmer's sugarcane is processed by the sugar mills of the Corporation.

(3) Wages of farm Labor.

Two kinds of wages were computed. (a) the wages of hired men and women laborers were calculated according to actual expenses reported by the farmers, including cash wage paid and estimated expenses for food provided; (b) the wages of family or exchange labor were calculated according to data of current cash wages paid in different periods gathered from the General Questionnaire. Generally speaking, the latter was about 80 percent of the former. The cost of animal labor, including both self-provided and hired, was calculated using figures reported by farmers, but if no figures were given by them, it was calculated from figures collected in the Gereral Questionnaire.

(4) Harvesting cost of sugarcane.

The work of harvesting sugarcane is usually undertaken by the sugarcane extension agents appointed by the Taiwan Sugar Corporation rather than by farmers themselves. Working in teams, one laborer can harvest on the average of about 1,000 kilograms of sugarcane per day including the work of loading. The costs for harvesting labor is paid by the farmers to the Corporation after their sugarcane is processed into sugar. The costs of such labor was calculated according to the data collected in the General Questionnaire.

(5) Receipts from sugarcane.

The receipts from sugarcane were calculated by several steps: first, sugarcane was converted into sugar at the conversion rate of 11.5 percent; then, the sugar was equally divided between the farmers and the sugar mills; and, finally, the farmers' sugar was

calculated at its official purchase price without subsidy. The subsidy is excluded in order to measure the total incentive needed to equate returns from sugarcane production with returns from rice production.

CHAPTER IV

PRESENTATION OF FINDINGS OF THE SURVEY

Rice and sugarcane cannot be compared directly. The amounts of time required for growing them are very different. The growing period of rice usually takes about four months, February to May for the spring rice crop or July to October for the fall rice crop, while that of sugarcane takes ordinarily 18 months. However, by introducing the method of Hu-tze planting, the average length of time required for growing sugarcane is reduced to 16 months, late September to late January of the second following year. In recent years, the ratooning method has been used in growing sugarcane, and the average growing period of sugarcane has been further reduced to 15 months. Also these crops are grown in cropping systems including intercrops or other minor crops. Rather than a simple choice between rice or sugarcane, farmers make their choice and decisions between a rice cropping system or sugarcane cropping system. The comparison then must be made between those cropping systems including rice and those including sugarcane as the major crop.

There are two kinds of paddy land in Taiwan: double cropping paddy land and single cropping paddy land. The difference between these two is due mainly to the availability of water supply. Double cropping paddy land has sufficient water during the year to grow two rice crops in the spring and fall major crop seasons, while single cropping paddy land is limited by water supply and can be used to grow only one rice crop, either in the spring or in the fall of the major crop season. Sweet potatoes usually supplement rice in the use of single cropping paddy land.

Fall Hu-tze sugarcane is chosen as the major sugarcane cropping system in Central Taiwan. There are three kinds of fall Hu-tze sugarcane, namely, fall Hu-tze sugarcane without intercrop, fall Hu-tze sugarcane with sweet potatoes as an intercrop, and fall Hu-tze sugarcane with flax as an intercrop. The growing period of fall Hu-tze sugarcane is 16 months, starting in late September and extending to late January about a year and a half later.

The crop season in Taiwan is generally classified into a major crop season and a minor crop season. The major crop season extends from mid-February to mid-October,

while the minor crop season runs from mid-October to the next mid-February. The major crop season is further divided into a spring crop season from mid-February to mid-June and a fall crop season from mid-June to mid-October. Double cropping paddy land is generally used for planting two rice crops in the major crop season, while single cropping paddy land is generally used for planting one rice crop and one sweet potatoes crop. Rice planted in the spring major crop season is called spring rice or the first rice crop, while that planted in the fall major crop season is called fall rice or the second rice crop. Many winter crops, such as flax, cabbage, tobacco, wheat, pod peas and others are planted in the minor crop season in winter on paddy land, and farmers may have a relatively wide range of crop choice in the winter season. Rice is usually the crop of first choice of farmers in the use of double cropping paddy land in the spring and fall major crop season, except that in some cases jute may be grown on part of the farmers' paddy land in the spring major crop season. As the major jute production area is in the southern part of Taiwan, the jute crop in Central Taiwan is in fact a very minor crop in terms of both acreage and output.

In August or September of every year, farmers should decide whether to use their double cropping paddy land to grow sugarcane or to grow winter crops and rice. If farmers choose to plant fall Hu-tze sugarcane in late September, the sugarcane growing must be carried through until late January of the second following year. Therefore, sugarcane growing requires farmers to sacrifice two winter crops and two rice crops in the 16 months. After 16 months, when the sugarcane cropping system is completed, the land is used again for growing spring and fall rice crops in the major crop season. In September of the second following year the same decision must be made again. As regards single cropping paddy land, sugarcane growing requires farmers to sacrifice only one rice crop and one sweet potatoes crop in 16 months. It is for this reason that a period of 16 months covering two winter crop seasons and one full major crop season is used for the comparison of cropping systems in this study. Nine major rice cropping systems have been chosen for comparison. Each of these also covers a 16 months period. The rice and sugarcane cropping systems chosen for comparison in this study are shown in Table 4.

Table 4. Rice and Sugarcane Cropping Systems under Comparison

Cropping System	First winter season	Spring major crop season	Fall major crop season	Second winter season
I. On double cropping paddy land				
No. 1	Flax	Rice	Rice	Shantung cabbage
No. 2	Tobacco	Rice	Rice	Tobacco
No. 3	Wheat	Rice	Rice	Wheat
No. 4	Fall Hu-tze sugarcane with intercrop flax			
No. 5	Pod peas	Rice	Rice	Green manure
No. 6	Sweet potatoes	Rice	Rice	Green manure
No. 7	Sweet potatoes	Jute	Rice	Cabbage
No. 8		Rice	Rice	
No. 9	Fall Hu-tze sugarcane with intercrop sweet potatoes			
No. 10	Fall Hu-tze sugarcane			
II. On single cropping paddy land				
No. 4	Fall Hu-tze sugarcane with intercrop flax			
No. 9	Fall Hu-tze sugarcane with intercrop sweet potatoes			
No. 10		Rice	Sweet potatoes	
No. 11		Sweet potatoes	Rice	
No. 12	Fall Hu-tze sugarcane			

The three sugarcane cropping systems Nos. 4, 9, and 12 could be practiced on both double cropping and single cropping paddy land, while the rice cropping systems cannot be interchanged between the two types of paddy land.

1. Comparison of Relative Profitableness between Rice and Sugarcane Cropping Systems.

One useful way to compare the relative profitableness of competitive crops is by their relative returns. In this study the comparison of relative profitableness between rice and sugarcane cropping systems is made on three bases: (1) gross receipts or gross returns, (2) receipts over expenses,which could be defined as net returns, and (3) receipts over cash expenses, which could be defined approximately as returns to land and family labor, or more accurately as returns to farm-furnished fixed resources.

As gross receipts per hectare are the products of yields per hectare times the unit prices of the crops, and the unit yields and prices are very simple and clear for farmers to understand, the comparison of gross receipts between crops or cropping systems provides an easy and simple basis for crop choice. However, as it does not take the expenses or cash expenses into consideration, it may not represent the actual benefit of competitive crops to the farmers, particularly when the expenses or cash expenses of different crops vary very much. Under the agricultural conditions existing in Asia and

the Far East, the major portion of expenses in crop production is noncash and farm-furnished fixed cost items. It is, therefore, believed that the concept of gross returns comparison is more useful than in other areas or countries in which crop are produced with greater portion of cash and variable costs under a commercial basis.

In this study, receipts are computed on the basis of crop yields times the average prices of the crops in the month of harvest. Crops used in the home are also included in the total yields for computing receipts. Included in the expenses per hectare are expenses for seeds and seedlings, man labor, animal labor, fertilizer, land, water fees and miscellaneous expenses. However, the depreciation of farm implement and farm buildings and wages of management are not included in the expenses. The receipts, expenses, and receipts over expenses per hectare are shown in Table 5.

Table 5. Comparison of Gross Receipts and Receipts over Expenses from Rice and Sugarcane Cropping Systems in Central Taiwan

Cropping system	Receipts per hectare	Expenses per hectare	Receipts over expenses per hectare	Order of Profitableness	
				Gross Receipts	Receipts over expenses
	dollars	dollars	dollars		
I. On double cropping paddy land					
1. Flax-rice-rice-Shantung cabbage	18,859	12,769	6,090	2	1
2. Tobacco-rice-riec-tobacco	42,134	36,146	5,967	1	2
3. Wheat-rice-rice-wheat	15,189	10,091	5,098	3	3
4. Fall "Hu-tze" sugarcane with flax as intercrop	11,396	8,259	3,138	6	4
5. Pod peas-rice-rice-green manure	10,972	7,903	3,069	7	5
6. "Hu-tze" sweet potato-rice-rice-green manure	11,561	8,640	2,921	5	6
7. "Hu-tze" sweet potato-jute-rice-cabbage	14,701	11,938	2,763	4	7
8. Rice-rice	9,252	6,849	2,403	8	8
9. Fall "Hu-tze" sugarcane with sweet potato as intercrop	8,732	7,008	1,724	9	9
12. Fall "Hu-tze" sugarcane	7,540	6,339	1,201	10	10
II. On single cropping paddy land					
4. Fall Hu-tze sugarcane with intercrop flax	11,396	8,259	3,138	1	1
9. Fall Hu-tze sugarcane with intercrop sweet potatoes	8,732	7,008	1,724	2	2
10, Rice-sweet potatoes	7,555	5,865	1,690	3	3
11. Sweet potatoes-rice	7,244	5,987	1,257	5	4
12, Fall Hu-tze sugarcane	7,540	6,339	1,201	4	5

When comparison is made on gross receipts, many rice cropping systems can bring more gross receipts than sugarcane cropping systems in the use of double cropping paddy land. Since tobacco is a high return crop, the rice cropping system No. 2 produces far more gross receipts per hectare than any other rice and sugarcane cropping system. However, as tobacco is under government monopoly and its acreage is limited by the government, only a limited group of farmers who obtain permits can choose this cropping system. Three other rice cropping systems, Nos. 1, 3, and 7, produce significantly more gross receipts than the most profitable sugarcane cropping system, No. 4, while two other rice cropping systems, Nos. 5 and 6, produce about the same gross receipts as the sugarcane cropping system, No. 4. The sugarcane cropping systems, Nos. 9 and 12, produce the least gross receipts among the all cropping systems under comparison on double cropping paddy land. In the use of single cropping paddy land, the sugarcane cropping systems with intercrops can bring more gross receipts than the two rice cropping systems. The sugarcane cropping system without intercrop produces about the same gross receipts as the two rice cropping systems.

Since the expenses of production may vary among crops and crops of high gross returns usually require high expenses of production, comparison should also be made on their relative net returns. In the use of double cropping paddy land, for instance, the rice cropping system supplemented with tobacco in the winter produces far more gross receipts than other cropping systems, but also requires about three times more expenses than rice cropping system No. 1 and about 4.5 times more expenses than the sugarcane cropping system No. 4. The rice cropping systems Nos. 1, 3, and 7 all require much more expenses than the sugarcane cropping systems. When comparison is made on net returns, the order of profitableness of rice cropping system No. 2 drops from the first to the second, while the order of sugarcane cropping system No. 4 jumps from the sixth to the fourth. This indicates that higher gross returns from rice cropping system No. 2 is not enough to offset its higher expenses, while lower gross returns from sugarcane cropping system No. 4 is more than compensated by its lower expenses. The net returns from the rice cropping systems Nos. 1, 2, and 3 range from NT$ 5,000 to NT$ 6,000 and are much greater than those from sugarcane cropping systems. The rice cropping systems Nos. 5, 6, and 7 produce about the same or a little less net returns than the sugarcane cropping system No. 4. The other two sugarcane cropping systems still retain their position as the least profitable

among all cropping systems under comparison. In the use of single cropping paddy land, the order of profitableness of all cropping systems is about the same under both comparisons. This indicates that higher gross returns from sugarcane cropping systems is more than enough to offset their higher expenses of production. The sugarcane cropping system No. 4 produces more net returns, while the net returns from the other two rice and two sugarcane cropping systems are about the same.

Since receipts over expenses of all cropping systems under comparison are positive as shown in the above table, it can be said that under the current price condition, farmers in Taiwan are able to earn some returns to their management and to meet the depreciation of farm implements and farm buildings.

The rice cropping systems, when supplemented with tobacco, flax, cabbage and wheat, produce much more gross returns and net returns than sugarcane cropping systems, and are, therefore, in a strong position to compete with sugarcane in the use of double cropping paddy land in the district. However, if double cropping paddy land is used to grow the rice cropping systems supplemented with extensive crops, such as sweet potatoes, green manure and pod peas, the gross returns or net returns from rice cropping systems are about the same as those from the most profitable sugarcane cropping system with flax as an intercrop. The sugarcane cropping systems with sweet potatoes as an intercrop or without intercrop are the least profitable systems in producing gross returns or net returns. As regards the use of single cropping paddy land, the sugarcane cropping systems with flax or sweet potatoes as intercrops can produce more gross returns or net returns than the rice cropping systems of "sweet potatoes-rice" and "rice-sweet potatoes."

The previous comparison was made on the bases of gross receipts and receipts over expenses for crop production. It represents a conventional method of comparison of relative benefit from crop production. However, while gross returns are very simple and clear and easy to understand by the farmers in Asia, net returns involve more complicated procedures of computation, evaluation and allocation of costs of fixed and self-provided resources used in crop production. Small subsistence farmers find it difficult to understand and to calculate the net returns from the crops. As many items of expenses in crop production in Taiwan are non-cash and farm-furnished, farmers may consider the attainment of highest returns to their fixed resources on

farms including mainly family labor and land resources as their goal for farming. Returns to fixed resources on farm are the residue of gross returns after expenses of market-purchased cost items and interest of borrowed capital are paid. They represent the amounts of returns available for disposal by the farm family for family living, saving, and re-investment in farm production. In view of this reason, the concept of total expenses for crop production including computed value for family labor and land may not be adequate for calculation of relative returns from competitive crops. Therefore, another comparison is made on the basis of receipts over cash expenses from rice and sugarcane cropping systems. The excess of gross receipts over cash expenses represents approximately the returns to land and family labor, or more accurately, the returns to fixed farm-furnished resources. Table 6 is computed to show the relative returns to fixed resources on the farm from rice and sugarcane cropping systems in Central Taiwan.

On double cropping paddy land, the rice cropping system supplemented with tobacco in the winter produce much higher returns to fixed resources on the farm than any other rice and sugarcane cropping system under comparison. The rice cropping systems, Nos. 1 and 3, rank second in returns to fixed resources. All of these three rice cropping systems produce much more returns to fixed resources than any sugarcane cropping system. Only the sugarcane cropping system with intercrop flax is in a relatively comparable position with rice cropping systems Nos. 5, 6, 7, and 8. Fall Hu-tze sugarcane with sweet potatoes as an intercrop or without intercrop produces the least returns to fixed resources among the ten rice and sugarcane cropping systems under comparison.

Table 6. Comparison of Returns to Fixed Resources from Rice and Sugarcane Cropping Systems in Central Taiwan

Cropping System	Receipts per hectare	Cash expenses per hectare	Returns to fixed resources per hectare	Order of Profitableness
	dollars	dollars	dollars	
I. On double cropping paddy land				
2. Tobacco-rice-rice-tobacco	42,134	12,503	29,631	1
1. Flax-rice-rice-Shantung cabbage	18,859	4,092	14,767	2
3. Wheat-rice-rice-wheat	15,189	1,936	13,253	3
7. Sweet potatoes-jute-rice-cabbage	14,701	3,829	10,874	4
6. Sweet potatoes-rice-rice-green manure	11,561	1,732	9,829	5
5. Peas-rice-rice-green manure	10,972	1,570	9,402	6
4. Fall Hu-tze sugarcane with intercrop flax	11,396	2,318	9,078	7
8. Rice-rice	9,252	1,216	8,036	8
9. Fall Hu-tze sugarcane with intercrop sweet potatoes	8,732	2,012	6,720	9
12. Fall Hu-tze sugarcane	7,540	1,751	5,789	10
II. On single cropping paddy land				
4. Fall Hu-tze sugarcane with intercrop flax	11,396	2,318	9,078	1
9. Fall Hu-tze sugarcane with intercrop sweet potatoes	8,732	2,012	6,720	2
10. Rice-sweet potatoes	7,555	939	6,616	3
11. Sweet potatoes-rice	7,244	976	6,268	4
12. Fall Hu-tze sugarcane	7,540	1,751	5.789	5

The most prominent effect of the change of basis of comparison from gross receipts or receipts over expenses to returns to fixed resources on the farm is to place the most profitable sugarcane cropping system No. 4 in an even more unfavorable position to compete with rice. Under the comparison of returns to fixed resources, more rice cropping systems are in a better position to compete with sugarcane in the use of double cropping paddy land.

On the basis of the comparisons of gross receipts, receipts over expenses, and returns to fixed resources as presented in the previous section, it is obvious that the

rice cropping system No. 2 with tobacco in the winter is always on the top in earning capacity. The rice cropping systems Nos. 1 and 3 rank second. While the sugarcane cropping system No. 4 and rice cropping systems Nos. 5, 6, 7, and 8 are roughly in the same group in earning capacity, the sugarcane cropping systems Nos. 9 and 12 are in the group in lowest earning capacity. Our preliminary conclusion is, therefore, that the addition of winter crops into the double rice cropping systems is a very important factor in favor of rice against sugarcane in the competition for the use of double cropping paddy land in the district. Since land in Central Taiwan is relatively fertile and irrigation facilities are available, farmers usually plant winter crops to supplement two rice crops in the year. From the standpoint of relative returns in terms of either gross receipts and receipts over expenses or returns to fixed resources on the farm per unit of land, it is better to devote double cropping paddy land in Central Taiwan to rice cropping systems.

As sugarcane cropping systems with intercrops produce more gross returns, net returns and returns to fixed resources on farm than the rice cropping systems in the use of single cropping paddy land, it is better for the farmers to devote their single cropping paddy land for sugarcane growing. However, if fall Hu-tze sugarcane is planted without intercrop, the returns in terms of either gross receipts and receipts over expenses or returns to fixed resources are all about the same as those derived from rice cropping systems. In this case, single cropping paddy land is better not used for sugarcane growing as sugarcane involves longer periods and higher risks in production.

The above analysis of relative profitableness of various cropping systems is based on the current price situation in Taiwan. Any change in the sugar-rice price ratio will undoubtedly affect the returns of the individual cropping systems and their relative profitableness. Discussion of this will be presented in a later section.

2. Importance of cash expenditures in different cropping systems.

Cash expenditures are always a major factor in the farmers' choice of crops or cropping systems. This is particularly true in the case of small farmers with limited capital. If other factors are not involved, farmers usually take those crops or cropping systems which require relatively less cash expenditures. Table 7 shows the importance

of cash expenditures in different rice and sugarcane cropping systems as indicated by this survey.

On double cropping paddy land, the rice cropping system No. 2 of "tobacco-rice-rice-tobacco" requires the largest cash expenditures per hectare. Tobacco is a very intensive crop requiring heavy fertilization and a great amount of man labor. Materials needed for tobacco growing and curing, such as chemical fertilizers, insecticides and pesticides, firewood, and curing equipments, are all non-farm supplies which must be purchased. Therefore, heavy cash outlay and investment are needed for this system.

Table 7. Comparison of Cash and Non-cash Expenditures in Different Rice and Sugarcane Cropping System in Central Taiwan
(dollars per hectare)

Cropping system	Cash expenses		Non-cash expenses		Total expenses	Rank in cash raquirement
	Actual value	Percent	Actual value	Percent		
I. On double cropping paddy land						
No. 2. Tobacco-rice-rice-tobacco	12,503	34.59	23,643	65.41	36,145	1
No. 1. Flax-rice-rice-Shantung cabbage	4,092	32.04	8,677	67.96	12,769	2
No. 7. Hu-tze sweet potato-jute-rice-cabbage	3,827	32.06	8,111	67.94	11,938	3
No. 4. Fall Hu-tze sugarcane with intercrop flax	2,318	28.07	5,941	71.93	8,259	4
No. 9. Fall Hu-tze sugarcane with intercrop sweet potato	2,012	28.71	4,996	71.29	7,008	5
No. 3. Wheat-rice-rice-wheat	1,936	19.18	8,156	80.82	10,091	6
No. 12. Fall Hu-tze sugarcane without intercrop	1,751	27.62	4,588	72.38	6,339	7
No. 6. Hu-tze sweet potato-rice-rice-green manure	1,732	20.05	6,907	79.95	8,640	8
Na. 5. Pod peas-rice-rice-green manure	1,570	19.86	6,333	80.14	7,903	9
No. 8. Rice-rice	1,216	17.76	5,633	82.24	6,849	10
II. On single cropping paddy land						
No. 4. Fall Hu-tze sugarcane with intercrop flax	2,318	28.07	5,941	71.39	8,259	1
No. 9. Fall Hu-tze sugarcane with intercrop sweet potatoes	2,012	28.71	4,996	71.29	7,008	2
No. 12. Fall Hu-tze sugarcane	1,751	27.62	4,588	72.38	6,339	3
No. 11. Sweet potatoes-rice	976	16.30	5,011	83.70	5,987	4
No. 10. Rice-sweet potatoes	939	16.01	4,926	83.99	5,865	5

The cash requirements per hectare for the rice cropping systems Nos. 1 and 7 of "flax-rice-rice-Shantung cabbage" and "Hu-tze sweet potatoes-jute-rice-cabbage" rank second. These three rice cropping systems require much heavier cash expenses than the three sugarcane cropping systems, which is a factor in favor of sugarcane against rice in the competition for the use of double cropping paddy land in the district. The cash requirements for the rice cropping systems Nos. 3 and 6 are about the same or a little less than those for all the three sugarcane cropping systems Nos. 4, 9, and 12. The other two rice cropping systems Nos. 5 and 8 require least cash expenses among all the rice and sugarcane cropping systems under comparison. On single cropping paddy land, all the three sugarcane cropping systems require more cash expenses than the two rice cropping systems under comparison.

The three rice cropping systems Nos. 1, 2, and 7 involve high percentages of cash outlay in the total expenses. The percentages of cash expenses of the three sugarcane cropping systems Nos. 4, 9, and 12 are moderate, while those of the other six rice cropping systems Nos. 3, 5, 6, 8, 10 and 11 are lower.

Rice cropping systems that include intensive crops, such as tobacco, flax, jute, and Shantung cabbage, require more cash expenses, both in dollars and in a percentage of total expenses than the sugarcane cropping systems. However, when the rice cropping systems are combined with extensive crops such as green manure and sweet potatoes; or involve only two crops a year, the cash expenses required for them, either in terms of actual dollars or in percentage, are generally less than those required for the sugarcane cropping systems. From the standpoint of rice and sugarcane competition, larger cash requirements for the more remunerative rice cropping systems combined with intensive crops is definitely a counterbalancing factor in favor of sugarcane against rice in the farmer's choice of cropping systems. However, it is still possible for well-to-do farmers with better financial resources to raise the rice cropping systems combined with intensive crops in order to take advantage of a greater excess of receipts over expenses. In such a case, rice is usually the crop of first choice of well-to-do farmers for the use of double cropping paddy land. Poor and small farmers, with a limited supply of capital, will take the rice cropping systems combined with extensive crops. Only farmers with an adequate supply of capital will be likely to devote part of their land to sugarcane and to prefer sugarcane cropping systems to rice cropping systems combined with extensive crops or with only two crops a year. It is for this reason that

an adequate credit supply is needed to enable the farmers, particularly the poor and small ones, to grow sugarcane.

3. Labor requirements and distribution for different cropping systems.

The total requirements and the seasonal distribution of labor vary greatly in the cultivation of different crops and cropping systems. Crops which require labor at the same period of time during the year are competitive in labor use with each other and farmers have to make choices between the one and the other in their farm organization. On the other hand, some crops are supplementary in the sense that they demand labor at different periods of time during the year, and hence farmers can choose the one in addition to the other in order to utilize more fully their labor forces. As the supply of family labor is usually constant throughout the year in the majority of farm families and as the hiring of labor involves cash outlay, farmers, after considering the competitive and supplementary relationships among crops, tend to choose a cropping system or a combination of cropping systems which will provide an opportunity for the full use of their family labor throughout the year and will require less hired labor to fill the gap between total labor requirement and available family labor supply at any given period during the year. It is for this reason that the labor requirements and distribution in the cultivation of different major rice and sugarcane cropping systems are related to the problem of competition between rice and sugarcane in the district.

The labor reqeirements per hectare and the distribution by crop seasons for the different rice and sugarcane cropping systems under comparison are shown in Table 8.

Table 8. Labor Requirements and Distribution by Crop Seasons for Rice and Sugarcane Cropping Systems in Central Taiwan. (Days)

Cropping system	First winter season*	Spring major crop season	Fall major crop season	Second winter season	Total
I. On double cropping paddy land					
1	91	162	140	250	643
2	731	160	368	553	1812
3	66	200	160	134	560
4	188	114	0	79	381
5	90	84	65	26	265
6	81	120	65	26	292
7	73	192	225	177	667
8	8	84	65	22	179
9	134	56	0	79	269
12	105	25	0	79	209
II. On single cropping paddy land					
4	188	114	0	79	381
9	134	56	0	79	269
10	8	84	68	52	212
11	0	59	94	22	175
12	105	25	0	79	209

* The labor for planting fall Ha-tze sugarcane is usually required in late September. However, it is included in the labor requirements of sugarcane cropping systems in the first winter season for the convenience of analysis.

The total area of the 1,000 sample farms covered in this survey was 906.7005 hectares and the average size of the sample farm was 0.9067 hectare. The average family size of the sample farm was 7.85 persons with 3.08 man-equivalent per farm. Assuming that 25 working days per farm worker per month were available for crop production and the other 5 days were reserved for livestock and poultry raising, family and community activities and other miscellaneous works, the available family labor supply for crop production was about 78 man days per farm per month or about 946 man days per year. The total family labor supply for the 16 months' period of the cropping systems under comparison was, therefore, about 1,250 man days. By using this average figure of the whole district as a basis to be compared with the total requirements of labor of different cropping systems as shown in the last column of the table, it may be seen that the available family labor supply is on the average more than enough to meet the demand for labor of all the 12 cropping systems except the rice cropping systems No. 2 of "tobacco-rice-rice-tobacco."

Uneven distribution of labor requirements by crop season is the general feature of

most crops and cropping systems. On double cropping paddy land, the rice cropping systems with intensive and extensive crops in the winter season require more total labor requirements than the majority of sugarcane cropping systems. The distribution of labor requirements of most rice cropping systems is also more even than that of sugarcane cropping systems, as the rice cropping systems require labor in all the four crop season under comparison. The sugarcane cropping systems Nos. 4, 9, and 12 with and without intercrops demand labor only in the first winter and the spring major crop seasons and require no labor in the fall major crop season. This extremely uneven distribution of labor requirements of all the sugarcane cropping systems is really a disadvantageous factor of sugarcane growing. This fact, among other factors, also explains why many farmers in Taiwan may devote all of their paddy land to grow rice only in the major crop season, but when they choose to grow sugarcane, they devote only part of their land for sugarcane in combination with other crops. From the standpoint of labor utilization, the rice cropping systems Nos. 1, 2, 3, and 7 require more intensive use of labor and provide more opportunities for better use of family labor throughout the year. The No. 2 rice cropping system of "tabacco-rice-rice-tobacco" requires 1,812 man days per hectare providing most opportunity for labor use among all the cropping systems under comparison. However, since tobacco is the crop under government monopoly and farmers must apply for permits to plant tobacco, the freedom of choice of tobacco planting is relatively limited. On the average, the rice cropping systems with intensive or extensive crops in the winter season give more outlet for the employment of family labor than the sugarcane cropping systems, which places rice in a favorable position to compete with sugarcane in the use of double cropping paddy land in the district. In terms of total labor requirements and use, the rice cropping systems with only two crops involved are in a disadvantageous position in the use of labor as compared with sugarcane cropping systems. This also explains the possibility of using single cropping paddy land in sugarcane growing as such land could usually be used to grow only the rice cropping systems with two crops a year.

4. Farmers' opinions on factors affecting choice of rice or sugarcane.

During the survey, the farmers were asked many questions as to why they chose to plant rice or sugarcane. Listed on the questionnaire were a number of economic and non-economic factors that might affect their choice. The factors of economic significance which involve the returns from the crops, turnover of the invested capital,

the relative stability of the prices of crops, the requirement of production expenses, and the utilization of labor are all classified as economic factors, while those of physical singnificance which involve natural and physical conditions of the land suitable for the crops, human factors, and use of the crops for home uses or for paying taxes in kind are all classified as non-economic factors. Each individual farmer was asked to answer this question by arranging the listed factors in order of importance according to his own estimate for ascertaining the weights of the individual factor answered. A farmer's answer was limited to five factors which he thought were the most important ones affecting his choice of rice or sugarcane. Weights of 5,4,3,2, and 1 were assigned respectively to each of the individual factors; i.e., the most important factor as reported by an individual farmer received a weight of 5 and the least important, 1. The weight of each individual factor as ascertained according to the report of all farmers was then added to arrive at a total weight for the respective factor. The total weights of all factors answered, when assumed as 100, was applied to compute the percentage distribution of total weights of each individual factor. These percentage distributions show the relative importance of each of the individual factors considered and estimated by farmers as a group in affecting their choice of rice or sugarcane.

(1) Economic factors affecting farmers' choice of rice.

The most important economic factor that affects farmers' choice of rice is its shorter growing period which facilitates a relatively quick turnover of capital. Among the various economic factors considered, this factor received a weight of more than 40 percent of total weights of all factors considered in the whole district. The economic factor next in importance is that there is more net returns from rice than from sugarcane, the weight of which was about one-fifth of the total weights. Next is the factor that there are more returns from winter crops combined with rice, the weight of which was about 15 percent. The details are shown in Table 9.

Table 9. Farmers' Estimate of the Degree of Importance of Economic Factors Affecting Choice of Rice in Central Taiwan

Economic factor	Degree of importance in terms of percent of total weights of all factors
Shorter growing period and quick turnover	42.04
More returns from rice than from sugarcane	20.43
Additional returns from winter crops	14.85
Better distribution of labor	10.94
Relative stability of rice price	8.65
Less production expenses	1.68
Sufficient labor supply	1.00
Others	0.41
Total	100.00

The first important economic factor is closely related to the farmers' need of credit. Farmers told us that before the land reform, they could almost always depend on their landlords for some short-term loans when needed. But following the enforcement of land rent reduction program, landlords were unable and no longer interested in making loans and consequently the close link between tenants and landlords was cut off. They said that although the Government has extended production loans to them twice a year, the amount was not sufficient to meet their needs. Because of the lack of capital, they did not dare to undertake the cropping systems which take longer growing periods.

With regard to the two other important factors, they are all related to returns. According to the information obtained from the survey, those farm families which have few members and very small acreages cannot even produce enough rice for their own consumption. They depend largely on the returns from winter crops and sideline business. Since they think that there are more returns from winter crops combined with rice, they therefore choose rice.

(2) Non-economic factors affecting farmers' choice of rice.

The most important non-economic factor that affects farmers' choice of rice is the farmers' desire for rice for family consumption. The weight of this factor occupies

on the average about one-third of the total weights of all factors considered in the whole district. The factor next in importance is for paying land taxes in kind, the weight of which amounts to about 13 percent of the total weights of all factors. Next in importance are the factors of barter of rice for fertilizer, adaptability of soil for rice growing, and using straw for fuel, feed and building materials, the weights of these factors range from 8 percent to 10 percent of the total weights of all factors. All other factors are relatively minor in importance. The details are shown in Table 10.

Of the five important non-economic factors, the first three and the fifth are all related to the farmers' own requirements of rice and its by-product. Rice is the principal food of Chinese farmers. Unless there is a more substantial return from sugarcane, normally farmers would like to save the trouble of selling sugar and then buying rice from the market. Besides, the Government has regulated that land taxes for paddy land should be paid with rice and that fertilizer should be bartered with rice, which all greatly affects the farmers' choice of rice.

Table 10. Farmers' Estimate of the Degree of Importance of Non-Economic Factors Affecting Choice of Rice in Central Taiwan

Non-economic factor	Degree of importance in terms of percent of total weights of all factors
For family food	34.83
Payment of land taxes in kind	13.25
Barter for fertilizer with rice	9.85
Adaptability of soil	8.99
Using straw for fuel, feed, and building materials	8.56
Traditional practice of cultivation	6.27
Availability of irrigation	5.84
Better knowledge of rice cultivation	2.79
Rotation	2.52
Others	7.10
Total	100.00

(3) Economic factors affecting farmers' choice of sugarcane.

The most important economic factor that affects the farmers' choice of sugarcane

is the availabilities of cash, fertilizer and sugarcane seedling loans from the Taiwan Sugar Corporation. This factor received a weight of about one-half of the total weights of all factors considered in the whole district. The economic factor next in importance is more opportunity for the family labor to meet the labor demand of all crops on the farm as a whole, the weight of which occupies about one-fourth of total weights of all factors. The next factor is that the production expenses of sugarcane are comparatively less, the weight of which counts for about one-tenth. All other factors are relatively minor in importance. The details are shown in Table 11.

Table 11. Farmers' Estimate of the Degree of Importance of Economic Factor Affecting Choice of Sugarcane in Central Taiwan

Economic factor	Degree of importance in terms of percent of total weights of all factors
Availabilities of cash, fertilizer and sugarcane seedling loans from Taiwan Sugar Corporation	45.20
More opportunity to meet the demand for labor for the farm as a whole	26.49
Less production expenses	10.35
More returns from sugarcane than from rice	5.56
Additional returns from intercrops	4.88
Others	7.52
Total	100.00

Of the three important economic factors, the first one is related to the availabilities of credit for sugarcane growing. Sugarcane has a long growing season; the slow turnover of capital and economic lag between expenditures and receipts discourage farmers from growing sugarcane. The Taiwan Sugar Corporation is quite aware of the importance of this factor. To overcome this difficulty, the Corporation has designed a credit program to extend various kinds of loans to sugarcane farmers who are under contract with the Corporation to grow sugarcane. The loans are extended to sugarcane farmers through the Sugar Mills in the respective areas and are repaid by the farmers after 16 months from the receipts of Sugar. This loan program is considered by the Taiwan Sugar Corporation as one of the effective measures and incentives for sugarcane extension.

The second important factor is related to the demand for labor. As sugarcane

requires considerable labor only in the initial eight-month period after planting, farmers with a relatively large acreage of paddy land and limited family labor may grow sugarcane on part of their paddy land in order to release labor for other crops during the later period of sugarcane growing. This enables the farmers to meet the demand for labor for all crops on the farm as a whole.

(4) Non-economic factors affecting farmers' choice of sugarcane.

The most important non-economic factors that affect farmers' choice of sugarcane were (1) sugarcane leaves and residues could be used for fuel, feed and building materials, and (2) the encouragement and persuasion of sugarcane extension agents. Each of these factors received a weight of about one-fourth of the total weights of all factors. Next in importance is lack of irrigation, the weight of which counts for about one-fifth of the total weights of all factors. All other factors are relatively minor in importance. The details are shown in Table 12.

Table 12. Farmers' Estimate of the Degree of Importance of Non-economic Factors Affecting Choice of Sugarcane in Central Taiwan

Non-economic factor	Degree of importance in terms of percent of total weights of all factors
Sugarcane leaves for fuel, feed and building materials	24.67
Encouragement of sugarcane extension agents	24.13
Lack of irrigation	21.23
Rotation	7.39
Adaptability of soil	5.38
Less risks in production	3.56
Traditional practice of cultivation	2.42
Others	11.22
Total	100.00

5. Size of farm in relation to planting of rice or sugarcane.

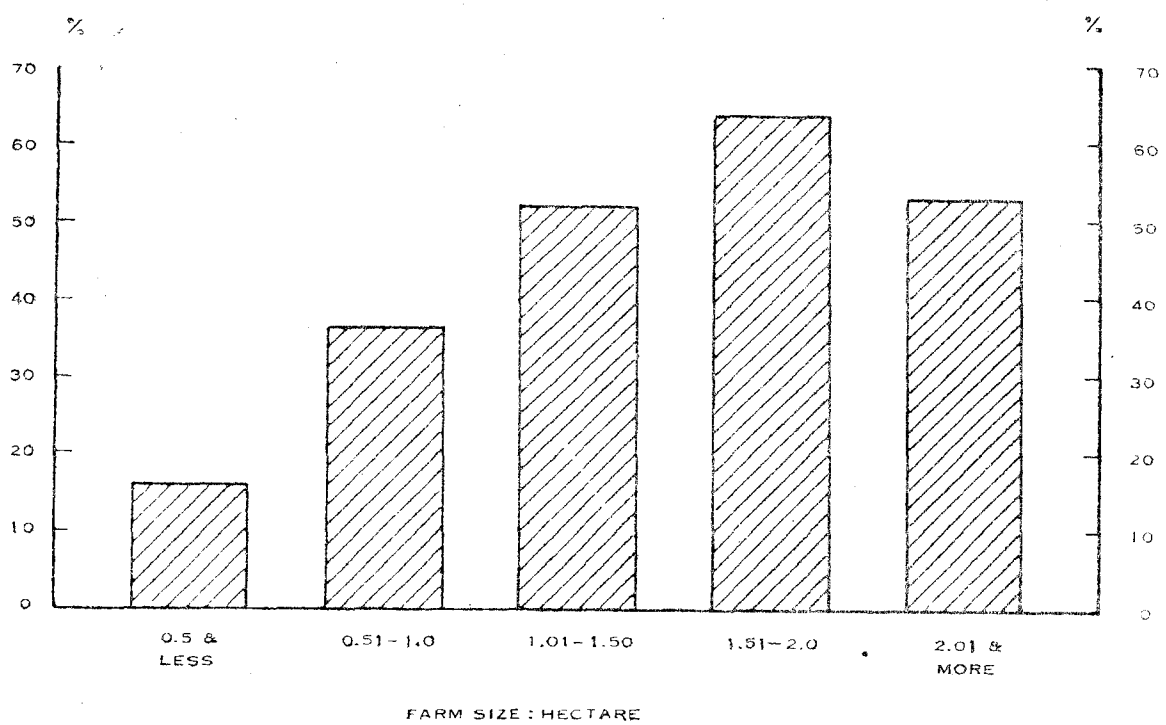
Besides the economic and non-economic factors mentioned above, there is one other important factor which also affects greatly farmers' planting of rice or sugarcane: namely, the size of the farm. The larger the size of farm, the greater the ten-

dency of farm families to plant sugarcane, while the smaller the size of farm, the greater the tendency of farm families to plant rice. In other words, following the increase of farm size, the percentage of farm families which plant sugarcane also generally increases. The details are shown in Table 13 and Figure I.

Table 13. Percentage of Farm Families Planting Rice or Sugarcane in Relation to Farm Size in Central Taiwan

Farm size (hectare)	No. of farms investigated		No. of farms planting spring rice crop		No. of farms planting fall rice crop		No. of farms planting sugarcane	
	No.	%	No.	%	No.	%	No.	%
0.5 and less	308	100	289	93.8	306	99.3	49	15.9
0.51—1.00	352	100	339	96.3	352	100.0	127	36.1
1.01—1.50	174	100	169	97.1	174	100.0	90	51.7
1.51—2.00	86	100	86	100.0	96	100.0	55	63.9
2.01 and more	80	100	77	96.2	80	100.0	42	52.5

Figure I. Percentage of Farm Families Planting Sugarcane in Relation to Farm Size in Central Taiwan.



After reviewing the above table and chart, the following explanation may be offered:

a. Farm families who have relatively large farms in relation to their family labor supply may find it necessary to use part of their paddy land for sugarcane, as sugarcane is more extensive and needs less labor than rice. If they devote all of their paddy land to rice, their family labor may not be enough to meet the demand for labor throughout the year.

b. Farm families who have larger farms may find that the supply of water may be insufficient if they use all of their land for rice. On the other hand, if they use part of their land for sugarcane, they would get enough water for rice and its unit yield will also be maintained.

c. As rice is the principal food of farmers, they naturally would give it priority in the use of paddy land. But if they have larger farms and more land for other crops, the persuasion and encouragement of the sugarcane extension agents will produce a greater effect to induce farmers to grow sugarcane.

CHAPTER V

ANALYSIS OF CHOICE AND COMBINATION OF RICE AND SUGARCANE CROPPING SYSTEMS ON FARM

1. Characteristics of Farms in Taiwan.

Farms in Taiwan are exceptionally small, particularly when compared with the size of farms in the United States. The small farm is further divided into 5 to 10 small fields which seldom lie next to one another. The scattered small plots of land of a farm unit usually complicate the planning, operation, and management of the farm business. Each plot of land may be cultivated as a technical unit with a cropping system independent of those on other plots.

Farms and the fermers' family are mixed up into a single composite unit for farming and living together. The main purpose of farming is to provide employment opportunity for the members of the farm family throughout the year in order to earn a living for the family. Therefore, the motivational forces behind the farm producing unit are consumption-inspired as well as profit-inspired. Maximization of satisfaction or welfare of the family is generally considered as the goal for farming. However, as there are in existance in Taiwan convenient local markets for the trading of farm products and convenient transportation systems, the goal of satisfaction or welfare maximization will not deviate very much from the goal of profit or return maximization. Particularly in the growing of cash crops like sugarcane, jute, tobacco, tea, and pineapple, which are all produced solely for sale, return maximization to the family for maximizing satisfaction is generally the goal of farming in Taiwan.

In general, it can be said that the most important limitational factor of production on farms in Taiwan is land. In a physical sense the acreage of land on a farm is absolutely fixed for a given planning period. However, in the use of land, farmers may vary their crop acreage under cultivation by varying the crops of longer or shorter growing period in the cropping systems. Since land is more limited than the supply of capital and labor on a majority of farms in Taiwan, the goal of farmers' planning for choice and combination of cropping systems on a farm is generally directed to

obtaining the highest return per unit of land. This explains why farm land in Taiwan is so intensively cultivated; as long as there is any possibility of obtaining a small positive margin between the value of additional yields from land and the variable costs, farmers tend to apply their family labor and other nonland fixed resources to cultivation. However, some particular farmers may have relatively more farm land and less family labor. Under such farm situations, consideration may be given to the use of labor and highest returns per unit of labor. Crops of relatively low returns per unit of land but requiring less labor may be chosen.

As Taiwan is one of the less mechanized agricultural regions of the world, human labor is of special importance on the majority of individual farms. All kinds of farm work are carried out by the hands of farmers with the assistance of simple implements and animal labor. Family labor, the major part of the labor supply, is considered as a relatively fixed resource on the farm during the year. Because the costs attached to family-furnished resources do not enter into the marginal cost structure, the general hypothesis is often put forth that crop production on family farms is less responsive to price changes than that on large-scale or commercial farms which must pay labor as a marginal or variable cost. This statement refers in fact to the price responsiveness of the aggregate individual farm output. However, when consideration is given to the production and choice of competitive crops on farms, it could be expected that farmers will respond to the changes of price ratios of competitive crops in Taiwan as long as such changes of price ratio will result in changes of relative returns to family labor from the competitive crops. From the standpoint of labor utilization, and assuming other considerations are not involved, farmers in Taiwan tend to choose a cropping system or combination of cropping systems which requires more intensive use of family labor throughout the year and provides better returns to the family labor as a whole.

Farms in Taiwan are generally characterized by self-sufficiency of food supply for the family. As long as the physical and natural conditions permit, farmers in general tend to use their paddy land in the major crop season to produce food crops for their families and to use a minor part of the land together with land in the summer and winter crop seasons to raise cash crops for money income to meet the cash requirements of farming and family living. Therefore, it can be said that the general characteristics of farms in Taiwan are: (1) intensive use of the limited land resource, (2) full employment for family labor and increase of labor productivity, (3) production

of food for the farm family, and (4) money-income production for farming and family living.

2. Appraisal of Factors Influencing Farmers' Choice of Rice or Sugarcane and Their Combination.

As discussed in the previous chapter, the factors influencing the farmers' choice of rice or sugarcane are many and rather complex as they are interrelated, mutually augmentative, or counterbalancing with each other in the farmers' decision-making. Furthermore, it is believed that even in a relatively homogeneous agricultural region like Central Taiwan, the degrees of importance of various influencing factors may vary from farm to farm with different quantities of land, family labor and capital resources available for crop production. Under the agricultural conditions in Taiwan and from the standpoint of supply of farm resources as a factor influencing farmers' choice of crops, it can be said that land is the most limiting factor in farm production. Capital is the second limiting factor, while labor is the least limiting. However, the family labor supply in a particular month or season may still be a serious limitation for farmers' choice of a particular crop or cropping system requiring intensive use of labor in the particular month or season, even though the total labor supply of the whole year is much more than enough to meet the total labor requirement of the particular crop or cropping system.

Since there is a local market for both rice and sugar and there is a possibility of labor employment in the rural village as indicated by the current prevailing farm wages in different crop seasons, the relative returns from rice and sugarcane cropping systems expressed in terms of gross receipts, receipts over expenses and returns to fixed resources on farm per unit of land as presented in the previous chapter are a rough indicator influencing farmers' choice.

When crops are competitive, the optimum choice and combination for the allocation of a given farm's resources between crops can be made only if the various alternatives and choice criteria are known. Price ratios between competitive crops usually provide the choice indicator. Maximum returns are attained when the marginal rate of product substitution is inversely equal to the product price ratio. Therefore, under a given technological condition, the sugar-rice price ratio is definitely a factor influencing

the farmer's choice and combination of rice and sugarcane. With a change in the sugar-rice price ratio, farmers should change their choice and combination of rice and sugarcane for optimum allocation and use of farm resources in order to maximize returns, if the line of product substitution has a gradual curvature.

As it is rather difficult to compute the marginal rate of product substitution between rice and sugarcane because their cropping systems involve so many crops and their growing seasons are so different in the length of time, analysis in this study is directed to assessing the effect of changes in sugar-rice price ratio on the relative profitableness of rice and sugarcane cropping systems in terms of gross receipts per hectare of land. The relative profitableness of rice and sugarcane cropping systems is affected by many factors, of which the important ones are the relative changes in the unit yields of the crops in the systems, the relative changes in the prices of the crops, the relative changes in the inputs of cost factors for producing the crops, and the relative changes in the prices of the cost factors. This study is made on the assumptions that farmers will have freedom in their choice of cropping systems, and that there will be no great changes in the unit yields of the crops in question, in the inputs of cost factors for producing the crops, and in the prices of cost factors in a short period of farm planning. Since tobacco is the only crop in Taiwan under strict government monopoly and farmers have no freedom of planting, the No. 2 rice cropping system of "tobacco-rice-rice-tobacco" is, therefore, excluded from this study.

Of the 904 farm families who answered our questions in relation to sugar-rice price ratio in this survey in Central Taiwan 3.87 percent were satisfied with the 1:1 ratio; 19.25 percent preferred a ratio of 1:1.1—1:1.5; 19.36 percent preferred that of 1:1.6—1:2.0; 10.84 percent preferred that of 1:2.1—1:2.5; 9.73 percent preferred that of 1:2.6—1:3.0; 4.2 percent preferred that of 1:3.0 upwards; while the remaining 32.74 percent expressed no opinion. In other words, 59.18 percent of them would like to see that the ratio be raised to 1:1.1—1:3.0 and were dissatisfied with the present ratio set by the government. As the sugar industry in Taiwan was protected by the government during the Japanese administration, the sugar price was also supported at a favorable level in order to expand and maintain the production. The present prospect for sugar prices is declining, and, therefore, the ratios of 1:2.0 and above are out of line with the foreseeable situation. On the other hand, the price ratios below 1:1 should be entered into comparison in order to correspond with the market condition. For the

sake of convenience, six different sugar-rice price ratios (1:0.7, 1:0.8, 1:0.9, 1:1.0, 1:1.5 and 1:2.0) were chosen for comparison of their effects on the gross receipts of three sugarcane cropping systems in question.

The comparison as shown in Figure II is made on the assumption that changes in sugar-rice price ratios will result in an increase or decrease of sugar prices, while the prices of rice will remain unchanged. Other factors are assumed to be constant. A change in the sugar-rice price ratio will result in an increase or decrease in the gross receipts of sugarcane cropping systems, while the gross receipts of rice cropping systems will remain unchanged. The curves showing the movement of gross receipts of sugarcane cropping systems are upward or downward, while those of rice cropping systems are horizontal. The formula used for computation of the gross receipts from sugarcane cropping systems following changes of sugar-rice price ratio is as follows:

$$R_{scl:x} = R_{sl:1} \pm (R_{sl:1} \times \%) + R_i$$

$R_{scl:x}$ = Gross receipts from the sugarcane cropping system following changes of sugar-rice price ratio

$R_{sl:1}$ = Total receipts from sugarcane at 1:1 sugar-rice price ratio

R_i = Total receipts from intercrop

$\%$ = Percentage increase or decrease of sugar price following changes of sugar-rice price ratio

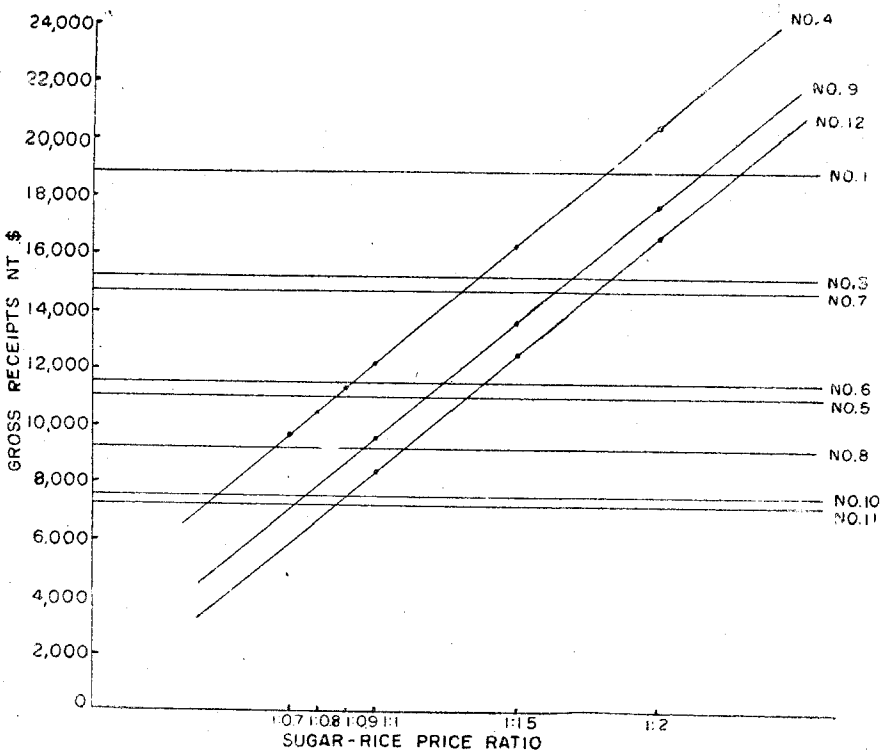


FIGURE 8 : THE MOVEMENT OF GROSS RECEIPTS FROM RICE AND SUGARCANE CROPPING SYSTEMS FOLLOWING CHANGES OF SUGAR-RICE PRICE RATIOS

For convenience of comparison, the three sugarcane cropping systems are classified into two groups according to their degrees of profitableness. The first is composed of the one most profitable sugarcane system, the second is composed of the two less profitable systems. The eight rice cropping systems are classified into four groups with the one most profitable system as the first group, the two next profitable systems as the second, the next three systems as the third, and the two least profitable systems as the fourth. When a comparison is made between the most profitable sugarcane cropping system (fall Hu-tze sugarcane with intercrop flax) and all the four groups of rice cropping systems, it may be seen from the Figure that this sugarcane cropping system is less profitable than the first and second groups of rice cropping systems at the current sugar-rice price ratio of 1:1, but more profitable than the third and fourth groups. When the sugar-rice price ratio is raised to 1:1.8 or upwards, this sugarcane cropping system is preferable to all the four groups of rice cropping systems inclu-

sive. Under the current sugar-rice price ratio of 1:1, the gross receipts from the second group of sugarcane cropping systems are lower than those from the majority of the third group of rice cropping systems, much lower than those from the first and second groups, and more than those from the least profitable group of rice cropping systems. In order to enable the second group of sugarcane cropping systems to compete with the first and second groups of rice cropping system in the use of paddy land, it is necessary to raise the sugar-rice price ratio to a level of about 1:2.0 or upwards.

Taking only the economic factors into consideration, it could be seen that, at the current sugar-rice price ratio of 1:1 the least profitable group of rice cropping systems on the single cropping paddy land could be easily replaced by any sugarcane cropping systems under comparison. In other words, the paddy land used for these two rice cropping systems will be easily converted into sugarcane fields. However, on the double cropping paddy land, nearly all rice cropping systems are more profitable than the sugarcane cropping systems under the sugar-rice price ratio of 1:1. The regulation of this 1:1 price ratio by the Taiwan Sugar Corporation is chiefly for maintaining the sugarcane acreage. But according to the changes of sugar and rice prices in 1951-1956, the price ratio is apparently less than 1:1. Futhermore, the winter crops that are most frequently combined with rice than with sugarcane, such as flax, tobacco, wheat and peas, are all of high economic value, which also tends to place sugarcane in a more unfavorable position to compete with rice in the use of double cropping paddy land in the district in the foreseeable future.

It is easy to understand that under the small subsistence farming conditions that prevail in Taiwan, the relative requirements of cash expenditures in terms of actual dollars in the growing of competitive crops may affect, along with other considerations, the farmers' choice of combination of crops. The requirement of a greater amount of out-of-pocket costs for growing a given crop involves not only the inability of the small farmers to pay the cash expenses, but also represents higher risks in the production of the given crop. Therefore, it can be expected that if other things are equal, farmers will choose the crop or cropping system requiring relatively less cash costs. However, the influence of this factor on the farmers' choice of crops may vary from farm to farm due to variations of the following situations among farms:

a. The availability of capital of the farmers and the ability of the farmers to obtain credit to meet the requirements of cash costs.

b. The willingness of the farmers to take the risks in the production of a given crop.

c. The existance or non-existance of private and public credit facilities accessible to individual farmers and the costs of credit.

In view of the function of a farm to provide employment for the family labor, it can be expected that the relative labor requirements for rice and sugarcane will influence the farmers' choice between these two crops. Under the agricultural conditions in Asia and the Far East, crops of higher returns involve, in the majority of cases, more intensive use of labor. Speaking purely from the standpoint of family labor utilization, farmers tend to choose a crop or cropping system which will provide an outlet for the family labor and at the same time produce more returns to family labor as a whole. However, this factor could be intergrated with and assessed under the previous analysis of relative returns to fixed resources.

A shorter growing period and a quick turnover of capital are relatively important factors causing farmers to choose rice as against sugarcane; sugarcane usually requires a growing period three times as long as one crop of rice. However, the various kinds of loans in cash, fertilizer and sugarcane seedlings extended by the Taiwan Sugar Corporation have reduced this disadvantage of sugarcane growing. This loan program is intended to counterbalance the disadvantage of a long growing season, slow turnover, and production financing in sugarcane production.

Since a farm in Taiwan is characteristcally a food-producing unit for the farm family, the need for family food is definitely a strong factor influencing the farmers' choice of rice growing. As sugarcane is produced solely for market, it involves greater uncertainty of price and market conditions and, therefore, higher risks. The support price program for sugar undertaken by the Taiwan Sugar Corporation is intended to eliminate this price uncertainty of sugar and will have a favorable effect on farmers' choice of sugarcane.

The supplementary relationship in the use of labor in sugarcane growing with other crops is another factor influencing farmers, particularly larger farmers with more land in relation to their family labor supply. The encouragement and persuasion of sugarcane extension agents through their personal friendship and relation with the farmers also induces farmers to grow sugarcane. As rice straw and sugarcane leaves are both good for fuel, feed and building materials, this is not significant in the competition of rice and sugarcane in farmers' choic of crop.

The availabilities of various kinds of resources, such as land, family labor and capital on the farm influence to a geart extent the farmers' choice of rice or sugarcane. While all farmers with small and large acreages of paddy land available will choose to grow rice to meet their family food needs, only farmers with a large acreage of paddy land tend to devote part of their acreage to sugarcane growing in combination with rice, provided sugar price is favorable. It can be expected that farmers with greater quantities of family labor and available capital tend to choose rice cropping systems requiring more intensive uses of labor and capital for the winter crops in the systems, whereas farmers with a more limited family labor and capital supply tend to choose a combination of rice cropping systems including extensive winter crops or without winter crops and sugarcane cropping systems in order to take advantage of supplementary relationship of rice and sugarcane in the uses of labor and capital. Therefore, the actual choice and combination of rice and sugarcane on an individual farm will depend to a great extent upon the relative availability and supply of land, labor and capital resources on the farm in question.

In the previous analysis, emphasis was directed to the discussion of the competitive relationship of rice and sugarcane in Central Taiwan. Uuder the actual situation of farm operation, it should be noted that while crops may be competitive in respect to the use of one factor of production, they may be entirely or to some extent supplementary in respect to the uses of other factors. In fact, rice and sugarcanc are competitive enterprises in the use of paddy land in Central Taiwan in the sense that output of sugarcane can be increased only through a sacrifice of production of rice. However, rice and sugarcane may be considered as supplementary enterprises in the use of labor and capital, as sugarcane requires no labor and capital in the later nine months' period of production. The existance of a competitive relationship in the use of land and a supplementary relationship in the uses of labor and capital between

rice and sugarcane will undoubtedly make the appraisal of individual factors influencing farmers' choice of rice or sugarcane more difficult. In view of this supplementary relationship between rice and sugarcane, it may be profitable under certain conditions for farmers to allocate part of their land to sugarcane in order to make the fullest use of their resources. The farmers' real task in their decision making is not to choose only rice or only sugarcane, but rather to select an optimum combination of rice and sugarcane for efficient use of their resources on the farm as a whole. Therefore, the problem for the farm operator, particularly those with larger acreage of paddy land, presents itself as a question of the combination of rice and sugarcane to be grown on the limited acreage of land and with given quantities of labor, capital and management resources.

The opportunity cost principle is perhaps the most important single factor for consideration in the choice of an optimum crop combination plan. This principle implies that a farmer should, if he wishes maximum returns, use each unit of scarce resources in those crops yielding the greatest return. Given a limited acreage of land, for example, would it pay the farmer to allocate all the land to rice growing, or should he allocate the land to both rice and sugarcane? The final choice, of course, depends on the relative returns from the two crops. The same allocation principle applies to other scarce resources, such as family labor or capital. It usually is not practical to consider the opportunity cost principle for any one resource by itself. Rather, an optimum choice requires that the opportunity cost principle be applied simultaneously to all of the scarce resources. This leads to the use of farm budgeting and linear programming to solve the problems of choice and combination of farm enterprises on the basis of whole farm situations and to the supply of multiple scarce resources.

3. Method of Approach

The presentation and analysis in Chapter IV have been made on the basis of financial returns per unit of land, cash requirements and labor distribution and use of the rice and sugarcane cropping systems as various factors affecting the farmers' choice of rice or sugarcane. Under the actual situations of farm operation in Taiwan, the farmers may not consider each individual factor independently. They may consider simultaneously the supplies of various resources and various factors influencing the farm as a whole and try to maximize the returns to the whole farm for a given planning

period. In addition, the farmers have indicated various other economic and non-economic factors influencing their choice of rice or sugarcane. In view of these situations, the procedure of linear programming may provide a basis for considering simultaneously all these factors in the selection and analysis of optimum crop combinations for the farm as a whole. More specifically, the purposes for the application of linear programming in this study are (1) to demonstrate how this technique could be applied to analyze the crop competition problem in Taiwan, and (2) to develop additional information concerning the competition between rice and sugarcane in particular, and the competition among crops in general in Taiwan.

The procedure of linear programming is a form of farm budgeting. A farm budget is a plan for future use of the farmers' resources. The procedure of conventional farm budgeting is a tool for testing out through a tabulation of comparative returns and expenses a best farm organization plan for the use of farm resources from a series of alternative farm organization plans under comparison. the procedure of linear programming adds a formal mathematical procedure to farm budgeting for selecting more objectively an optimum farm organization which will yield the highest returns to the farm operator under certain specified conditions and input-output coefficients. Essentially, the major difference between these two procedures of farm budgeting is the substitution of objective maximization formulae in the linear programming approach for the subjective research worker's judgment in conventional farm budgeting approach. The application of these formulae insures that the farm organization finally chosen will maximize returns to the farm operator under the conditions set forth by the input-output data and the assumptions given. It is a procedure whereby the one optimum farm organization plan can be selected from among many alternative plans.

The first assumption in linear programming is that production is carried out by processes and there is less than an infinite number of processes amongst which the farmer can choose. A process is a specific way of combining input factors to yield a unit of physical product or value product. A process is defined in respect to (1) kinks of inputs, (2) kinds of outputs, (3) ratios of the inputs to each other, and (4) ratios of inputs to outputs. If two productive processes are the same in these four respects, then they are instances of the same process. In the first part of the following section rice and sugarcane competition is made not on an individual crop basis, but on the basis of a rice or sugarcane cropping system, the term "productive process"

in this section refers to the whole rice or sugarcane cropping system including not only the production of rice or sugarcane, but also the production of winter crops and intercrops, if any, in the respective systems. As there is usually more than one crop in a rice or sugarcane cropping system, the term "output" of a productive process is expressed not in terms of physical yields of individual crops, but in terms of the aggregate value product of the whole cropping system.

The second assumption in linear programming is that a combination of productive processes is chosen which will maximize returns to the farm operator within a given set of restrictions of resources and other considerations. The restrictions may be the amounts of resources available, as land, labor and capital; they may also be certain goals which have priority, as provision of a minimum amount of food for the family may be more important than production of cash crops.

Linear programming obtains its name from the assumptions used in respect to production coefficients. It is assumed that the productive processes are (1) linear, (2) divisible, and (3) additive. Linearity implies constant production coefficients or a linear production function within each productive process. In this study, the term "linear" refers to constant resource requirements per unit of land and constant physical or value output for each additional unit of land, day or labor, or dollar of capital used for a given crop or cropping system. Divisibility implies that the farmers' resources are perfectly divisible within the farm business, and a productive process or cropping systems can be carried on at any positive level as ascertained by the mathematical procedure. Additivity implies that the total returns from a combination of several productive processes are the summation of returns of each individual process in the combination and the total quantity of each resource used is the sum of the quantity of that resource used for each individual process in the combination.

4. Input and Output Data

The linear programming technique requires information of input-output coefficients of each resource used in the rice and sugarcane cropping systems being considered in the selection of the optimum farm organization plan. In the first part of this section an input-output coefficient is defined as the quantity of resources required to produce a gross return of $1,000 output from a specified rice or sugarcane cropping system

when valued at the current prices used in this study. Input-output coefficients are computed on the basis of the raw data obtained from this survey in Central Taiwan for each rice or sugarcane cropping system for the three resources—labor, capital and land. The data on gross returns per hectare and labor and capital requirements per hectare of land from each rice and sugarcane cropping system are shown in Table 14. The cash expenditures of different rice and sugarcane cropping systems are considered as the capital requirements for the respective cropping systems in this study. The labor, capital, and land required per $1,000 gross returns are shown in Table 15.

Table 14. Gross returns and labor and capital requirements per hectare of land for rice and sugarcane cropping systems in Central Taiwan

Cropping system	Cross returns	Labor requirements	Capital requirements
	dollars	days	dollars
No. 1	18,859	643	4,092
No. 2	42,134	1,812	12,503
No. 3	15,189	560	1,936
No. 4	11,396	381	2,318
No. 5	10,971	265	1,570
No. 6	11,561	292	1,732
No. 7	14,701	667	3,827
No. 8	9,252	179	1,216
No. 9	8,732	269	2,012
No. 10	7,555	212	939
No. 11	7,244	175	976
No. 12	7,540	209	1,751

Table 15. Input-output Coefficients of Rice and Sugarcane Cropping Systems In Central Taiwan

Cropping system	Labor requirement per $1,000 gross return	Capital requirement per $1,000 gross return	Land requirement per $1,000 gross return
	days	dollars	hectares
No. 1	34	217	.053
No. 2	43	297	.024
No. 3	37	127	.066
No. 4	33	203	.088
No. 5	24	143	.091
No. 6	25	150	.087
No. 7	45	260	.068
No. 8	19	131	.108
No. 9	31	230	.115
No. 10	28	124	.132
No. 11	24	135	.138
No. 12	28	232	.133

5. Analysis and Interpretation

With the input-output coefficients of various rice and sugarcane cropping systems and the resources available under different individual farm situations, the procedure of linear programming can be used in the selection of an optimum crop choice and combination plan for maximization of returns from given resources.

Paddy land in Taiwan is classified into two kinds: double cropping paddy land and single cropping paddy land. The sugarcane cropping systems Nos. 4, 9, and 12 can be grown on both kinds of paddy land. The rice cropping systems Nos, 1, 2, 3, 5, 6, 7, and 8 with more than two crops or with two rice crops are all practiced on the double cropping paddy land, while the rice cropping systems Nos. 10 and 11 with only one rice crop and one sweet potatoes crop are practiced only on the single cropping paddy land. Separate analysis of crop choice is made for these two kinds of paddy land as their uses are quite different.

For convenience of presentation in the following analysis, each rice and sugarcane cropping system is considered as a productive process represented by a "number". Cropping system No. 1 is represented by P1, cropping system No. 2 by P2, and so on. The input requirements of land, capital and labor for producing $1,000 gross returns of different productive processes are regrouped for the two kinds of paddy land in Table 16.

Table 16. Requirements of land, capital and labor per unit of the productive processes

I. On double cropping paddy land

Resource	P1	P2	P3	P4	P5	P6	P7	P8	P9	P12
Land(hectare)	.053	.024	.066	.088	.091	.087	.068	.108	.115	.133
Capital ($)	217	297	127	203	143	150	260	131	230	232
Labor (days)	34	43	37	33	24	25	45	19	31	28

II. On single cropping paddy land

Resource	P4	P9	P10	P11	P12
Land(hectare)	.088	.115	.132	.138	.133
Capital ($)	203	230	124	135	232
Labor (days)	33	31	28	24	28

One of the advantages of the method of linear programming is that it provides a simple and convenient technique to eliminate successively the inferior productive processes among alternative. From the above table, it can be seen that in the use of double cropping paddy land, process P7 requires more land, capital and labor than the processes P1 and P3. Therefore, P7 is an inferior process and can be eliminated from the alternatives considered. Processes P4, P5, P6, P8, P9, and P12 all require more of both land and capital than the process P3, but their requirements of labor are less. These processes could become a part of an optimum farm organization plan only if labor is limited and land and capital are both unused. Labor will become a limiting factor of P3 if the family labor supply is below 1.4 man-equivalents or 560 man days per hectare of land. On the average, this labor shortage can not occur. According to an island-wide survey of 4,000 sample farms in 1952, the family labor supply averaged 3.21 man-equivalents per farm with an average farm size of 1.27 hectares. Therefore, the average ratio of labor to land is about 3 man-equivalents to 1 hectare. The total family labor supply under the average farm situation is more than enough to meet the total labor demand of P3. The labor available in different crop seasons under the average farm situation is also enough to meet the labor demand of P3 in

different crop seasons. Therefore, since labor is sufficient and no land would be unused, it could be assumed that processes P4, P5, P6, P8, P9, and P12 could also be eliminated from consideration. Based upon the same principle, the processes P9, P11 and P12 could be eliminated from the alternatives in the use of single cropping paddy land. This process of elimination is only true with the current prices used in this study. If the relative prices of crops in the respective cropping systems change, the processes to be eliminate from consideration in the final farm organization program may be different.

Since labor is most likely not a limiting factor in the choice of alternative processes, it is first assumed in the following analysis that the supply of family labor under the average farm situation is in general enough to meet the demand for labor for the cropping systems under consideration. When a check is made on the labor requirements per hectare of different rice and sugarcane cropping systems with the amounts of family labor supply under the average farm situation, it is found that this assumption is in line with the actual situation except in the case of the rice cropping system No. 2 "tobacco-rice-rice-tobacco". However, farmers' freedom of choice of this rice cropping system is limited by government monopoly and limitation of tobacco acreage. Therefore, as a first approximation, this analysis assumes that land is the most important limiting factor on crop choice, and capital second, with a probability that labor might not be limited. An optimum crop choice and combination plan is worked out within these limitations. Then, the labor requirements by crop seasons for the optimum crop combination plan so selected are checked and compared with the available family labor supply of the particular farm situation in question. If the available labor supply is more than enough to meet the demand for labor of the selected crop combination plan, it is apparent that labor is not a limiting factor in the choice of crops. However, if the available labor supply in a given crop season is less than the labor demand in the same season for the selected crop combination plan, it indicates that the selected crop combination plan should be modified due to the additional limitation of labor supply.

The alternative processes for final testing and consideration in the selection of an optimum crop combination plans are, therefore, reduced to only a few processes, as shown in Table 17.

Table 17. Alternative Processes for Final Testing and Consideration

I. In the use of double cropping paddy land

Resource	P1	P2	P3
Land (hectare)	.053	.024	.066
Capital (dollars)	217	127	127

II. In the use of single cropping paddy land

Resoure	P4	P10
Land (hectare)	.088	.132
Capital (dollars)	203	124

From the above table, it can be seen that all sugarcane cropping systems P4, P9 and P12 are eliminated from alternative processes in the use of double cropping paddy land due to their requirements of more of both land and capital resources to produce a given amount of gross returns. The sugarcane cropping system P4 can enter into the alternative processes for final selection in the use of single cropping paddy land. This conclusion is quite in conformity with the analysis in the previous chapter that under the current price and technological conditions in Taiwan, sugarcane is in a definitely unfavorable position to compete with rice in the use of double cropping paddy land. The sugarcane cropping systems with intercrops may compete to a considerable extent with rice in the use of single cropping paddy land. Therefore, the following analysis is made only on choice and combination of rice and sugarcane cropping systems in the use of single cropping paddy land in Central Taiwan.

If a farmer has single cropping paddy land, his choice of cropping systems must be made between the sugarcane cropping system P4 and the rice cropping system P10 or a combination of both P4 and P10 should be chosen. Since the productivity of single cropping paddy land is lower than that of double cropping paddy land, the

availability of capital to the farmer cultivating single cropping paddy land is expected to be more limited than that to the farmer cultivating double cropping paddy land. The labor supply on farm with poor land is also expected to be less. Therefore, the capital and family labor supplies are assumed to be $2,000 and 2.0 man-equivalents respectively for the farmer cultivating 1.0 hectare of single cropping paddy land.

The graphic method of solution is applied to solve the crop combination problem under this farm situation. Figure III shows the solution of the problem. The final crop combination plan, the allocation of land and capital, the levels of different processes and the gross returns are presented in Table 18.

Table 18. Optimum crop combination for 1.0 hectare of single cropping paddy land

Process	Levels of process	Land used	Capital used	Gross returns
P4	8.719	0.76 ha.	$1,770	$8,719
P10	1.854	0.24	230	1,854
Total		1.00 ha.	$2,000	$10,573

Another question that remains to be answered is whether the available family labor supply is enough to meet the labor requirements for the above combination of P4 and P10 in different crop season. To answer this question, it is necessary to compute the labor requirements by crop seasons for the above combination of P4 and P10 at the ascertained levels of operation. Using the information of labor requirements per hectare by crop seasons for P4 and P10 and the hectares of land allocated for P4 and P10 in the above combination, the labor requirements for the above crop combination plan is computed and shown in Table 19.

Table 19. Labor requirements for the optimum crop combination by crop seasons

Process	Land used	First winter season	Spring major crop season	Fall major crop season	Second winter season	Total
	ha.	days	days	days	days	days
P 4	0.76	142.9	86.6	0	60.0	289.5
P10	0.24	2.0	20.2	16.3	12.5	51.0
Total	1.00	144.9	106.8	16.3	72.5	340.5
Available family labor supply		200	200	200	200	800

It can be seen from the above table that the available family labor supply is more than enough to meet the labor demand of the crop combination plan in different crop seasons, and therefore, labor is not a limiting factor in the choice of crops under the given farm situation.

Using the yield data and the amounts of land allocated to P4 and P10, the physical outputs of different crops produced under this crop combination plan are shown in Table 20.

Table 20. Output of various crops produced under the optimum crop combination

Process	P4	P10	Total
Crops grown	Sugarcane with intercrop flax	Rice-sweet potatoes	
Land used(ha.)	0.76	0.24	1.00
Crops produced(kg.)			
Sugar	3,498		3,498
Flax flax	1,895		1,895
seed	418		418
Paddy rice		789	789
Sweet potatoes		2,996	2,996
Gross returns($)	8,719	1,854	10,573

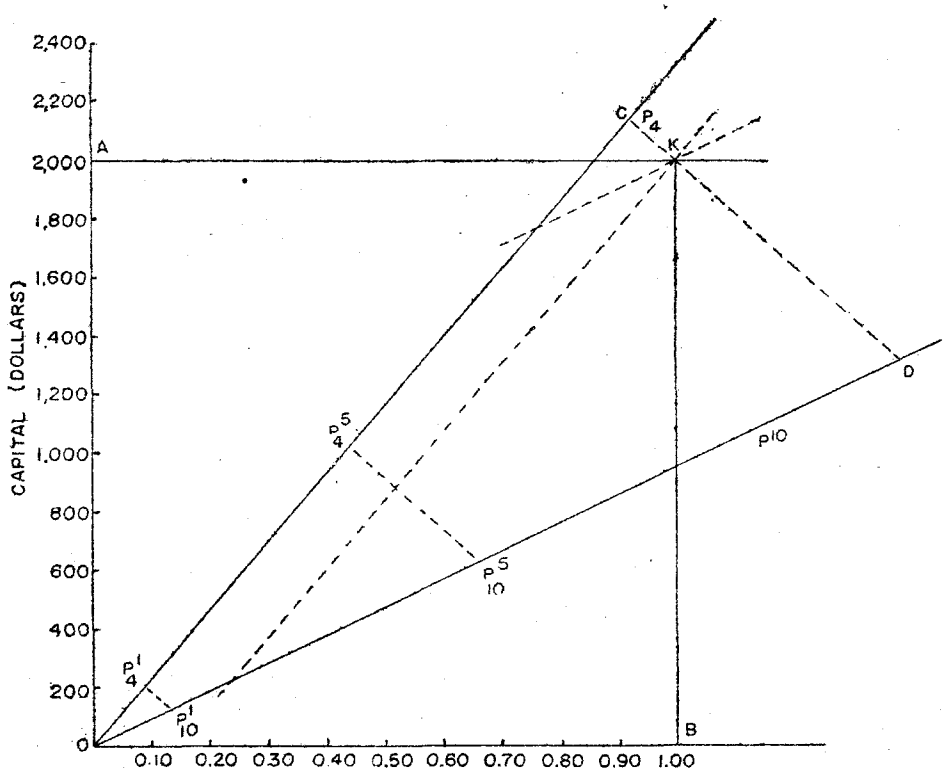


FIGURE III : THE GRAPHIC SOLUTION OF OPTIMUM CROP COMBINATION PROBLEM

It can be seen from the above Figure that when labor is not limitational, an optimum farm organization under the resource combination of 1 hectare of single cropping paddy land with $2,000 of capital includes the combination of the sugarcane cropping system P4 and the rice cropping system P10. Changes in proportion of land and capital resources available will cause changes in the optimum crop combination plan. If the capital available per hectare of land is only $960, the optimum farm organization will include only P10, all land will be used, and the gross returns will be $7,555. If capital is reduced below $960 per hectare, P10 will still be the only process used, but the quantity of land used and the gross returns will be reduced proportionally. If capital exceeds $960 per hectare, P4 will be substituted for P10 at the rate of 0.068 hectare for each $100 of capital, gross returns will increase at the rate of $260 for each extra $100 of capital. If $2,300 of capital per hectare is available, all of the land will be used for P4, with a gross returns of $11,396. If more capital per hectare is available, it will not affect the optimum organization; the capital in

excess of $2,300 per hectare will be left unused. The preceding figures of high returns to capital does not necessarily mean that farmers in Taiwan would be able to borrow money at a high rate of interest under these conditions. The major portion of gross returns from farm production in Taiwan is non-cash receipts which represent computed value of products used by the farm family and could not be used to repay the loans. Farmers may, therefore, consider cash returns to capital instead of gross returns as the yardstick for borrowing money for farm production. Also, more borrowed money used in farm production represents higher risks which small farmers in Taiwan may be reluctant to undertake. Furthermore, the rural banking institution has not been established in Taiwan to channel sufficient funds to the rural areas for the convenience of farmers.

The previous analysis will also apply to farms of different sizes. The proportions in which P4 and P10 will be combined will be determined by the ratio of capital to land.

The relative changes of prices of the crops will affect the optimum farm organization only at some critical points. Within a given range of fluctuation of relative prices of two crops, a given crop may be always more profitable than the other crop in the use of the restricted farm resources. Change in price within this range will produce no effect on the optimum farm organization. However, when change in price is beyond this range, some other crop becomes more profitable and the optimum farm organization will be affected.

From our previous analysis, it is clear that under the present price situation, sugarcane cropping systems can compete with rice only in the use of single cropping paddy land and are excluded from consideration in the use of double cropping paddy land due to their requirements of more of both land and capital to produce a given value of output. However, it may be worthwhile to know what increase in the price of sugar is required in order to enable sugarcane to compete with rice in the use of double cropping paddy land in Central Taiwan. We apply the simplex table in linear programming for illustration and the most profitable rice cropping systems Nos. 1 and 3 and the most profitable sugarcane cropping system No. 4 are put into the simplex table for testing the extent of price increase of sugar required. The rice cropping system No. 2 is excluded from the comparison due to the limitation of farmers' freedom

of choice. The quantities of land and capital available are assumed to be 1.0 hectare of double cropping paddy land and $3,000 respectively, since this farm situation represents fairly well the average farm situation in Taiwan.

Table 21. Simplex Solution—Increase in the Price of Sugar Required.

Original Basis (I)

C		Po	P1 1000	P3 1000	P4 1000	P13 0	P14 0	Po/P3
0	P13	1.00	0.053	0.066	0.088	1	0	15.152
0	P14	3000	217	127	203	0	1	26.622
	Z	0	0	0	0	0	0	
	Z-C		-1000	-1000	-1000	0	0	

First change of Basis (II)

1000	P3	15.152	0.803	1	1.333	15.152	0	Po/P1 18.869
0	P14	1076	115	0	33.709	-1924	1	9.352
	Z	15,152	803	1000	1,333	15,152	0	
	Z-C		-197	0	333	15,152	0	

Final Basis (III)

1000	P3	7.629	0	1	1.098	28.586	-0.007	
1000	P1	9.352	1	0	0.293	-16.730	0.009	
	Z	16,981	1000	1000	1,391	11,856	2	
	Z-C		0	0	391	11,856	2	

The opportunity cost(Z) of one unit level of operation of P4 is $1,391, while it adds only $1,000 of gross returns to the operator. Therefore, substitution of P4 for P1 or P3 into the program will result in a loss of $391 per unit level of operation of P4. Naturally, P4 will be dropped for consideration and excluded from the use of double cropping paddy land. However, if the gross returns from one unit level of P4 could be increased from $1,000 to more than $1,391, or more than 39.1 percent increase in gross returns, P4 will add more returns to the farm organization than P1 or P3. Then, P4 will substitute for P1 or P3 or both and sugarcane will be planted on double

cropping paddy land. The gross returns per hectare of land of P4 are $11,396, of which $7,540, or 66 percent, are contributed by sugarcane and $3,856, or 34 percent, by flax. Therefore, a 10 percent increase in sugar price will produce only a 6.6 percent increase in gross returns of P4. It is necessary for the sugar price to increase by about 60 percent over the current price in order to produce a 39.1 percent increase in gross returns of P4. In terms of the sugar-rice price ratio currently adopted in Taiwan for encouragement of sugarcane planting, the 1:1 ratio between sugar and rice prices should be increased to a level of 1:1.6 in order to enable sugarcane to compete with rice cropping systems P1 and P3 in the use of double cropping paddy land in Central Taiwan. The prospective situation in the sugar market indicates that such a sugar-rice price ratio is unlikely to be supported by the Government. Therefore, it can be expected that the cultivation of rice cropping systems on double cropping paddy land in Central Taiwan is a reasonably stable crop pattern. This method of solution also provides a means for testing the effect of change of price relationship between crops on the stability of the optimum farm organization plan chosen.

In our previous analysis, gross returns of the various processes were used for computing input-output coefficients and analysis of optimum crop combination plan under a given farm situation. Similarly, net returns could also be used. When net returns are used, all that is necessary is to compute various input requirements for producing a given amount of net returns, say, $1,000, $100, or $10 of net returns, and to establish a new set of input-output coefficients on the basis of net returns. The figures in the "price" row in the original Basis of the simplex table are then replaced by the figures of net returns. The figure in the Po column and Z row becomes an indication of net returns of each Basis. The essential procedures and approach of the graphic and tabular methods of solution for optimum crop combination plan are just the same.

In the method of linear programming, the effect of changes of resources available on a farm on the optimum crop combination plan can be measured easily. When the amount of any resource on the farm changes, all that is necessary is to change the resource boundary line in the graphic method of solution or to change the figure indicating the amount of that resource in the Po column of the original Basis in the tabular method of solution. Through the application of these methods and procedures, the effect of changing resources available on the optimum crop combination plan could be easily tested.

The above analysis is made on two limiting factors - - land and capital. If more than two limiting factors are considered simultaneously or resources are further subdivided into periods or crop seasons in the solution of the optimum crop combination plan, the tabular method of solution using the simplex table should be applied.

It is reasonable to believe that labor is in general not a limiting factor in crop choice under the majority of farm situations in Taiwan. However, a particular farmer may have more double cropping paddy land and limited family labor supply. In such a case, the limitation of family labor may justify the farmer to choose sugarcane in combination with the rice cropping systems, since both of the rice cropping systems No. 1 and No. 3 require on the average about 600 man days of labor per hectare, while the sugarcane cropping system No. 4 demands only about 380 man days per hectare. Furthermore, sugarcane requires no labor in the fall major crop season and may supplement rice cropping systems in labor use. Since one man-equivalent will provide about 300 man days of labor per year, or about 400 man days of labor per 16 months' period, it is necessary to have a minimum number of 1.5 man-equivalents per hectare of double cropping paddy land in order to carry out the rice cropping systems No. 1 and No. 3 or their combination. When the family labor supply of a given farm is below the ratio of 1.5 man-equivalents to one hectare of land, the given farmer may include sugarcane in his crop combination plan in the use of double cropping paddy land provided capital is not more limitational than labor. The actual level of combination of sugarcane with rice cropping systems under such farm situations could be worked out by using the simplex table and putting the quantities of land, labor and capital resources into the Po column for final solution of optimum farm organization problem.

To analyze this, we assume a farm with 2.0 hectares of double cropping paddy land, 4 man-equivalents or 1,600 man days of labor and $5,000 of capital. Since the ratio between labor and land is 2 man-equivalents to 1 hectare of land, labor supply will not limit farmers to choose more profitable rice cropping systems No. 1 and No. 3 or their combination. However, when the labor supply is reduced from 4 to 2.5 man-equivalents or 1,000 man days with other resources unchanged, labor becomes a limiting factor on crop choice, and sugarcane cropping system No. 4 will be included in the optimum farm organization plan in combination with the rice cropping systems. This situation is illustrated in the simplex table as shown in Table 22.

Table 22. Simplex Table—Effect of Changing Labor Supply on Rice and Sugarcane Combination

Original Basis (A)

C			Po	P1 F-R-R-C 18859	P3 W-R-R-W 15189	P4 SC-F 11396	P5 0	P6 0	P7 0	Po/P1
0	L	P5	2.00 ha.	1	1	1	1	0	0	2.00
0	C	P6	$5000	4092	1936	2318	0	1	0	1.22
0	M	P7	1000 days	643	560	381	0	0	1	1.56
	Z			0	0	0	0	0	0	
	Z-C			-18859	-15189	-11396	0	0	0	

First Change of Basis (B)

									Po/P3
18859	P1	1.22	1	0.47	0.57	0	0.00	0	2.58
0	P5	0.78	0	0.53	0.43	1	-0.00	0	1.48
0	P7	241.31	0	255.79	16.76	0	-0.15	1	0.94
	Z	23044	18859	8922	10683	0	5	0	
	Z-C	23044	0	-6267	-713	0	5	0	

Second Change of Basis (C)

									Po/P4
15189	P3	0.94	0	1	0.07	0	-0.00	0.00	14.40
18859	P1	0.78	1	0	0.54	0	0.00	-0.00	1.45
0	P5	0.28	0	0	0.40	1	0.00	-0.00	0.70
	Z	28956	18859	15189	11094	0	0.69	24.35	
	Z-C	28956	0	0	-302	0	0.69	24.35	

Final Basis (D)

11396	P4	0.70	0	0	1	2.51	0.00	-0.01
15189	P3	0.90	0	1	0	-0.16	-0.00	0.00
18859	P1	0.40	1	0	0	-1.34	0.00	0.00
	Z	29169	18859	15189	11396	758	0.75	23
	Z-C	29169	0	0	0	758	0.75	23

In the above simplex table, figures in the C row and column indicate gross returns per hectare of the rice and sugarcane cropping systems respectively. Resource supplies are represented in the Po column of the original Basis (A). Other elements except the Z and Z-C rows in the original Basis represent input requirements per hectare of land for the three active processes P1, P3 nad P4 and the three disposal processes P5, P6 and P7. The solution of the problem as shown in the Po column in the final Basis (D) indicates that an optimum crop combination plan involves the operation of P1 at 0.40 level (or about 0.4 hectare of land), P3 at 0.90 level (or about 0.9 hectare of land) and P4 at 0.70 level (or about 0.7 hectare of land) for the realization of $29,169 of maximum gross returns from the given farm resources.

The previous analysis was made on the basis of cropping systems in which the winter crops supplemented with the rice crops in the major crop season were considered to be fixed under the whole cropping system. The supplies of land and labor resources were considered in aggregate terms without specification by periods or crop seasons. Since farmers in Taiwan may have freedom in the choice of winter crops and the supplies of land and labor by crop seasons may influence the farmers' choice of crops, an analysis, as a second approximation, is made under the assumptions that (1) selection of winter crops is open to the farmers, (2) labor is included as a limiting factor in addition to the restrictions of land and capital, and (3) the supplies of land and labor resources are further sub-divided into crop seasons. As flax, shuntang cabbage and wheat are the three relatively profitable winter crops for which farmers have freedom to choose, it is further assumed that farmers can make their choice among these three crops in the winter season. It also is assumed that the farmer is maximizing the returns over cash costs. In other words, it is assumed that the farmer maximizes returns to his land, labor and fixed overhead items.

The basic matrix for this analysis is shown in Table 23. In this analysis a unit level of a process is defined as the use of one hectare of land. The line "C" shows the returns over cash expenses per hectare. The body of the matrix shows the seasons when each crop uses land, the labor used by seasons, and the capital used. Since the solution from the simplex table is a routine operation, only the original Basis is shown here.

Table 23. Simplex Table—Solution of Crop Combination Under the Restrictions of Resources by Crop Seasons

C*	Po*	P1* SC_{no} 5790	P2* SCf 9100	P3* SCsp 6720	P4* R 8030
0	L_{w1}** P8 2.0 ha.	1	1	1	0
0	L_{sf}** P9 2.0 ha.	1	1	1	1
0	L_{w2}** P10 2.0 ha.	1	1	1	0
0	M_{w1}** P11 250 days	105	188	134	8
0	M_{sf}** P12 500 days	25	114	56	150
0	M_{w2}** P13 250 days	79	79	79	22
0	C ** P14 $5000	1750	2300	2000	1220
	Z	0	0	0	0
	Z-C	-5790	-9100	-6720	-8030

$P5_a$* F_a 3300	$P5_b$* F_b 3300	$P6_a$* C_a 3420	$P6_b$* Cb 3420	$P7_a$* W_a 2610	$P7_b$* W_b 2610
1	0	1	0	1	0
0	0	0	0	0	0
0	1	0	1	0	1
160	0	302	0	117	0
0	0	0	0	0	0
0	160	0	302	0	117
550	550	2330	2330	360	360
0	0	0	0	0	0
-330 0	-3300	-3420	-3420	-2610	-2610

* C column .....receipts over cash expenses from the respective productive processes.
Po column.....restrictions of land and labor by crop seasons and of capital for the whole period.
P1 or SCno.....sugarcane with no intercrop.
P2 or SCf .....sugarcane with flax as an intercrop.
P3 or SCsp.....sugarcane with sweet potatoes as an intercrop.
P4 or R .....rice production in the major crop season.
P5a or Fa .....flax production in the first winter season.
P5b or Fb .....flax production in the second winter season.
P6a or Ca .....Shantung cabbage production in the first winter season.
P6b or Cb .....Shantung cabbage production in the second winter season.
P7a or Wa .....wheat production in the first winter season.
P7b or Wb.....wheat production in the second winter season.

** Lw1.....land in the first winter season.
Lsf .....land in the major crop season.
Lw2.....land in the second winter season.
Mw1 .....labor supply in the first winter season.
Msf .....labor supply in the major crop season.
Mw2 .....labor supply in the second winter season.
C.....capital supply for the whole period.

All other figures, except in the Z and Z-C rows, represent input requiriments of land, labor and capital per hectare of land for different processes under consideration. P8, P9,.....and P14 are seven disposal processes for the respective resources. The input requirements of the seven disposal processes are omitted from the table.

An optimum crop combination plan within these restrictions as specified in the Po column of the above simplex table could be worked out through the application of mechanical process of calculation to the solution of the simplex table. While the whole simplex table indicating the changes of Basis is shown in Appendix II, the processes and their levels of operation included in the different changes of Basis of the simplex table are shown in Table 24.

Table 24. Processes and Their Levels of Operation in Different Changes of Basis of the Simplex Table

Original Basis (A)		Second Basis (B)		Third Basis (C)		Fourth Basis (D)	
P	Po	P	Po	P	Po	P	Po
P8	2.00	P2	1.33	P4	0.70	P6b	0.44
P9	2.00	P8	0.67	P2	1.30	P4	0.70
P10	2.00	P9	0.67	P8	0.70	P2	1.30
P11	250	P10	0.67	P10	0.70	P8	0.70
P12	500	P12	348.40	P12	246.80	P10	0.26
P13	250	P13	144.95	P13	131.90	P12	246.80
P14	5000	P14	1941.46	P14	1155.99	P14	138.36
Z	0		12,101		17,451		18,945

Fifth Basis (E)		Sixth Basis (F)		Seventh Basis (G)		Final Baiis (H)	
P	Po	P	Po	P	Po	P	Po
P5a	1.46	P5b	1.29	P7a	2.00	P7b	1.76
P6b	0.68	P5a	1.46	P5b	1.29	P7a	2.00
P4	2.00	P4	2.00	P5a	0.00	P5a	0.00
P8	0.54	P8	0.54	P4	2.00	P4	2.00
P10	1.32	P10	0.71	P10	0.71	P10	0.24
P12	200.00	P12	200.00	P12	200.00	P12	200.00
P14	166.32	P14	1047.50	P14	1131.85	P14	1206.13
Z	23,219		25,135		25,529		25,876

Sugarcane with flax as an intercrop (P2) gives the highest return per hectare of land. As shown in Table 23, the return over cash expenses is $9,100 per hectare. This process is the first brought into the program, since land usually is the most im-

portant limitation. The maximum possible level of operation of this process is 1.33 units; that is, 1.33 hectares of land is used for this process. This amount of P2 uses all of the labor available in the first winter season, but leaves unused a part of all other resources (all other processes P8 through P14 are in the second Basis at a positive level below that of the original Basis). The return over cash expenses is $12,101.

Process P4 (rice) can be added to use the idle land. The level of P2, however, must be reduced to 1.30 hectares to release some labor in the first winter season for preliminary work for rice planting (third Basis in Table 26). The sugarcane and rice now use all of the land during the major crop season, but 0.70 hectare of land is idle in both winter seasons. Some labor is idle in the major crop season and second winter season, and some capital is unused. This addition of rice to the organization increases return over cash expenses substantially, to a total of $17,451.

Since some land and some labor are both unused in the second winter season, and some capital is still unused, shantung cabbage in the second winter season ($P6_b$) could be brought into the program. The maximum level of operation of $P6_b$ is 0.44 hectare due to the restriction of unused labor available in the second winter season. The inclusion of $P6_b$ in the program (fourth Basis) does not affect the levels of operation of P2 and P4 since it does not require release of resources from P2 and P4 for the operation of $P6_b$.

Labor now becomes limitational in both winter seasons. The process $P5^a$ producing lower return per hectare of land but requiring less labor in the winter season replace P2 in the fifth Basis. After the replacement of P2 by $P5_a$, more land and labor are also released in the major crop season and the second winter season, and the levels of operation of P4 and $P6_b$ are both increased. Unused land in the second winter season is also increased. This change of organization increases returns over cash expenses to a considerable extent, to a total of $23,219.

$P6_b$ is replaced by $P5_b$ in the sixth Basis since land in the second winter season is unused and $P6_b$ requires much more labor than $P5_b$, and it produces a little more returns. The replacement of $P6_b$ will release labor in the second winter season required by $P5_b$ to use the idle land. This change of organization increases the return

by about $2,000. Since $P5_b$ requires only about one-fourth of the capital required by $P6_b$, more capital is unused under sixth Basis. Some land is still unused in both winter seasons due to the limitation of labor supply in both winter seasons.

Since labor is still more limitational than land, the processes $P7_a$ and $P7_b$ requiring less labor and producing lower return will finally replace $P5_a$ and $P5_b$ in the final Basis. This change from flax to wheat puts more land into cultivation in the winter season and releases a little capital. The increases in return through these last changes of organization are rather insignificant. The last three Basis might be considered as indifferent organizations so far as returns over cash expenses are concerned. However, as Central Taiwan is the most important wheat region on the island and its wheat acreage is much more than flax acreage, it can be said that the organization in the final Basis could be considered as a representative farm organization under actual farm situation. The final Basis (H) indicates that an optimum farm organization within these restrictions includes the operation of 1.76 hectares of wheat in the second winter season ($P7_b$), 2.00 hectares of wheat in the first winter season ($P7_a$), and 2.00 hectares of rice in the major crop season (P4) for the realization of $25,876 of maximum returns from the given farm resources. The final Basis (H) also indicates that land in the first winter and major crop seasons (P8 and P9) and labor in the first and second winter seasons (P11 and P13) were all used up with 0.24 hectares of land in the second winter season (P10), 200 man days of labor in the major crop season (P12) and $1,206 of capital (P14) left idle.

In the above simplex solution, sugarcane with flax as an intercrop (P2) is finally excluded from the optimum farm organization. Within the restrictions of given resources and under the current price situations, rice in the major crop season supplemented with wheat in both winter seasons will produce more returns to land and labor than the sugarcane process P2. Rice combined with wheat requires the same amount of land in the three seasons as P2, and a little less capital. Wheat supplements very nicely with rice in labor use in both winter seasons. Under these situations, sugarcane is unable to compete with rice in the use of paddy land. When the returns over cash expenses of P2 are increased by more than 45 percent and are greater than the combined returns of rice and wheat, sugarcane will be able to compete with rice to share the use of paddy land.

In the above simplex solution, labor supplies in both winter seasons are most limitational. Therefore, the processes $P7_a$ and $P7_b$ both producing lower returns per hectare but requiring less labor in the winter season are included in the final optimum farm organization. However, when labor supplies in both winter seasons are increased from 125 man days per hectare of land to more than 180 man days per hectare, the processes $P5_a$ and $P5_b$, both producing higher returns but requiring more labor in the winter season, will replace $P7_a$ and $P7_b$ in the final optimum farm organization. When the ratios among resources are increased to $5,900 of capital and 320 man days of labor per hectare of land, $P6_a$ and $P6_b$ might be included in the final optimum organization. Therefore, change in proportions of resource combinations will cause changes in optimum farm organization plan.

As a third approximation, it may be worthwhile to consider how the restrictions of land, labor and capital on crop choice and combination could be defined even more realistically under the farm situations in Taiwan. In the case of land, farmers in Taiwan may have three kinds of land on the farm: double cropping paddy land, single cropping paddy land and dry or non-irrigated land. Since these three kinds of land are not homogeneous and the uses of them are quite different, they should be defined as different resource categories. If each kind of land is further sub-divided into one major and two winter crop seasons, there is a total of nine categories of land resource to be considered in the simplex solution. Furthermore, each kind of land on the farm is usually further divided into several small plots which seldom lie next to one another. Each small plot of land is generally cultivated as a technical unit, and in the majority of cases, further sub-division of this small plot of land for more than one productive process is not practical from the standpoint of farm operation. Therefore, the assumption of divisibility of land in linear programming approach should be modified. The small plot of a given kind of land may be considered as a unit to be used for a given productive process. In the linear programming approach, the divisibility of land must be assumed. The result of solution of land allocation under the optimum farm organization could be checked with the units of small plot of a given kind of land. If the linear programming solution indicates that the major portion of a given small plot of land be used for crop A and minor portion for crop B, it may be advisable for farmer to use the whole small plot for crop A and none for crop B under actual farm operation. Also, a computation of returns could be made under the plan to use whole of a small plot for crop A which could be compared with the

returns under optimum organization through linear programming solution. If the difference in returns is insignificant, it can be concluded that further sub-division of the small plot for two processes is not worthwhile in actual farm operation. However, if the difference in returns is rather significant, farmers should be advised to use their small plot of land for two processes even if it may involve some inconveniences in farm operation.

In the case of labor, it is believed that in terms of total labor supply, labor is not a limiting factor on crop choice in the majority of farm situations. However, when labor supply is divided into months, labor may become a limiting factor in the choice of a crop requiring heavy labor demand in a given month. When the family labor supply on a farm decreases, the number of months in which labor is limiting may increase. Under the farm situations in Taiwan, labor supplies during the busy seasons of farming (February-March, May-July, and October-November) are most likely to be limiting factors in the choice of certain crops or cropping systems. In such a case, labor supply in the limiting months during the busy crop seasons might be put into the Po column of the simplex table as additional restrictions in the selection of optimum farm organization.

As the majority of labor supply on farms in Taiwan is family labor and the members of family are usually willing to work longer hours per day as required by the farm work during the busy season, the limitation of labor supply is more flexible than that of land. If the farmers in general are willing to work 12 hours per day during the busy month, while under normal situations, the farmers usually work 10 hours per day, the labor supply in the busy month as shown in the Po column may be inflated by 20 percent to relax the restriction of labor in the given month.

Different crops or cropping systems usually require capital in different periods. In the case of a cropping system, the first crop in the system may generate some capital to meet the demand for capital of the following crop. The restriction of capital on crop choice could be defined more realistically if supply of capital of a farm and demand for capital of the crops are further divided into periods. The capital generated by the previous crops and other farm enterprises and the loans made available by the credit or public institutions for extension of a given crop should be included in the supply of capital in the respective periods. However, it can be expected that the res-

triction of capital is even more difficult to define than that of land and labor, since the capital for family use and for farm production is interchangeable. With unexpected emergencies of the family, capital originally planned for farm production is used for family purposes. On the other hand, some money might be transferred from family use to farm production when the price expectation of a given farm enterprise becomes favorable.

As a fourth approximation, it is necessary to consider how the farmers' consideration of family food and the relative risks in different crop production could be included in the linear programming solution of optimum farm organization in Taiwan. Since farms in Taiwan are generally characterized by self-sufficiency of food supply for the family, farmers may consider the production of a minimum amount of rice to meet their own requirements as the paramount function of farm planning. Under such a farm situation, farmers may put a relatively higher subjective value than the going market price on rice produced for home consumption. The difference of these two prices depends to a great extent upon the convenience of selling sugar and buying rice from the local market. It is, therefore, necessary to have an extra increase in the level of sugar price in order to induce farmers to sacrifice the production of home-use rice for sugarcane growing. In working out an optimum choice and combination of rice and sugarcane for the farmers, this minimum amount of rice production should be guaranteed and provided beforehand. The method of linear programming could be applied to take this factor into consideration. This can be illustrated by using the problem presented in Table 23. A part of this Table, with some modifications is presented in Table 25.

Table 25. Simplex Table—Provision of Minimum Amount of Rice Production for the Family

C		P0	P1 SCno 5790	P2 SCf 9100	P3 SCsp 6720	P4a Rs 8030	P4b Rh 12660
0	Lw1	P8 2.00 ha.	1	1	1	0	0
0	Lsf	P9 2.00 ha.	1	1	1	1	1
0	Lw2	P10 2.00 ha.	1	1	1	0	0
0	Mw1	P11 400 days	105	188	134	8	8
0	Msf	P12 800 days	25	114	56	150	150
0	Mw2	P13 400 aays	79	79	79	22	22
0	C	P14 $5000	1750	2300	2000	1220	1220
0	M.R.R.	P15 2660kg.	0	0	0	0	6000
		Z	0	0	0	0	0
		Z-C	-5790	-9100	-6720	-8030	-12660

The following modifications have been made:

(1) The process P4 or R in Table 23 is divided into two processes $P4_a$ or R_s and $P4_b$ or R_h in Table 25. $P4_a$ or R_s represents the process of rice production for sale, and its returns are computed on the basis of going market price of rice; $P4_b$ or R_h represents the process of rice production for home use, and its returns are computed on the basis of a subjective value of the farmer (here this is assumed to be a price 50 percent higher than the going market price of rice.)

(2) One more row M.R.R. is added to the simplex Table. M.R.R. represents the minimum rice requirements for the family for the whole period of 16 months. The figure of 2660 kgs. represents the amount of minimum paddy rice requirement, and is computed on the basis of 200 kgs. of paddy rice requirement per person per year and 10 persons in the family with 2.0 hectares of paddy land. The figure in M.R.R. row and under $P4_b$ column, 6,000, represents the yield of paddy rice per hectare of land in the Spring and Fall major crop seasons.

(3) One more disposal process P15 is added.

Since the minimum amount of rice required is put into the Po column of the

simplex table as an additional limitation to the solution of the optimum crop combination plan and the return of $P4_b$, process for the production of rice for home use, is raised subjectively to a high level, the solution of the simplex table will insure, at the current levels of the prices of competing crops, the inclusion of the process for the production of a minimum amount of 2660 kgs. of paddy rice for home use in the final optimum crop combination plan. The figure indicating returns as shwon in the Z row and Po column in the final Basis of the simplex table does not represent the actual financial returns to the farmer since it includes the subjective value of home-use rice which should be subtracted from the total returns. Therefore, in addition to the minimum output of rice for home use, the total returns will be the summation of returns from other active processes except $P4_b$ included in the final optimum farm organization plan.

It is a common knowledge that risk in sugarcane production is usually greater than that of rice production which is another factor discouraging farmers from choosing sugarcane and influencing the competition between rice and sugarcane. In fact, risk in crop production represents an item of cost. However, the magnitude of this cost depends to a great extent upon the subjective valuation of individual farmers and could not be determined objectively in monetary term. It is, therefore, rather difficult to include the consideration of risk in crop production in the linear programming solution of optimum farm organization. However, it might be possible to consider the factor of risk by making either one of the following two adjustments in the simplex table.

(1) Since risk represents an item of subjective cost of crop production, the returns as shown in the C row under the respective processes producing the crops with higher risks could be adjusted by discounting. The adjusted returns are used to replace the original returns for the simplex solution. The higher the risk, the greater the discount made on the returns. However, it involves the subjective judgment of research workers or farmers as to the amount of discount to be made.

(2) Since risk represents one kind of uncertainty and higher cost of crop production, farmers, in view of higher risk, may set a maximum limit in the growing of a given crop with higher risk even if the price of the crop is favorable. For example, a farmer in Taiwan with 2.0 hectares of paddy land may set 1.0 hectare for sugarcane

growing as the maximum even if the price of sugar is much higher than that of rice. In such a case, the maximum acreage set by the farmers for a given crop with higher risk could be put into the Po column as an additional restriction for the simplex solution.

CHAPTER VI

SUMMARY AND CONCLUSIONS

As rice and sugarcane are the two most important crops in the economy of Taiwan, competition between them in the use of farmers' resources, particularly paddy land, has long been considered as an important farm organization problem of individual farmers. The competition is particularly keen in Central Taiwan, because the major portion of cultivated land in the district is paddy land which can be used for cultivation of both rice and sugarcane.

This study is made from the viewpoint of the individual farmers in maximizing their returns. The major purposes of this study are (1) to apply cost and income data as a basis for making an interpretation and analysis of the factors influencing farmers' choice of rice and sugarcane and the possible responsiveness of farmers in the planting of rice and sugarcane which might be expected to follow changes of sugar-rice price ratios, and (2) to apply the limited input-output data as a basis for making an analysis of choice and combination of rice and sugarcane cropping systems on individual farms for optimum allocation and efficient use of farmers' limited resources.

The lengths of time required for growing rice and sugarcane are very different. The growing period of rice usually takes about 4 months for one rice crop, while that of Hu-tze sugarcane takes generally about 16 months. Also, these crops are grown in cropping systems including intercrops or other minor crops. Rather than a simple choice between rice or sugarcane, farmers make their choice and decisions between a rice cropping system or a sugarcane cropping system. Hence, study of rice and sugarcane competition should not be made of the two crops alone, but of cropping systems including rice or sugarcane respectively as the principal crop.

There are two kinds of paddy land in Taiwan; (1) double cropping paddy land which has sufficient water during the year to grow two rice crops, and (2) single cropping paddy land which is limited by water supply to grow only one rice crop supplemented usually with one sweet potatoes crop during the year. The competition between rice and sugarcane on these two kinds of paddy land is, therefore, different.

Three major sugarcane cropping systems and nine major rice cropping systems with a growing period of 16 months have been chosen for this study. The three sugarcane cropping systems could be practiced on both kinds of paddy land, while seven rice cropping systems could be practiced on double cropping paddy land and two rice cropping systems on single cropping paddy land. The rice cropping systems can not be interchanged between the two types of paddy land.

The relative profitableness of rice and sugarcane cropping systems provides an indicator for the farmers in the choice of rice or sugarcane. One useful way to compare the relative profitableness of competitive crops or cropping systems is by their relative returns. On the basis of the comparison of gross returns, net returns, and returns to fixed resources on the farm, this study reveals that under the present technical and price conditions in Central Taiwan, the rice cropping systems supplemented with winter crops, particularly flax, tobacco and wheat, yield higher returns than sugarcane in the use of double cropping paddy land in the district. As land in Central Taiwan is relatively fertile and irrigation facilities are available, farmers usually plant winter crops to supplement two rice crops in the year. The addition of winter crops in the double rice cropping systems is a very important factor in favor of rice against sugarcane in the competition for the use of double cropping paddy land in the district. From the standpoint of relative returns per unit of land, it is better for the farmers to devote their double cropping paddy land for rice cropping systems. Single cropping paddy land could be devoted to sugarcane growing if intercrops are planted with sugarcane.

As cash expenditures for crop production are out-of-pocket costs to the farmers which involve not only farmers' inability to pay, but also represent risks in crop production, there is a general tendency for farmers in Taiwan to choose those crops or cropping systems which require the least cash expense when other factors are not involved. The requirement of a greater amount and higher percentage of cash expenses by the rice cropping systems when supplemented with winter crops is a counterbalancing factor in favor of sugarcane against rice in the farmers' choice of cropping systems.

As the supply of family labor is usually constant throughout the year in the majority of farm families in Taiwan, farmers, after considering the competitive and

supplementary relationships among crops, tend to choose a cropping system or a combination of cropping systems which will provide the best opportunity for the full use of their family labor throught the year. The rice cropping systems with intensive or extensive crops in the winter give an outlet for the employment of more family labor than the sugarcane cropping systems under comparison, which places rice in a favorable position to compete with sugarcane in the use of farmers' paddy land in the district.

The survey shows that the most important economic factors affecting farmers' choice of rice are (1) shorter growing period and quick turnover, (2) more return from rice than from sugarcane, and (3) additional returns from winter crops, while the non-economic factors are (1) for family food, (2) for payment of land taxes in kind, and (3) for barter of fertilizer with rice. The most important economic factors affecting farmers' choice of sugarcane are (1) availabilities of cash, fertilizer and sugarcane seedling loans from the Taiwan Sugar Corporation for sugarcane planting, (2) more opportunity to meet the demand for labor for the farm as a whole, and (3) less production expenses in growing sugarcane, while secondary considerations are (1) use of sugarcane leaves and residues for fuel, feed and building materials, (2) encouragement of sugarcane extension agents, and (3) lack of irrigation.

The survey also shows that farm size is a definite factor affecting farmers' choice of sugarcane. It is necessary for the farmers to have a farm of considerable size in order to be able to choose sugarcane. The larger the size of farm, the greater the tendency of farm families to plant sugarcane, while the smaller the size of farm, the greater the tendency of farm families to plant rice.

Farmers' choice of rice or sugarcane is not only determined by the relative earning capacity of rice or sugarcane, but also influenced to a great extent by the relative availability of scarce resources under the command of a given farmer. Farmers are compelled to make their decision within the restrictions of resources and alternative productive processes available to them. Their real task in decision-making is not to choose only rice or only sugarcane, but rather to select an optimum farm organization plan for efficient use of their resources on the farm as a whole. In this respect, the method of linear programming provides an effective tool for consideration simultaneously of the opportunity cost principle to all of the scarce farm resources, and

could be applied to determine an optimum choice and combination of rice and sugarcane on the farm within the restrictions of given resources. Furthermore, the farmers have indicated that other factors affect their choice of rice or sugarcane. Linear programming may provide a basis for including these factors in the analysis. This methed could also be used to appraise the effects of changing the relative quantities of scarce resources and price relationships on the competition between rice and sugarcane. More specifically, the purposes for use of linear programming in this analysis are (1) to demonstrate how this technique could be applied to analyze the crop competition problems in Taiwan, and (2) to develop additional information concerning competition among crops.

Both through the comparison of relative returns per hectare of land and the elimination of inferior productive processes in linear programming approach, it is obvious that under the present price and technological conditions in Central Taiwan, sugarcane is in a definitely unfavorable position to compete with rice in the use of double cropping paddy land. All sugarcane cropping systems are inferior productive processes requiring more of both land and capital to produce a given amount of value output than the preferred rice cropping systems, and therefore, could not enter into a farmer's optimum farm organization plan. However, sugarcane with intercrops may compete to a considerable extent with rice in the use of single cropping paddy land and can enter into the alternative processes for final selection of an optimum crop combination plan. As a first approximation, analysis is made under the assumptions that land is the most important limiting factor, and capital second, with a possibility that labor might not be limited. An optimum crop choice is worked out by using the graphic method of solution in linear programming. It has been ascertained that in the use of single cropping paddy land, an optimum farm organization plan involves generally a combination of rice and sugarcane cropping systems. Therefore, sugarcane can compete with rice to share the use of farmers' single cropping paddy land.

It is worthwhile to know what increase in the price of sugar is required to enable sugarcane to compete with rice in the use of double cropping paddy land in Central Taiwan. Taking the gross returns per hectare of land as a yardstick, it is necessary for the price of sugar to incresse by 80 percent over the current price level (a sugar-rice price ratio of 1:1.8) in order to equate returns from the most profitable sugarcane cropping system, No. 4, with returns from the most profitable rice cropping

system, No. 1. However, when tested by the tabular method of solution in linear programming, it is found that in the use of double cropping paddy land, an optimum farm organization involves a combination of the most and the second most profitable rice cropping systems No. 1 and No. 3. A little more than 60 percent increase in the price of sugar (a sugar-rice price ratio of 1:1.6) will enable sugarcane to substitute for either of these two rice cropping systems in the simplex table, and sugarcane will enter into the optimum farm organization plan to share the use of farmers' double cropping paddy land.

Since the most and the second most profitable rice cropping systems Nos. 1 and 3 both require more labor than the most profitable sugarcane cropping system No. 4, it is necessary for farmers to have a minimum number of 1.5 man-equivalents per hectare of double cropping paddy land in order to carry out the rice cropping systems. Sugarcane may be included in the farmers' optimum farm organization plan to share the use of double cropping paddy land if the family labor supply of a given farmer is below this minimum ratio between labor and land.

As a second approximation, analysis is made under the assumptions that (1) selection of winter crops is open to the farmers, (2) labor is included as a limiting factor in addition to the restrictions of land and capital, and (3) the supplies of land and labor are divided into crop seasons. The tabular method of solution in linear programming using the simplex table is applied to the solution of optimum farm organization problem. The final optimum farm organization involves the operation of rice production in the major crop season and wheat production in both winter seasons since wheat requires least labor among the three most profitable winter crops.

As a third approximation, considerations are directed to define even more realistically the restrictions of land, labor and capital under the farm situations in Taiwan. In the case of land, different kinds of land can be defined as different resource categories and the small plot of each kind of land can be considered as a unit to be used for a given productive process. In linear programming approach, the divisibility of land could be first assumed. The result of the solution of land allocation among processes could be checked with the units of various small plots of land. Returns from optimum farm organization through linear programming solution could be compared with returns by using the small plot of land as a unit in order to

determine whether it is significant to make further sub-division of land for more than one productive process. In the case of labor, the restrictions of labor supplies in the limiting months during the busy crop seasons can be considered, and the farmers' willingness to work longer hours during the busy crop season can be included in order to relax the restrictions of labor in the respective months. In the case of capital, the capacities of capital generation of the previous crops in a cropping system can be included in the supply of capital in the respective periods. Loans made available to the farmers for crop extension can be also included in capital supply. The interchangeableness between capital for farm production and funds for family purposes should be considered.

As a fourth approximation, considerations are given to include farmers' requirements of minimum rice production for family food and relative risks in crop production in linear programming approach. Since farms in Taiwan are generally characterized by self-sufficiency of food supply for the family, farmers may consider the production of minimum amount of rice to meet their own requirements as the paramount function of farm planning. The procedure of linear programming could be applied to take this factor into consideration by (1) putting the minimum rice production into the Po column of the simplex table as an additional restriction, and (2) placing a relatively high subjective value on the rice produced for home consumption and adjusting its returns to a higher level. The solution of the simplex table will guarantee the production of a minimum amount of rice for home use.

Risk represents an item of cost in crop production and uncertainty in its yield and income. Risk in crop production could be considered in the simplex solution by making either one of two adjustments in the simplex table: (1) the returns as shown in the C row under the respective processes producing the crops with higher risks could be adjusted by discounting to counter-balance the cost of risk, and (2) putting a maximum limit of acreage for the growing of a given crop with higher risk in the Po column as an additonal restriction in the simplex solution, since farmers, in view of higher risk, may set a maximum limit in the growing of a given crop even the price or income from that crop is favorable.

APPENDIX I.

EXAMINATION OF ASSUMPTIONS AND APPLICABILITY OF LINEAR PROGRAMMING TO FARM MANAGEMENT STUDIES IN TAIWAN*

Linear programming as applied to farm management studies can be defined as a technique by which either an optimum choice and combination of farm enterprises could be worked out for maximization of returns, or an optimum combination of inputs for producing a given output could be worked out for minimization of cost both under certain restrictions of resources and other specified conditions. In the last few years, this newly-developed method of linear programming has been widely applied to farm management research in several countries, and its application has produced valuable results in the literature and practical application of agricultural economics. It has also proved that this method as a refinement of conventional farm budgeting approach is an useful and effective tool in farm management research to deal with the problems of optimum crop and livestock combination and resource use of the individual farmers and other problems of production economics and regional analysis in agriculture. This paper is intended to (1) examine the validity and limitations of the assumptions underlying linear programming approach under Taiwan's agricultural conditions, and (2) determine and appraise the extent and limitations of applicability of linear programming to farm management studies in Taiwan.

I. Examination of Assumptions in Linear Programming under Taiwan's Agricultural Conditions.

The method of linear programming is formulated under a given set of essential assumptions. The application of this method to farm management studies requires the

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fulfillment and satisfaction of these assumptions under the actual farm production situations investigated. Therefore, an examination of these assumptions is the first essential step for the practical application of this method to farm management research.

The first assumption in linear programming is that production is carried out by processes and there is less than an infinite number of productive processes among which the farmer can choose. A process is generally defined in respect to (1) kinds of inputs, (2) kinds of outputs, (3) ratios of the inputs to each other, and (4) ratios of inputs to outputs. If two productive processes are the same in these four respects, then they are instances of the same process. In the linear programming approach, change in a production organization is not by substitution between input factors, but by substitution between productive processes. Under Taiwan's farm conditions, a process may refer to either one of the following productive activities:

1. A process may refer to the production of a given crop or a given class of livestock using a given practice or method of production. Different practices or methods for producing a given crop or for raising a given class of livestock may be considered as different processes.

2. Since crops in Taiwan are usually grown in cropping systems including inter-crops or other minor crops, a process may refer to the whole cropping system including the production of the major crops and minor crops in the system using a given method of production. Different methods used in producing a given cropping system may also be considered as different processes.

3. Since a farm in Taiwan is characteristically a food-producing unit for the farm family, farmers may place a relatively higher subjective value than the going market price on the portion of food crops produced for family consumption. Therefore, the production of a given food crop even using same method of production may be divided into two different processes due to the difference in farmer's valuation of different portions of the physical output. For example, rice production for home use may be considered as one process in which the value of rice is placed at higher than going market price, while rice production for sale may be considered as another process in which the rice is valued at going market price. This same procedure can be applied any time when the producers face a down-sloping demand curve. However, it is more

convenient to apply this procedure if the demand curve is a step-wise downsloping one.

It is reasonable to assume that the technological cendition in agricultural production in Taiwan is relatively more static than in the western world, and that within a short period of farm planning, farmers in a relatively homogeneous agricultural region usually follow a relatively uniform method of production, or at least follow uniform practices in the major aspects of the method of production for a given farm enterprise. Therefore, a process is better defined in terms of production of different crops or livestock using a given customary or improved method of production in the area. In a given agricultural region, the kinds of crop and classes of livestock among which the Taiwan farmers can choose are always limited in number. The assumptions in linear programming that production is carried out by processes and that there is less than an infinite number of processes among which the farmer can choose are valid under Taiwan's farm conditions.

The second assumption in linear programming is that a combination of productive processes is chosen which will maximize returns to the farm operator within a given set of restrictions of resources and other considerations. The restrictions may be the amounts and qualities of resources available, as land, labor and capital; they may also be certain goals which have priority, as provision of a minimum amount of rice production for the farm family may be more important than production of cash crops. They may also be the qualities of management as indicated in the choice of input-output coefficients. Agricultural production in Taiwan is generally diversified, and an ordinary farm plan involves usually a combination of several crops for fullest use of farm resources which will maximize returns to the farm operator. Linear programming is usually directed to maximize returns or minimize cost in farm production. Since under Taiwan's agricultural conditions, farms and the farmer's family are mixed up into a single composite unit for faming and living together, and the main purpose of farming is to provide employment opportunity for the members of the farm family in order to earn a living for the family, one may argue that farmers in Taiwan are interested only in maximizing their satisfaction. However, as there is in existance a convenient local market for trading farm products, return maximization is still the primary goal for farming as a means for satisfaction maximization. But the problem is more complex under Taiwan's farm conditions. Use of crops or by-

products for home consumption may have values above market price. These could be handled as previous case of rice for home consumption.# Therefore, the second assumption in linear programming that a combination of productive processes is chosen which will maximize returns to the farm operator within a given set of restrictions of resources and other considerations is valid under Taiwan's farm conditions, but it may not be feasible for widespread use.

The third assumption in linear programming is that the productive processes are (1) linear, (2) divisible and (3) additive. Linearity implies constant production coefficients or a linear production function within each productive process. The assumption of linearity is one of the important conditions in linear programming approach. It implies also constant returns to scale of operation or no economies of large-scale operation. Under many production situations, it is quite reasonable to assume the proportionality of input and output relationship and constant returns to scale of operation. It is, therefore, not too bad to assume linearity over the relevant ranges of the production functions. Amounts of raw materials or input factors per unit of output in many productive activities are quite constant. If all input factors are variable and could be increased proportionally with each other as indicated by the technical coefficients, the assumption of linear production function is likely to hold. However, the situation under which some input factors could not be varied while other factors vary might lead to decreasing returns. Therefore, the reason to depart from linear assumption in linear programming is due to the fixity of some input factors. In the linear programming approach, it is assumed that the production is carried out by processes, and each process is represented by a given combination of scarce inputs for one unit level of operation. Other non-scarce inputs could be used and combined proportionally as required by the technical coefficients of production. When all input factors of a given process are varied proportionally to the levels of operation, the assumption of linear production function is valid under such condition. The assumption of linear production function is particularly true under Taiwan's farm condition since the possible range of variation of the scale of operation of each farm enterprise is relatively small due to the limited availabilities of land and capital resources. Over a wide range of the scale of operation of a given farm enterprise, the curve

A bigger problem is that it is rather difficult to access and define accurately the subjective value of individual farmers to be placed on the portion of products for home consumption. The secondary problem is that it increases computational burden in linear programming approach.

indicating the functional relationship between returns and inputs may show some degree of curvature. However, within a relatively small range of variation of scale, the curve may be considered as a straight line indicating a linear function of production. A farmer's managerial ability in Taiwan is also likely to be able to manage each farm enterprise and their combination within a relatively small range of variation of scale of operation, and therefore, the fixity of management will not cause decreasing returns from farm production in Taiwan. Furthermore, even under the situation of diminishing returns, the method of linear programming can be used by defining the productive activitites with different levels of returns as different processes in the system.

Divisibility of the productive processes implies that the farmers' resources are perfectly divisible within the farm business, and a productive process can be carried on at any positive level as ascertained by the mathematical procedure of computation in linear programming. Each process is perfectly divisible as far as its participation in the final optimum farm organization is concerned. Land, labor and capital can be allocated between farm enterprises in very small units. Under farm conditions in Taiwan, each kind of land on the farm is usually further divided into several small plots which seldom lie next to one another. Each small plot of land is generally cultivated as a technical unit, and in the majority of cases, further sub-division of this small plot of land for more than one productive process is not practical from the standpoint of farm operation. Therefore, the assumption of divisibility of land in linear programming approach should be modified. The small plot of a given kind of land may be considered as a unit to be used for a given productive process. In the linear programming approach, the divisibility of land must be assumed. The result of solution of land allocation under the optimum farm organization could be checked with the units of small plots of a given kind of land. If the linear programming solution indicates that the major portion of a given small plot of land be used for crop A and minor portion for crop B, it may be advisable for the farmer to use the whole small plot for crop A and none for crop B. Also, a computation of returns could be made under the plan to use whole of a small plot for crop A which could be compared with the returns under optimum farm organization through linear programming solution. If the difference in returns is insignificant, it can be concluded that further sub-division of the small plot for two processes is not worthwhile in actual farm operation. However, if the difference in returns is rather significant, farmers should be advised to use their

small plot of land for two processes even if it may involve some inconveniences in farm operation.

Under the farm conditions in Taiwan, the divisibilities of labor (in terms of working days or hours) and capital (in terms of dollars of working capital) are consistent with the assumptions in linear programming approach. However, skilled farm labor and specific kinds of capital equipment may involve difficulties. Skilled man-labor for curing tobacco leaves and certain kinds of farm implements are cases in point. Here a step-wise expansion line rather than a straight, smooth curve of a production function may be involved. Fortunately, under the actual situation of farm operation in Taiwan, skilled farm labor is an exception rather than a rule, and the majority of the farm implements are small in nature, particularly when compared with those used in the United States. Furthermore, most of the farm implements could be used for the cultivation and operation of various farm enterprises in Taiwan. The majority of farm equipment in Taiwan is general-purpose type rather than special-purpose. Therefore, the discrepancy of the assumption of divisibility due to the step-wise discontinuous expansion line of capital equipment is less serious. Even though some capital equipment may show lumpiness, their services are still divisible through the organization of utility cooperatives or by rental arrangement. Only when capital is a limiting factor, may this step-wise expansion line have adverse effects on linear programming approach.

Additivity of the productive processes implies that the total returns from a combination of several productive processes are the summation of returns of each individual process in the combination and the total quantity of each resource used is the sum of the quantity of that resource used for each individual process in the combination. Additivity assumes that the productive processes in the combination are independent of each other and that there are no complicating interactions among the productive processes in the combination. This assumption also denies the complementary and antagonistic relationships between farm enterprises in agricultural production. Since complementary and antagonistic relationships are in existence between some farm enterprises in Taiwan, this assumption of additivity and independence of the productive processes may involve some difficulties in the application of linear programming. Therefore, an application of linear programming to study farm production problems in Taiwan necessitates a careful examination and definition of the productive processes to insure their independence and additivity. If there are important interactions between

enterprises, it is necessary to define those enterprises in terms of joint processes. Any violation of this assumption of additivity is one of the reasons why linear programming may not select the best combination of farm enterprises for a farm.

The fourth assumption in linear programming is that the availabilities of at least some resources on the farm are limited in both quantity and quality, and the choice and combination of the productive processes can be carried out only within the restrictions of the limited resources. Under the farm conditions in Taiwan, two aspects of this assumption are important: (1) there are definite physical limit to the amounts of some resources which a farmer holds or can obtain in the short run period of farm planning. These are rigid limitations to the supply of land, spaces of farm buildings, large farm equipment and skilled labor, (2) as more resources are used the unit cost of the resources may increase, thus making it unprofitable for the farmer to buy or hire additional resources. These are flexible limitations, such as the uses of capital and hired labor; the farmers need to pay higher rate of interest and higher rate of wage to obtain additional capital and labor. Hence, these limitations tend to be somewhat ill-defined. But the application of the linear programming approach requires that the research workers specify the limits of the restrictions.** This is important because the choice of farm enterprises and their combination in the final optimum farm organization are functions of the amounts of resources available as well as the productivities or earning capacities of the productive processes. Under the actual situation of farm operation, some resources do not lend themselves too well to the restriction of rigid limitations. For example, capital and labor are usually available at increasing rates of interest and wage. However, in many cases, financial institutions may place upper limits on the amount of borrowing regardless of interest rate. Labor may also have an upper limit. In the majority of farm management problems, the rigid limitations can be fully or partially replaced by the more flexible limitations of increasing costs under Asian farm situations. It is for this reason that under Asian agricultural conditions it is relatively easy to define the limit of restriction of land resource, as compared with the restrictions of capital and labor. However, the linear programming expert can set up alternative programs with varying assumptions in respect to resource

** It is possible theoretically to solve the problem when the restrictions are flexible (that is, the price of an input or output varies with the quantity), but the computational load is increased. A bigger problem is that we are in many cases unable to define exactly the quantity available or the exact price for any quantity.

restrictions.

Accurate definition of the labor supply for linear programming approach in Taiwan is further handicapped by the fact that much of the labor supply on the farms is family labor. Family members are usually willing to work longer hours per day as required by the farm work during the busy crop seasons. Also, the hours the members of the family are willing to work is a function of the earnings. This introduces another factor in addition to the possibility of hired labor to make the labor supply even more flexible and more difficult to define its exact limitation. In the case of capital, the capital supply generated by the previous crops in the cropping systems or other farm enterprises during the planning period could be handled by using negative input-output coefficients under the column of the preceding productive processes and in the row of capital supply of the respective period. However, the always existing possibility of transfer of capital between family use and farm production is likely to place some difficulties in defining the restriction of capital supply in linear programming approach in Taiwan. Therefore, our real problem is how to determine the limits on availabilities of resources accurately enough so that an error in this determination does not result in a relatively major change in the final optimum farm organization. In this respect, we may estimate the possible range of availabilities of certain resources to check with the data in the Po column in all simplex tables and the original input-output coefficients to visualize the stability of the linear programming solution within the possible range of availabilities of certain resources. This check will provide us some information and knowledge on the effect of varying availabilities of certain resources on optimum farm organization and on what direction the linear programming solution should be modified and adjusted.

II. Applicability of Linear Programming to Farm Management Studies in Taiwan.

The application of linear programming to farm management studies in Taiwan requires (1) information of the input-output coefficients of the various alternative farm enterprises available to farmers in different agricultural regions, (2) the restrictions on various resources, (3) non-monetary considerations in the farmer's choice of alternative enterprises, and (4) the alternative enterprises available and open to farmers under the actual farm situations. With the availability of this information, the method of linear programming could be applied to farm management studies in Taiwan and to help

solve many farm management problems of the individual farmers. The result of such an analysis will provide a basis to check with the actual choice and combination of enterprises on the farm. Deviation of the actual situation from the result of the linear programming solution will indicate that either the basic data and restrictions in linear programming solution are not correctly defined or the existing farm organization is not optimum. The reasearch workers may use this result to improve and develop their basic data, information and assumptions in linear programming approach, and extension workers may use this result for agricultural extension and farmer's education.

Before the method of linear programming can be used to farm management studies in Taiwan, basic information of input-output data of individual farm enterprises in different types of farming areas must be developed. Stratified random sample surveys should be conducted to collect average input-output information of individual farm enterprises by farm size, crop pattern, land types, etc. Enterprise studies should also be made to provide adequate input-output data. Since linear programming approach generally assumes that the input-output coefficients of alternative farm enterprises are known with certainty, these surveys and studies are prerequisite steps to provide basic information for its application. However, the assumption of certainty of input-output coefficients in primary production of farm crops is quite different from the production of other industrial products where the products are scarcely a function of weather and other similar non-controllable factors. In the fields of crop production, yields are clearly a function of natural conditions and other variables outside the control of farmers and the realm of resources that the farmer can specify. Therefore, the input-output coefficients in crop production vary not only from year to year in the same area and on the same farm, but also vary from area to area and from farm to farm in the same year. The final outcome of the farmer's production plan depends not only on the fluctuations of natural conditions, but also on a use of resources inputs differing in amounts from those originally planned at the beginning. Therefore, the sample survey will provide only those input-output information which are "mean" expectations of a group of selected representative farmers in a given region under normal or average natural conditions. The actual input-output coefficients of a given farm in a given year may differ to some extent from those "mean" expectation. When the purpose of farm management studies is to work out an optimum farm organization program for the average farms in an area under average natural conditions, these "mean" expectations of input-output coefficients could be applied with considerable satisfaction. How-

ever, when the purpose is to help a specific farmer work out his specific cropping program, these "mean" expectations should be adjusted to fit his specific farm condition.

Adequate statistical procedure has been developed to explore the ranges of possible optimum farm organization plans when variations in input-output coefficients are known to exist. As a first step, estimation could be made of the optimum farm organization when the input-output coefficients are equal to the "mean" or average expectation as ascertained by the sample survey or study of a group of farms covering the period of years studied. Then, studies could be made for the specification of outcomes for various probability levels where variance in input-output coefficients exists.

Under Taiwan's agricultural conditions, the information of input-output coefficients of the productive processes could be better developed in terms of the amount of capital and labor required per hectare of land, since information in this fashion is more in line with the thinking of individual farmers in Taiwan. Farmers understand easily how much capital and how many days of labor are required for growing different crops in the region. However, for comparison of the productivities or earning capacities of different productive processes, it is more convenient to transform the input-output coefficients of different processes under comparison into standard form, such as the input requirements for producing $1,000, $100 or $10 of gross returns or net returns of a unit level of operation of different processes. This standardization of productive processes is particularly essential in the elimination of inferior or inefficient processes before formal computation of the simplex table in linear programming approach is started. In general, most studies use "per acre" or "per head" units for the processes. But this is only convenient for comparison of the productivity per unit of land or per head of animal, and not convenient for comparison of productivity of other scarce factors. Standardization of input-output coefficients will facilitate the elimination of inferior processes from the standpoint of relative productivities of all scarce resources under consideration.

In conducting farm management studies in Taiwan, we usually encounter a great deal of difficulty in computing the costs of land; family labor and self-provided capital, and the depreciation of farm equipment and buildings. The application of linear programming approach will enable us to avoid these difficulties of assigning costs

and depreciation to these fixed resources. It is necessary only to defind the supply of those fixed resources in physical terms without going further to assign a unit cost or price to each fixed resource as in the conventional farm management and cost studies. On the other hand, the linear programming solution will provide us information on the marginal value productivities of each fixed resource which is in full use under the optimum organization. If some fixed resources are not in full use under the optimum organization, the marginal value productivities of those resources are zero. Therefore, the appropriate rates to charge for those fixed resources are their marginal value productivities under the optimum farm organization as ascertained by linear programming approach. These kinds of information will be valuable to guide the farmers in the expansion of their business and the use of their fixed resources through the comparison of the marginal value productivities of various fixed resources with current wages of labor, current rates of interest of capital, and current costs of other input factors. It is for this reason that the results of linear programming analysis can help farmers not only by indicating a short run optimum farm organization under the restrictions of scarce resources, but also by visualizing some knowledge of the direction of longer run adjustment of their farm business.

Under Taiwan's agricultural condition, labor in general is in relative abundant supply. Therefore, in defining the restrictions of farm resources, consideration may be given first to the restrictions of land and capital in the linear programming approach. In such a case involving only two scarce resources of homogeneous land and capital, the graphic method of solution may provide a simple and effective tool for testing out the optimum farm organization within the restrictions of land and capital. However, if variations in the quality of land and types of capital are taken into consideration, it will be difficult to use the graphic method.

Working capital used in farming in Taiwan may take various forms, such as the use of chemical fertilizer, the use of insecticides, hiring of labor, and others. All of these uses compete with each other for the use of limited working capital on the farm. It is necessary to test out some rules of allocating the working capital to various alternative uses in order that every dollar of the limited working capital will derive approximately equal benefit from different uses. In the linear programming approach, it is possible to consider different patterns of allocating capital for producing a given farm product as different productive processes. By placing these different processes in

the simplex table, the optimum pattern of working capital allocation and use could be ascertained.

As paddy land in Taiwan in the major crop season is generally used for the growing of rice crops to meet the food needs of the farm family, the problem of crop choice in the major crop season is relatively simple. However, farmer may have a relatively wide range of crop choice in the winter season. The procedure of linear programming could be applied effectively in Taiwan to determine the optimum crop choice and combination in the winter season to supplement with rice crops in the major crop season. Howeeer, it is necessary to make sure that the winter crops under study do not involve complementary effects on rice crops in the major crop season. Under Taiwan's conditions, not all winter crops bear complementary effects with rice crops in the major crop season. Furthermore, if some winter crops may involve complementary effects, two alternative ways are available to handle this situation: (1) consideration could be given to the difference of complementary effects of two winter crops. In this case, efforts should be made to ascertain the complementary effects of the winter crops in order to be able to make adjustments on their returns, or (2) the whole cropping system including the winter crop and the following rice crop could be defined as one single activity or process to take care the supplementary effect. The problem of fertilizer carryover from the winter crop could be solved under the second alternative method.

The application of linear programming to farm management studies in Taiwan will enable the research workers to consider (1) the farmer's requirement of minimum food production for the family, (2) the minimum requirement of cash receipt from the farm production program, and (3) the relative risks of different farm enterprises in working out optimum farm organization. Since farms in Taiwan are generally characterized by self-sufficicncy of food supply for the family, farmers may consider the production of a minimum amount of rice to meet their own requirement as the paramount function of farm planning. Under such a farm situation, farmers may put a relatively higher subjective value than the going market price on rice produced for home use. The difference of these two prices depends to a great extent upon the convenience of selling other competing crops and buying rice from the local market. In working out an optimum farm organization, this minimum amount of rice production should be guaranteed and provided beforehand. The procedure of linear programming could be

applied to take this factor into consideration. The process of rice production could be divided into two processes: One represents the process of rice production for sale, and its returns are computed on the basis of going market price of rice, and the other represents the process of rice production for home use, and its returns are computed on the basis of a subjective value of the farmer on the rice for home consumption. In addition, one more row representing the minimum amount of rice required for home use for the whole planning period is added to the original basis of the simplex table as an additional restriction, and the yield of rice per unit level of operation of the rice production process should be put into the new row and under the process of rice production for home use as an input coefficient in working out the linear programming solution.

On the other hand, farmers in Taiwan may require a minimum amount of cash receipts from their farm production program to meet their family needs and other cash obligations. In such a case, one more row indicating the minimum amount of cash receipts required could also be added to the original basis of the simplex table as an additional restriction and the amount of cash receipts per unit level of operation of cash crop production should be put into the new row and under the respective process of cash crop production as an input coefficient. But when there is insufficient land resource to supply both minimum food and cash needs of the family, it is necessary to weigh the relative importance of the minimum food and cash requirements before the introduction of additional restriction in linear programming solution. Under Taiwan's farm conditions, it is reasonable to assume that the importance of minimum food requirement is in general greater than that of cash needs. Without pre-determination of minimum cash receipts requirement, the linear programming solution will be able to indicate the cash receipts produced in addition to the provision of minimum rice requirement for the family under the optimum farm organization.

The relative risks in production of different farm enterprises usually differ from each other, and the ability of small farmers in Taiwan to bear the risk of production is expected to be limited. Therefore, the relative risks of different farm enterprises may exercise some influence on a farmer's choice of enterprises in the optimum farm organization. In fact, risk in farm production represents an item of cost. However, the magnitude of this cost depends to a great extent upon the subjective valuation of individual farmers and could not be determined objectively in monetary terms. It is,

therefore, rather difficult to include the consideration of risk in crop production in the linear programming solution. However, it might be possible to consider the factor of relative risk by making either one of the following two adjustments in the simplex table:

1. Since risk represents an item of subjective cost of crop production, the returns as shown in the C row under the respective processes producing the crops with higher risks could be adjusted by discounting. The adjusted returns are used to replace the original returns for the simplex solution. The higher the risk, the greater the discount made on the returns. However, it involves the subjective judgment of research workers or farmers as to the amount of discount to be made.

2. Since risk represents one kind of uncertainty and higher cost of crop production, farmers, in view of higher risks, may set a maximum limit in the growing of a given crop with higher risk even if the price of the crop is favorable. For example, a farmer in Taiwan with 2.0 hectares of paddy land may set 1.0 hectare for sugarcane growing as the maximum acreage even if the price of sugar is much higher than that of rice. In such a case, the maximum acreage set by the farmers for a given crop with higher risk could be put into the Po column of the original basis of the simplex table as an additional restriction for the simplex solution.

One of the advantages of linear programming approach as it applies in farm management studies in Taiwan is that it provides a simple means to visualize the effects of (1) changes in proportions of scarce resources on the farm, (2) changes in the relative prices of competitive farm products in the local market, and (3) changes in the relative yields of competitive crops on the optimum enterprise choice and combination in farm organization. This information will provide a basis for evaluating the stability of the optimum farm organization as ascertained by linear programming computation. Therefore, it gives a ready and simple approximation to guide the research and extension workers in their farm management research and extension services.

Under the farm situations in Taiwan, linear programming is more useful in the choice and combination between individual competitive crops than between competitive cropping systems. It is easier to define the restrictions of land, labor, and capital when choice is made between individual competitive crops. In the choice of cropping

systems, the overlapping in the use of land and labor and the use and re-generation of capital of the crops in the systems usually complicate the restrictions of land, labor and capital resources. However, the assumption of additivity should be carefully examined in order to insure independence between individual crops.

The application of linear programming to farm management studies in Taiwan will enable the research workers to consider simultaneously the restrictions of various resources and other considerations on the farm as a whole. These include the provision of minimum food production and cash receipts for the family and relative risks in crop production. However, as more restriction and considerations are included in the linear programming approach, the mechanical process of calculation may become a disadvantageous factor under Taiwan conditions. It is, therefore, suggested that only more important restrictions and considerations should be included in the linear programming solution in Taiwan. These include the restrictions of land and capital, limiting months of labor, and provision of minimum rice requirements for the farm family. In some cases, it is unnecessary to consider the utilization of all the resources listed in the simplex table, and efforts could be made to find out the effective bottleneck resources which really restrict the crop choice. By constructing a graph indicating alternative feasible combinations of two competitive farm enterprises considering each resource in turn as the only limiting resource, the most limiting factor of production in crop choice could be easily tested. Those resources which are at least potentially limiting and those which are likely to remain in surplus supply for all feasible programs could be identified. Therefore, the numbers of effective bottleneck resources to be considered in the simplex computation could be reduced to a necessary minimum to save the time required for computation.

Linear programming is not necessarily a suitable technique for solving all kinds of farm management problems. It is only a technique for solving a class of optimization problems dealing with the interaction of many variables in farm organization subject to certain restraining conditions. In solving these problems, objectives such as returns, costs, quantities produced or other measures of effectiveness are to be obtained in the best possible, or optimal fashion under specified restrictions. Therefore, linear programming can be used only when the farm management problem in question satisfies the following two conditions:

1. There must exist an objective which is to be optimized and can be expressed or represented by a linear function.

2. There must be restrictions on the amount or extent of attainment of the objective and these restrictions must be expressible or representable by a system of linear equalities or inequalities.

Linear programming is especially suitable for solving the allocation problem of scarce farm resources among competitive enterprises on the individual farm level for integrating enterprises and practices into an optimum whole farm plan. As suggested by Dr. E. O. Heady of Iowa State College, the opportunities for the application of the linear programming technique in farm management research are for determining the following three categories of farm management problems:

1. The best combination of crop alone, livestock alone, and crop and livestock enterprises together.

2. The best or least cost technique, such as different types of mechanization, different strains and qualities of crop or livestock, different conservation farming, etc.

3. The optimum combination of all these different enterprises and practices considered together.

Under Taiwan's agricultural conditions, linear programming is particularly suitable for solving the problens of crop choice and allocation of land and capital resources among competitive crops in the farm organization. It is also suitable to supplement the use of other methods for solving the problems of selection of alternative practices in the production of a given crop, such as the levels of fertilization, the frequencies of inter-tilling of the crop field, the levels of irrigation, the degrees of deep plowing, and others. Linear programming is particularly useful to solve these problems if the choice of best method is offset by the rest of the farm organization. When a given farm management problem involves the selection of a farm organization plan among a wide range of alternatives, the procedure of linear programming can be applied to a great advantage. However, when it is a problem where choice is limited, the procedure of farm budgeting may be a better tool of analysis.

It is generally believed and widely recognized that farm labor is in excess supply in relation to land in the majority of farms in Taiwan and the provision of part-time employment by developing subsidiary enterprises on the farms and creation of out-of-farm employment in order to make fullest use of farm labor for improving farm income situation usually present themselves as the major problems in Taiwan. However, there is still lacking accurate and detailed knowledge on the part of research workers and government planners regarding the amount of labor in surplus and the periods of availability. The application of linear programming to individual farm organization studies will indicate the extent of labor in surplus and the periods of availability on individual farms within the present limitations of land and capital resources. These information on individual farm level will be useful to estimate the aggregate surplus farm labor in different periods and in different regions, which will help the government planners and research workers understand more definitely and clearly the regional labor surplus situation for formulating their public work and other regional developmental projects for more efficient use of labor resources. In the case of capital, it is possidle by linear programming approach to figure out the adequate amount of capital required for optimum farm organization for efficient use of our scarce land and other resources. By placing a zero supply of capital in the original Basis of the simplex table in linear programming computation and iteration, the amount of capital required for optimum farm organization could be ascertained in the final Basis of the simplex table. These information will be useful for the public and private credit agencies in the provision of capital for agriculture in particular and in the formulation and operation of agricultural credit programs in general.

the problem of homogeneity of farm resources may present some difficulties in the application of linear programming to farm management studies in Taiwan. For a given category of scarce resources, it is assumed that the quality and efficiency of this resource are homogeneous for all units within farms and among farms. Under the actual farm situation in Taiwan the lack of homogeneity of some resources may involve some complications. The quality and efficiency of farm workers vary by sex, age, education and training, and experience of work. The quality of land also varies by location, soil types, and availability of irrigation. In the linear programming approach, the strict homogeneity of each category of resource is a necessary condition for analysis. Although efforts could be made to define labor and land with different qualities and efficiencies into more detailed categories of resources, the complexity

of the simplex table and the more detailed input coefficients will result in a tremendous computational burden.

The objective of linear programming approach is usually defined in terms of return maximization or cost minimization in monetary terms. Under the farm conditions in Taiwan, farmers may attach more or less subjective values of farming and other non-monetary or social considerations to their farm business which could not be defined and expressed in monetary terms. This factor may also present some difficulties in linear programming approach.

Another limitation in the application of linear programming approach in Taiwan is the problem of computation and calculation. The application of linear programming requires a great deal of computational work for calculation of input-output coefficients and other basic data, iteration of simplex table, and checking of the results. The scarcity of high-speed and multiple-purpose calculators in Taiwan may also present some difficulties for the solution of computational problem in linear programming approach.

In conclusion, it can be said that as long as the input-output data and restrictions of resources and other important considerations can be developed and defined to a fair degree of accuracy, the procedure of linear programming is applicable under farm conditions in Taiwan and it will provide an effective tool to solve many farm management problems in the region. Furthermore, it will also provide a means to develop additional information concerning the competition among crops and general farm organization problems in the region as the result of linear programming analysis will serve as a basis to check with the actual farm situations to visualize the underlying factors influencing crop competition, fatmers' choice of enterprises, and farm organization and operation in the region.

APPENDIX II. SIMPLEX TABLE FOR THE SOLUTION OF OPTIMUM CROP COMBINATION AND RESOURCE USE

Original Basis (A)

C		P_0	P_1 SCNO 5790	P_2 SCF 9100	P_3 SCSP 6720	P_4 R 8030	P_{5a} Fa 3300	P_{5b} Fb 3300	P_{6a} Ca 3420	P_{6b} Cb 3420	P_{7a} Wa 2610	P_{7b} Wb 2610	P_8 0	P_9 0	P_{10} 0	P_{11} 0	P_{12} 0	P_{13} 0	P_{14} 0	P_0/P_2
0	Lw_1 P_8	2.0 ha.	1	1	1	0	1	0	1	0	1	0	1	0	0	0	0	0	0	2.0
0	Lsf P_9	2.0 ha.	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	2.0
0	Lw_2P_{10}	2.0 ha.	1	1	1	0	0	1	0	1	0	1	0	0	1	0	0	0	0	2.0
0	Mw_1 11	250	105	188	134	8	160	0	302	0	117	0	0	0	0	1	0	0	0	1.3298
0	Msf P_{12}	500	25	114	56	150	0	0	0	0	0	0	0	0	0	0	1	0	0	4.3859
0	Mw_2P_{13}	250	79	79	79	22	0	160	0	302	0	117	0	0	0	0	0	1	0	3.1645
0	Ca P_{14}	5000	1750	2300	2000	1220	550	550	2330	3330	360	360	0	0	0	0	0	0	1	2.1739
		Z	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		Z-C	-5790	-9100	-6720	-8030	-3300	-3300	-3420	-3420	-2610	-2610	0	0	0	0	0	0	0	

Basis (B)

																				P_0/P_4
9100	P_2	1.3298	.55851	1.00000	.71276	.04255	.85106	0	1.60638	0	.62234	0	0	0	0	.00531	0	0	0	31.289
0	P_8	.6702	.44149	0	.28724	-.04255	.14894	0	-.60638	0	.37766	0	1	0	0	-.00531	0	0	0	—
0	P_9	.6702	.44149	0	.28724	.95745	-.85106	0	-1.60638	0	-.62234	0	0	1	0	-.00531	0	0	0	.69998
0	P_{10}	.6702	.44149	0	.28724	-.04255	-.85106	1.00000	-1.60638	1	-.62234	1	0	0	1	-.00531	0	0	0	—
0	P_{12}	348.4028	-38.67014	0	-25.25464	145.14930	-97.02084	0	-183.12732	0	-70.94676	0	0	0	0	-.60534	1.00000	0	0	2.4003
0	P_{13}	144.9458	34.87771	0	22.69196	18.63855	-67.23374	160	-126.90402	302	-49.16486	117	0	0	0	-.41949	0	1	0	7.7767
0	P_{14}	1941.4600	465.4270	0	360.65200	1122.1350	-1407.4380	550	-1364.6740	2330	-1071.3820	360	0	0	0	-12.2130	0	0	1	1.7301
	Z	12101	5082	9100	6486	387	7745	0	14618	0	5663	0	0	0	0	48	0	0	0	
	Z-C	12101	-708	0	-234	-7643	4445	-3300	11198	-3420	3053	-2610	0	0	0	-48	0	0	0	

Basis (C)

																				P_0/P_{6b}
8030	P_4	.69998	.46111	0	.30000	1	-.88888	0	-1.67776	0	-.65000	0	0	1.0444	0	-.00555	0	0	0	—
9100	P_2	1.30002	.53889	1.00000	.70000	0	.88888	0	1.67776	0	.65000	0	0	-.04444	0	.00555	0	0	0	—
0	P_8	.69998	.46442	0	.30001	0	.11112	0	.67777	0	.35000	0	1	.04444	0	-.00555	0	0	0	—
0	P_{10}	.69998	.46111	0	.30001	0	-.88880	1	-1.67777	1	-.65000	1	0	.04444	1	-.00555	0	0	0	.69998
0	P_{12}	246.80119	-105.59993	0	-68.79943	0	31.99947	0	60.39837	0	23.40029	0	0	-151.59393	0	.20024	1	0	0	—
0	P_{13}	131.89919	26.28329	0	17.10040	0	-50.66631	160	-95.63301	302	-37.04980	117	0	-19.46610	0	-.31605	0	1	0	.43675
0	P_{14}	1155.98794	-52.00067	0	24.01150	0	-409.99464	550	517.99922	2330	-341.99425	360	0	-1171.95777	0	-5.98515	0	0	1	.49613
	Z	17451	8607	9100	8779	8030	4951	0	1796	0	695	0	0	7963	0	6	0	0	0	
	Z-C	17451	2817	0	2059	0	1651	-3300	-1604	-3420	-1915	-2610	0	7963	0	6	0	0	0	

Basis (D)

																				P_0/P_{5a}
3420	P_{6b}	.43675	.08703	0	.05662	0	-.16776	.52980	-.31666	1	-.12268	.38741	0	-.06445	0	-.00104	0	.00331	0	—
8030	P_4	.69998	.46111	0	.30000	1	-.88888	0	-1.67776	0	-.65000	0	0	1.04444	0	-.00555	0	0	0	—
9100	P_2	1.30002	.53889	1.00000	.70000	0	.88888	0	1.67776	0	.65000	0	0	-.04444	0	.00555	0	0	0	1.46253
0	P_8	.69998	.46442	0	.30001	0	.11112	0	.67777	0	.35000	0	1	.04444	0	-.00555	0	0	0	6.29931
0	P_{10}	.26323	.37408	0	.24339	0	-.72104	.47020	-1.36111	0	-.52732	.61259	0	.10889	1	-.00451	0	-.00331	0	—
0	P_{12}	246.80119	-105.59993	0	-68.79943	0	31.99947	0	60.39837	0	23.40029	0	0	-151.59393	0	.20024	1	0	0	7.71266
0	P_{14}	138.36044	-254.78057	0	-107.91310	0	-19.11384	-684.43400	1255.81702	0	-56.14985	-542.66530	0	-1021.78929	0	-3.56195	0	-7.71230	1	—
	Z	18945	8905	9100	8973	8030	377	1812	713	3420	235	1325	0	7743	0	2	0	11	0	
	Z-C	18945	3115	0	2253	0	-2923	-1488	-2707	0	-2335	-1285	0	7743	0	2	0	11	0	

Basis (E)

																				P_0/P_{5b}
3300	P_{5a}	1.46253	.60625	1.12501	.78750	0	1	0	1.88749	0	.73125	0	0	-.04999	0	.00624	0	0	0	—
3420	P_{6b}	.68210	.18873	.18873	.18879	0	0	.52980	-.00001	1	-.00001	.38741	0	-.07284	0	.00001	0	.00331	0	1.28746
8030	P_4	1.99999	.99999	1.00000	.99999	1	0	0	-.00001	0	-.00001	0	0	.99996	0	0	0	0	0	—
0	P_8	.53746	.39705	-.12501	.21250	0	0	0	.46803	0	.26874	0	1	.04999	0	-.00624	0	0	0	—
0	P_{10}	1.31777	.81121	.81118	.81121	0	0	.47020	-.00016	0	-.00006	.61259	0	.07285	1	-.00001	0	-.00331	0	2.80257
0	P_{12}	200.00101	-124.99961	-35.99972	-93.99901	0	0	0	-.00031	0	.00068	0	0	-149.99428	0	.00056	1	0	0	—
0	P_{14}	166.31500	-243.19780	21.50326	-92.86095	0	0	-684.43400	1291.89420	0	-42.17285	-542.66530	0	-1022.74479	0	-3.44268	0	-7.71230	1	—
	Z	23219	10676	12388	11274	8030	3300	1812	6229	3420	2413	1325	0	7616	0	21	0	11	0	
	Z-C	23219	4886	3288	4554	0	0	-1488	2809	0	-197	-1285	0	7616	0	21	0	11	0	

Basis (F)

																				P_0/P_{7a}
3300	P_{5b}	1.28746	.35622	.35622	.35634	0	0	1	-.00001	1.88750	-.00001	.73123	0	-.13748	0	.00001	0	.00624	0	2.00004
3300	P_{5a}	1.46253	.60625	1.12501	.78750	0	1	0	1.88749	0	.73125	0	0	-.04999	0	.00264	0	0	0	—
8030	P_4	1.99999	.99999	1.00000	.99999	1	0	0	-.00001	0	-.00001	0	0	.99996	0	0	0	0	0	1.99992
0	P_8	.53746	.39705	-.12501	.21250	0	0	0	.46803	0	.26874	0	1	.04999	0	-.00624	0	0	0	—
0	P_{10}	.71241	.64372	.64369	.64366	0	0	0	-.00016	-.88750	-.00006	.26877	0	.13749	1	-.00001	0	-.00624	0	
0	P_{12}	200.00101	-124.99961	-35.99972	-93.99901	0	0	0	-.00031	0	.00068	0	0	-149.99428	0	.00056	1	0	0	
0	P_{14}	1047.49640	.61628	265.31234	151.03026	0	0	0	1291.88736	1291.86918	-42.17969	-42.18663	0	-1116.84078	0	-3.43584	0	-3.44143	1	
	Z	25135	11206	12918	11805	8030	3300	3300	6229	6229	2413	2413	0	7411	0	9	0	9	0	
	Z-C	25135	5416	3818	5085	0	0	0	2809	2809	-197	-197	0	7411	0	9	0	9	0	

Basis (G)

																				P_0/P_{7b}
2610	P_{7a}	1.99992	1.47745	-.46517	.79073	0	0	0	1.74157	0	1	0	3.72107	.18602	0	-.02322	0	0	0	
3300	P_{5b}	1.28748	.35623	.35622	.35635	0	0	1	.00001	1.88750	0	.73123	.00004	-.13748	0	.00001	0	.00624	0	1.76071
3300	P_{5a}	.00009	-.47414	1.46517	.20928	0	1	0	.61397	0	0	0	-2.72103	-.18602	0	.01962	0	0	0	—
8030	P_4	2.00000	1.00000	1.00000	1.00000	1	0	0	.00002	0	0	0	.00004	.99996	0	0	0	0	0	—
0	P_{10}	.71253	.64381	.64366	.64371	0	0	0	-.00006	-.88750	0	.26877	.00022	.13750	1	-.00001	0	-.00624	0	2.65108
0	P_{12}	199.99965	-125.00061	-35.99940	-93.99955	0	0	0	-.00149	0	0	0	-.00253	-149.99441	0	.00058	1	0	0	—
0	P_{14}	1131.85241	62.93466	245.69161	184.38301	0	0	0	1365.34624	1291.86918	0	-42.18663	156.95358	-1108.99451	0	-4.41525	0	-3.44143	1	—
	Z	25529	37026	12826	24787	8030	3300	3300	6572	6228	2610	2413	733	7448	0	4	0	21	0	
	Z-C	25529	31236	3726	18067	0	0	0	3152	2808	0	-197	733	7448	0	4	0	21	0	

Basis (H)

2610	P_{7b}	1.76071	.48717	.48715	.48733	0	0	1.35756	.00001	2.58127	0	1	.00005	-.18801	0	.00001	0	.00853	0
2610	P_{7a}	1.99992	1.47745	-.46517	.79073	0	0	0	1.74157	0	1	0	3.72107	.18602	0	-.02322	0	0	0
3300	P_{5a}	.00009	-.47414	1.46517	.20928	0	1	0	.61397	0	0	0	-2.72103	-.18602	0	.01962	0	0	0
8030	P_4	2.00000	1.00000	1.00000	1.00000	1	0	0	.00002	0	0	0	.00004	.99996	0	0	0	0	0
0	P_{10}	.23930	.51287	.51273	.51273	0	0	-.36487	-.00006	-1.58127	0	0	.00021	.18803	1	-.00001	0	-.00853	0
0	P_{12}	199.99965	-125.00061	-35.99940	-93.99955	0	0	0	-.00149	0	0	0	-.00253	-149.99441	0	.00058	1	0	0
0	P_{14}	1206.13083	83.48672	266.24283	204.94182	0	0	0	1365.34666	1400.76426	0	0	156.95569	1116.92602	0	-4.41483	0	-3.08158	1
	Z	25876	11593	12922	12056	8030	3300	3543	6572	6737	2610	2610	733	7411	0	4	0	22	0
	Z-C	25876	5803	3822	5336	0	0	243	3152	3317	0	0	733	7411	0	4	0	22	0

Resource Use

Active Process in Final Basis:	P_7b	P_7a	P_5a	P_4
Level of operation:	1.76071	1.99992	.00009	2.0000
Input Coefficients Per unit Level of operation:				
Lw_1	0	1	1	0
Lsf	0	0	0	1
Lw_2	1	0	0	0
Mw_1	0	117	160	8
Msf	0	0	0	150
Mw_2	117	0	0	22
Ca	360	360	550	1220
Total Input Requirements:				
Lw_1	0	1.99992	.00009	0
Lsf	0	0	0	2.0000
Lw_2	1.76071	0	0	0
Mw_1	0	234	.01440	16
Msf	0	0	0	300
Mw_2	206	0	0	44
Ca	634	720	.04950	2440

Resource in use for Active Processes	Idle Resource for Disposal Processes	Total Resource Available
2.00000	0	2.00000
2.00000	0	2.00000
1.76071	P_{10}=.23930	2.00000
250.01440	0	250
300	P_{12}=200	500
250	0	250
3794.04950	P_{14}=1206	5000

Remarks:

Lw_1=Land in the first winter season
Lsf=Land in the major crop season
Lw_2=Land in the second winter season
Mw_1=Labor supply in the first winter season
Msf=Labor supply in the major crop season
Mw_2=Labor supply in the second winter season
Ca=Capital supply for the whole period
P_1=Sugarcane with no intercrop
P_2=Sugarcane with flax as an intercrop
P_3=Sugarcane with sweet potato as an intercrop
P_4=Rice production
P_{5a} or P_{5b}=Flax production in the first or second winter season
P_{6a} or P_{6b}=Shantung cabbage production in the first or second winter season.
P_{7a} or P_{7b}=Wheat production in the first or second winter season
C row indicating the return over cash expenses of the respective processes.
Z row indicating the opportunity cost of the respective processes.
P_8, P_9, P_{10}, P_{11}, P_{12}, P_{13} and P_{14} are the seven disposal processes for the seven items of resources.

REFERENCES

1. James N. Boles: Linear Programming and Farm Management Analysis. Journal of Farm Economics, Vol. XXXVII, No. 1, Feb. 1955 pp. 1-22

2. James N. Boles: Short Cuts in Pragramming Computations. Journal of Farm Economics, Vol. XXXVIII, No. 4, Nov. 1956, pp. 981-990.

3. Bernard Bowlen and Earl O. Heady: Optimum Combination of Competitive Crops at Particular Location (Application of Linear Programming). Research Bulletin 426, Agricultural Experiment Station, Iowa State College, April, 1955.

4. L. A. Bradford and G. L. Johnson: Farm Management Analysis. John Wiley and Sons. Inc. New York, 1953 Chapters 8, 9, and 10

5. H. W. Caldwell: An Application of Linear Programming to Farm Planning. Canadian Journal of Argicultural Economics, Vol. IV, No, 2, 1956

6. Wildred Candler: A Modified Simplex Solution for Linear Programming with Variable Capital Restrictions. Jouanal of Farm Economics, Vol. XXXVIII, No. 4, November, 1956, pp. 940-955.

7. A. Charnes, W.W. Cooper, and A. Henderson: An Introduction to Linear Programming. John Viley and Sons, Inc. New York, 1953

8. Robert Dorfman: Application of Linear Programming to the Theory of the Firm. University of California Press, Berkeley, California, 1951, Chapters I, II, and IV.

9. Robert Dorfman: Methematical or "Linear" Programming: A Non-Mathematical Exposition. The American Economic Review, Vol. XVIII, December 1953, pp. 797-825.

10. Earl O. Heady: Economics of Agricultural Production and Resource Use. Prentice-Hall Inc. New York, 1952. Chapters 7 and 8.

11. Earl O. Heady: Simplified Presentation and Logical Aspects of Linear Programming Technique. Journal of Farm Economics, Vol. XXXVI, No. 5, Dec. 1954 pp. 1035-1048

12. Earl O. Heady and H. R. Jensen:
Farm Mangement Economics. Prentice-Hall, Inc. New York, 1954. Chapters 4, 5, and 6.

13. Earl O. Heady, G. L. Johnson, and L. S. Hardin.
Resource Productivity, Returns to Scale and Farm Size. Iowa State College Press, 1956, Chapters 7,8,12 and 20.

14. R. F. Hutton: A Row Sum Check Upon Computational Accuracy in Mathematical Programming Problems (Notes). Journal of Farm Economics, Vol. XXXVII, No. 4, Nov. 1955, pp. 734-736.

15. Richard A. King: Some Applications of Activity Analysis in Agricultural Economics. Journal of Farm Economics, Vol. XXXV, No. 5, Dec. 1953 pp. 823-833

16. R. A. King and Freund.
A Procedure for Solving A Linear Programming Problem. North Carclina Agricultural Experiment Station, Journal Paper No. 503 (mimeographed), 1953, pp. 8-11

17. Chester O. McCorkle Jr.:
Linear Programming as a Tool in Farm Management Analysis. Journal of Farm Economics Proceedings Number, Vol. XXXVII, No. 5, Dec. 1955, pp. 1222-1235

18. N. Rorholm: Linear Programming as a Possible Refinement of Farm Budgeting Techniques, Ph.D. Thesis, University of Minnesota, 1954

19. Sugar Statistics, Vol. I and II, Published by the Department of Agriculture and

Forestry, Taiwan Provincial Government

20. Earl R. Swanson: Application of Linear Programming in Agricultural Production Economic Research, Paper presented to Cowles Commission Seminar, University of Chicago, Feb. 1955

21. Earl R. Swanson: Intergrating Crop and Livestock Activities in Farm Management Analysis. Journal of Farm Economics Proceedings Number, Vol. XXXVII, No. 5, Dec. 1955. pp. 1249-1258

22. Jay P. Swanson: The Economic Effects of Varying Amounts of Forage on the Organization of Minnesota Farms, Ph.D. Thesis, University of Minnesota, 1955

23. Taiwan Agriculture Yearbook, Published by the Department of Agriculture and Forestry, Taiwan Provincial Government.

24. F. V. Waugh and G. L. Burrows:
A Short Cut to Linear Programming, Econometrica, Vol 23, No. 1, Jan. 1955, pp. 18-29.

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