APPLICATION OF MATHEMATICAL PROGRAMMING IN BURMESE AGRICULTURE

by

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PREFACE

Application of Mathematical Programming in Agriculture is not new to those who are interested in the development of agriculture and familiar with the literature on Mathematical Programming. However, it is still a new field into which many industrious mathematicians and economists are probing. In Burma, only a few papers have been brought forward up to this time.[1]

This work tries to apply mathematical programming in agriculture, using the data for some farmers in Henzada township where the average farm is taken as a basic unit of study. It is introduced by describing the purpose of the study as a contribution to the development of agriculture sector, and explaining the methodology used.

Chapter one deals with the review of applicable mathematical tools in agriculture. Some other popular topics as Cost-benefit Approach, Budgeting Method, Econometric Methods and Input-Output analysis are discussed to certain extent giving real examples whenever possible. Mathematical programming is discussed in detail describing its historical sketch, Linear Programming and extensions of Linear Programming.

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1 Dr. Mya Than, "Selection of Crop-Pattern Models for Two Burmese Townships", (1973).

Htin Kyaw & Tin May Lwin, "Counter Current Flow Technique in Economic Planning", M.Sc. Thesis (1976).

In chapter two, mathematical tools such as Cost-benefit Approach, Budgeting Method and mathematical programming are applied in selecting optimum crop pattern for some farmers in Henzada tonwship. This chapter is concluded by comparing the applications of other mathematical tools with those of mathematical programming and its superiority is proved by the post-optimal analysis which has been applied to Linear Programming Model in this chapter.

Application of mathematical programming for possible crop patterns and double-cropping is dealt in chapter three where possible crop patterns are considered first classifying crops on seasonal base and then two models for double-cropping are constructed. Model one is constructed with static conception by using possible pairs of crops whereas model two is constructed with dynamic conception by assuming additional capital is available for the second crops from the yields of the first crops.

In conclusion, we point out the weakness of our study together with the ways and means of improvements that can be made in applying the mathematical programming in agriculture.

CONTENTS

CONTENTS (Contd.)

INTRODUCTION

The purpose of the study

The purpose of this thesis is to find some ways of development in agricultural planning. Like other developing countries, the growth process in our agriculture sector is assumed to be of crucial importance for the overall economic development. Therefore, it is necessary to find alternatives to increase the farmers' individual income as well as to improve the agriculture development programmes for the country as a whole.

In Burma's economic structure, agriculture is the key sector for the whole system. It provides food for increased demand stemming from population growth, investments for industrialization and earns valuable foreign exchange by exporting agricultural produce. Some years back, Burma's agriculture sector was characterized by the following conditions:

(a) small size of a large number of holdings or large number of uneconomic holdings of cultivatable land,

(b) uncertainty in farming arising from a variety of internal and external sources,

(c) excessively low yield per man and per acre,

(d) low level of income which hardly furnishes bare subsistance for the cultivator and his family,

(e) land concentration in a few rich owners who do not utilize the land to the fullest extent and below them large number of medium and small cultivators who have not enough capital,

(f) insecurity of tenure among all cultivators due to indebtedness, mortgages into possession, absence of ownership rights etc.,

(g) absence of investment for land improvement,

(h) lack of effective organization for the completely disorganised peasantry at the village level,

(i) conservative outlook of peasants and absence of management of inputs in farming.

Most of these conditions are common in developing countries.[1] Because of these conditions, the Burma Socialist Programme Party plans to make socialization process in the 20 years plan. Up to now, except

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1 Jain, S.C., "Agricultural Planning in Developing Countries", Kitab Mahal PTV. Ltd., Allahabed, 1966.

conditions (e) and (f), nothing has been changed positively. In order to support the socialization process and to increase productivity in agriculture sector, modern management techniques can be used fruitfully. In doing so, the Mathematical Programming technique, a management tool, can be an aid in the agricultural planning process for the following aspects.

1. To choose the optimum crop pattern in farm level, township level, regional level and national level.
2. To choose the best farm size for each farm, township and region.
3. To choose the least-cost feed mix and the production pattern for the livestock farms.
4. To evaluate the inputs for higher productivity.
5. To solve the transportation problem for shipping agricultural goods from the production centres to the consumer points.

Among these aspects, this thesis will deal only with the choice of optimum crop pattern which is best suited with the available data collected from Henzada township in the Irrawaddy Division.

Methodology

The data on economic aspects of the farms are mainly taken from the paper on "Cost of cultivation and income of sampled farms in Burma" which is available in Research Department, Institute of Economics.[1] This includes:-

(a) crop pattern and acreage,

(b) production cost for different crops,

(c) rate of production,

(d) required man hours for production of different crops,

(e) average utilization of land,

(f) average number of members in the family,

(g) average income of the family,

(h) prices of different crops, (current prices and government prices).

The additional facts and figures required for this thesis are collected from other sources such as Township Peoples' Council, Township Peasants' Council, Land Record Department, Agriculture Corporation etc. The questionnaires designed for the required data are

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1 Rural Socio-Economic Research Series, Data Paper No.2, 1977.

in appendix (1 to 3). The input-output coefficients are calculated from these data and formed to fit in the Linear Programming model. These coefficients are iterated by means of Simplex method with the Linear Programming Package from the University Computer Centre. Some of the conditions or assumptions underlying conventional Linear Programming models occasionally need to be modified to meet several changes found in agriculture. For this we introduce Sensitivity Analysis to determine the effect of changes in prices of crops and changes in the limited resources, i.e. increase or decrease in Capital, Labour and Land.

Chapter I

APPLICABLE MATHEMATICAL TOOLS IN AGRICULTURE

Farming is an interdisplinary occupation or process. It involves relationships in soils, plant physiology, mechanical engineering, chemistry, nutrition, pest and disease control, accounting, economics and sociology. Traditionally, agriculture experts have emphasized research and education which are highly specialized and insulated from other disciplines and fields. As a consequence, results from one discipline were often under-estimated or inaccurately predicted when applied at the farm level because they neglected interactions with variables representing the relationships of other phenomena and disciplines. But, the rapid advance of agricultural science has brought with it a greater understanding of the interdisciplinary nature of the farming industry through the application of mathematical programming techniques.[1] Different types of techniques with examples are shown in this work. They are -

1. Cost-benefit Approach.
2. Budgeting method.

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1 Agrawal & Heady, "Operations Research Methods for Agricultural Decisions", Iowa State University Press, U.S.A., (1972), p.4-5.

3. Econometric methods

   (a) Regression and Correlation

   (b) Production Function

      i. Concept of Production Function
      ii. Cobb-Douglas Production Function

   (c) Demand and Supply Function

4. Input-Output analysis

5. Mathematical programming

1.1 Cost-benefit Approach.

In choosing suitable crop pattern for a township we can use the cost-benefit analysis. The notion of cost-benefit analysis is as follows.[1]

If we have to decide whether to choose crop A or not, the rule is: Choose A if the benefit (income) exceeds that of the next best alternative crop, and not otherwise. If we apply this to all possible crops we shall generate the largest possible benefits. Going on a step, it seems quite natural to refer to the "benefit of the next best to crop A" as the "cost of A". For if crop A is chosen that alternative benefit is cost. So the rule becomes: choose crop A if its benefit exceeds

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1 R. Layard, "Cost-Benefit Analysis", The Chancer Press Ltd., Bungay, Suffolk (1972), p.9.

its cost, and not otherwise. In doing so, we have to find the ratio of net income to cost per acre for each crop and make a priority list for all crops in the ascending order from the most profitable crop to the least profitable one. As an example, Table (I) assists us in choosing the crop pattern for Maubin township.

Table I . Cost, Income and Ratio of Net Income to Cost Per Acre in Maubin Township (1973-74).

Sr. No.	Crops	Cost Per Acre		Net Income Per Acre		Ratio of Net Income to Cost		Priority
		In Cash	Total	In Cash	Total	In Cash	Total	
1	Rice	88.00	175.00	227.00	140.00	1.29	0.80	2
2	Groundnut	220.00	360.00	305.00	165.00	.84	.45	4
3	Jute	160.00	297.00	370.00	233.00	1.24	.79	3
4	Sugar-cane	160.00	298.00	560.00	422.00	1.87	1.45	1

Source: Research Paper on "Selection of Crop Pattern Models for Two Burmese Townships" by U Mya Than.

The results obtained reveal that sugar-cane will be given the first priority since its ratio of net income to cost is the highest (1.45) due to the fact that the difference between the value of net income per acre and the value of cost per acre, both in total and in cash is significantly higher than those of the others. In the same way rice, which has the least cost per acre and the least net income per acre but with the ratio of net income to cost as the second highest, will be given second priority. Jute, the cost of which is equal to sugarcane but having a lower ratio of net income to cost will be given third priority although it is a planned crop for the township. The lowest priority will be given to groundnut since the ratio of net income to cost is obviously less than the others.

The weakness of this method is that it concentrates only on net income and cost and ignores the other factors such as available resources which are important in considering the optimum crop-pattern for the township.

1.2 Budgeting Method

The major objective of budgeting is to compare alternative plans for prospective profitability. The goal is not one of setting down a single plan to be followed without deviation but to figure out two or more systems of farm organization, compare incomes and select the most profitable one. When a large number of alternative plans are possible for a farm, the budget choice can usually be narrowed to 3 or 4 major alternatives and only these need to be compared in detail. We have to approach our farm budgeting in the following orderly way.[1]

(a) Make an inventory of the resources, i.e. capital, labour, machinery, land etc.

(b) Set down different cropping programs or rotations and estimate the yields and production forthcoming from them.

(c) Estimate labor and other expenses which are appropriate for each plan.

(d) Determine the prices for the future.

(e) Assemble the income and expense data into a final or complete budget.

(f) Choose the most profitable plan for the farm.

Figure (I) represents the sample farm budget for a typical rice farm.

Budgeting itself is carried on to aid in the most efficient use of our labour, capital, land and management resources. It is an attempt to the soil and crop management, livestock production and practices, machinery and building investment, conservation and irrigation adjustments and farm forestry into a balanced and

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1 Heady, E.O. and Jensen, H.R., "Farm Management Economics," Prentice Hall of India (Private) Ltd., New Delhi, (1964), p. 97-114.

Figure (1). Farm Budget for a Typical Rice Farm (1976-77).

A. General Characteristics

1. Farm size - 10 acres
2. Livestock - 1 bullock pair & 10 chickens
3. Marketing practice - About 55% sale to the Government.
4. Family size - 5
5. Inventory of implements and equipments - 150 Kyats/year.

B. Physical Volume of Production

1. Land use

Land use	Acre	Yield/acre	Production
Rice	10	35	350 baskets

2. Labour

Labour	Man Days	Rate	Value
(a) Family Labour	149	6-9 kyats	1056.75
(b) Hired Labour	77	6-9 kyats	416.00

3. Cash Inputs

Cash Inputs	Quantity	Price	Value
Seed	10 baskets	10	100.00
Manure	6 carts	10	60.00
Fertilizer	6 bags	12	72.00
Pesticides	-	-	8.70

C. Receipts, Expenses and Net Income

Receipts	Price	Cash	Non Cash	Total
Rice	900	1800	1350	3150.00
Livestock			100	100.00
Others		100	-	100.00
Total		1900	1450	3350.00
Expense				
Labour		416.00	1056.00	1472.00
Inputs		60.00	180.70	240.70
Others		310.80	160.25	471.05
Total		786.80	1396.95	2183.75
Net Income				
Including unpaid labour				K 1166.25
Excluding unpaid labour				K 2222.25

most profitable farming system. But it takes a lot of time to reach the best plan for the farm. Moreover, the weakness of this method lies in the fact that when critical changes take place it is not easy to evaluate the effect of the changes and there are also difficulties in handling the problems of adjustment and control.

1.3 Econometric Methods

Econometrics may be defined as the discipline which attempts the establishment of quantitative relationships between economic variables with the aid of statistical methods. It is the synthesis of mathematics, economics and statistics that makes econometrics into the powerful tool. The methods mostly used in econometrics are basically those of regression analysis and investigations of relationships like demand functions and production functions. All these methods are important for forecasting, or for assessing the effect of policy decisions at the farm level or government level.

1.3.1 Correlation and Regression

The most elegant and simple way to express a relationship between two (or more) variables is by means of a mathematical equation. We can also represent each of these mathematical equations as some sort of a geometrical curve. Suppose there is a dependent variable Y which is to be predicted from an independent variable X. The general nature of regression equations involve the path of the means of Y values for given values of X. If the regression of Y on X is linear, or a straight line relationship, we can write an equation as follows:

$Y = \alpha + \beta X$ where both α and β are constants.

The regression model is not directly useful in its theoretical form. We shall fit the data with a best-fitting straight line according to the least-squares criterion, getting an equation of the form

$$Y = a + bX .$$

Then we have to compute the a and b which determine the line with the desired property. This problem can easily be solved by means of calculus and leads to the following computing formulas for a and b.

$$a = \bar{Y} - b\bar{X}$$

$$b = \frac{\sum_{i=1}^{N} x_i y_i}{\sum_{i=1}^{N} x_i^2}$$

where $x_i = X_i - \bar{X}$ and $y_i = Y_i - \bar{Y}$

(or) $$b = \frac{N\sum XY - \sum X \sum Y}{N\sum X^2 - (\sum X)^2}$$

We want not only to know the form or nature of the relationship between X and Y so that one variable can be predicted from the other, but also it is necessary to know the degree or strength of the relationship. Therefore, we have to use the correlation coefficient r, which we can easily find out in terms of the formula

$$r = \frac{\sum (X - \bar{X})\ (Y - \bar{Y})}{\sqrt{\left[\sum (X - \bar{X})^2\right]\left[\sum (Y - \bar{Y})^2\right]}} = \frac{\sum x\overline{}}{\sqrt{\sum x^2 \sum y^2}}$$

The value of r may vary between -1.0 and 1.0 depending on whether the relationship is positive or negative. As an example, Table (2) shows the correlation between farm size and Net Profit of Zeegon, Yedashe and Maubin townships.

Table (2). Correlation between Farm Size and Net Profit in Sampled Farms.

Observations	Township	Crop	Regression	Correlations
59	Zeegon	Paddy	.0248+.0014	.031
27	Yedashe	Paddy	11.59 - .0229	.38
36	Maubin	Paddy	.016 + .002	.28
69	Zeegon	All Crops	69.36 - .822	.10
56	Yedashe	All Crops	-.0277 + .007	.85
79	Maubin	All Crops	.05 + .0021	.45

X = Farm Size
Y = Net Profit

Source: Rural Socio-economic Research Series, Paper No. , p.16.

Although this method is generally used by the researchers of different aspects, it concentrates only on relationships of variables, whereas our main purpose is to find the optimum conditions within the limits of the resources.

1.3.2 Production Function

The problem of establishing production functions, or technical relationships in production, is a classical one in econometrics and has attracted a great deal of attention. The two main purposes of deriving or solving production functions are:-

(1) to provide 'yardsticks' of how efficiently resources are being used on farms under particular conditions;

(2) to compute physical input-output ratios to be used for guiding farmers in the use of agricultural practices, for use in Budgeting, Linear Programming and other types of analysis to indicate optimum farm organisation or resource use.

In order to fulfill these purposes, we have to apply the concept of production function and its modified method, Cobb-Douglas production function.

(a) Concept of production function

The production function provides information concerning the quantity of output that may be expected when particular inputs are combined in a specified manner. The chemical, physical, and biological properties of inputs determine the kind and amount of outputs which will be received from combinations of inputs. The form of relationship can be written as:-

$$Y_1 = f(X_1)$$

It tells us that the amount of product Y_1 depends upon the amount of X_1 used in producing Y_1. For example, Paddy can be produced by combining land, seed, rainfall, temperature, labour, fertilizer etc.. The farmer should know something about the manner in which these inputs must be combined in order to produce paddy. That is, he must know how and when to prepare the land, apply the fertilizer and sown the seed. When a farmer is considering the question of how much urea or superphoshate to use in his rice production, he may consider the other inputs as given or fixed in specified kinds and quantities. In this case, we can express it as follows:-

$Y_1 = f(X_1 / X_2, X_3, ----, X_n)$, that is, the amount of Y_1 (rice) depends upon the amount of X_1 (urea) given the other inputs $(x_2, x_3, ----, x_n)$ which might be land, seed, labour, rainfall etc. Now the manner in which the amount of rice varies depends on the amount of urea used.

There are three general types of relationship in the production of a commodity when one input is varied and the quantities of all other inputs are fixed. First, it is possible that the amount of product increases by the same amount of each additional unit of input. It is known as constant returns from the input being varied in the production of the particular commodity. Secondly, each additional unit of input results in a larger increase in product than the preceding unit. We say that there are increasing returns from the input. Thirdly, each additional unit of input results in a smaller increase in production than the preceding unit. We say that it is the case of decreasing or diminishing returns which we would normally expect to find in the production of agricultural products.

The concept of production function deals only with the effect of changes in one variable at a time, assuming other things being constant. Consequently, this concept is not suitable for finding optimum condition which calls for considering all related variables. Cobb-Douglas function is a modified method which considers more than one variable.

(b) Cobb-Douglas Production Function

The statistical investigation into laws of production by C. W. Cobb and P. H. Douglas are among the most celebrated in the history of econometrics. They have proposed the general function

$$x = A n^{\alpha} k^{\beta} \mu,$$

x = output,

n = labour input,

k = capital input,

μ = random disturbance,

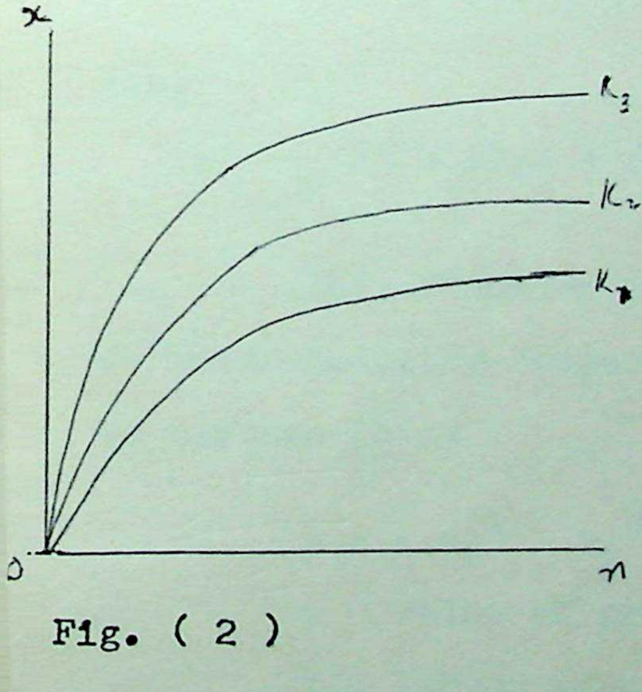

Fig. (2)

The Cobb-Douglas function has constant elasticities of output variation with respect to labour or capital input.

α = elasticity with respect to labour input.

β = elasticity with respect to capital input.

The relationship is nonlinear. For constant levels of capital, the output-labour input relation is shown as the series of curved lines in Fig. (2). If either input is zero (n=0, k=0), output is zero. Thus, both inputs are necessary to the production process. The curvature is such (each elasticity assumed to be less than unity) that marginal productivity falls as input grows.

Although the function is nonlinear, it can be transformed with ease into a linear function by converting all variables to logarithms. In logarithms, the associated linear function is

$$\log x = \log A + \alpha \log n + \beta \log K + \log \mu .$$

(or)

$$x' = A' + \alpha n' + \beta k' + \mu'$$

This function is convenient in international or inter-industry comparisons. In agriculture sector we may use it as

$$y = A\, x_1^{\beta_1} \; x_2^{\beta_2} \; x_3^{\beta_3} \, \mu \quad ,$$

y = value of production (in kyats)

x_1= labour (man days)

x_2 = land (acres)

x_3 = capital (kyats). This includes inputs such as seeds, fertilizer, pesticides, machinery expenses etc.

A = constant

This function, for an example, has been applied to the sampled farms in Lower Burma collected from data paper No.(1), Research Department. The result obtained from the program run are as follows:

$$y = A N^b K^c = 98.314 \quad N^{.100} \quad K^{.310}$$

where A = constant; N = labour; K = capital

b = elasticity with respect to labour

c = elasticity with respect to capital

We can conclude that there can be 10% increase in production as a result of 1% increase in labour and 31% increase in production as a result of 1% increase in capital.

Although Cobb-Douglas function help us to consider the effect of more than the one important variable at a time, a basic weakness lies in the fact that the elasticities of output with respect to the input factors can be obtained only by isolating each variable. Thus, it is not sure that the figures obtained can represent the real elasticity of output.

1.1.3 Demand and Supply Functions

The econometric problem consists in constructing numerical relationships between the demand for a commodity or commodities and the factors which influence the demand. Such a relationship may be called a demand function. Factors influencing demand obviously include the price of the commodity and the income of the group of consumers under consideration. Other possible factors include: the price of a substitute for the commodity; the general price level; the distribution of income; the stock of the commodity held by the consumers; and air temperature. It is of course not necessary for all these factors to enter a particular demand function.

Of particular interest to the demand function are income and price elasticities of demand. Denoting demand by q, income by Y, and price by p, the demand relationship expresses q as a function of Y, p, and possibly some other variables. The income elasticity $\frac{Eq}{EY}$ and the price elasticity $\frac{Eq}{Ep}$ are then defined as follows:

$$\frac{Eq}{EY} = Y \frac{\partial q}{\partial Y} \Big/ q$$

$$\frac{Eq}{Ep} = P \frac{\partial q}{\partial P} \Big/ q$$

The main advantage of discussing demand in terms of elasticities is that these are independent of the units of measurement; thus results are comparable even if derived for countries with different currencies or where the commodities are measured in different physical units. However, considering only demand function in the case of finding out the optimum condition in farm production will be obviously a one-sided approach.

On the other side the supply function is to be considered. The supply function gives a relation between output and market prices. In order to derive supply function we have first to consider profit maximization subject to constraint of production function as follows:[1]

Profit maximization Real factor cost (i^{th} factor) = Marginal Productivity (i^{th} factor)

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1 Lawrence R. Klein, "An Introduction to Econometrics", Prentice Hall of India (Private) Ltd., New Delhi, (1965), p. 112,126,127.

Production function output = f (r factor inputs)

or

$$\frac{W_i}{P} = m_i\,(n_1, n_2, \ldots\ldots n_r),$$

$$i=1,2 \ldots\ldots r.$$

$$x = f\,(n_1, n_2, \ldots\ldots n_r)$$

where, W_i = i^{th} factor cost

P = price of output

m_i = marginal productivity (i^{th} factor)

n_i = i^{th} factor input

In the first set of equations we have real factor cost equated to marginal productivity, but marginal productivity will depend on the same variables as the production function. Therefore, we express it as $m_i\,(n_1, n_2, \ldots, n_r)$. There are r such marginal productivity functions one for each factor. If, instead of writing each real factor cost as a function of all the inputs, we turn the equations about and express each input as a function of all the real factor costs, we have a set of equations.[1]

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1 The inversion can generally be done if marginal productivity functions are "well-behaved."

$$n_i = q_i \left(\frac{w_1}{P}, \frac{w_2}{P}, \ldots \frac{w_r}{P} \right)$$

Substitution of each of the q_i functions into the production function would give us -

$$x = f(q_1, q_2, \ldots q_r)$$

$$= S\left(\frac{w_1}{P}, \frac{w_2}{P}, \ldots \frac{w_r}{P} \right)$$

This is a supply function. It is derived from more basic relations involving the production function and marginal productivity conditions. It depends on the whole group of unit factor costs and the price of output. Estimation of supply responses to prices in agricultural markets with cobweb effects is usually illustrated due to the fact that the lag structure effectively costs the relationship into a form suitable for a regression estimate of the one-way effect of past price on current supply.[1] The supply function, which equates real factor cost and marginal productivity, is applicable only under competitive market conditions.

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1 op. cit. p. 75-81, 128-129.

1.4 Input-Output Analysis

An entirely different approach to the problems of production and cost analysis is associated with the work of Leontief under the heading of input-output models. The main purpose of input-output analysis is to show the inter-industrial structure of production. For example, the agricultural sector produces some of its output for use as input in another sector or they may be used in final demand by an ultimate purchaser. Some of its output are used as input in the food manufacturing sector (grain used for producing bread), some for use in the textile sector (cotton used for producing cloth), some for direct use in final consumption (fresh vegetables used for the home table), some for final export demand (tobacco used in the overseas cigarette industry). From the point of view of the domestic economy, the grain and cotton used in producing bread and cloth domestically are intermediate outputs to be used as inputs elsewhere in the industrial structure of production. The fresh vegetables and tobacco used in home consumption and export trade are final products sent to ultimate buyers as judged by domestic economic activity.

In general terms we write:-

$$x_i = \sum_{j=1}^{n} x_{ij} + F_i ,$$

x_i = total output of the i^{th} sector, $i=1,2,\ldots,n$,

x_{ij} = output of the i^{th} sector used as input by the j^{th} sector,

f_i = final demand for output of the i^{th} sector.

It states that all output of the i^{th} sector ends up in some resting place, either as input in one of the sectors (including itself) or as a final demand. We shall define the sector of final demand to consist of personal consumption, capital formation (fixed and working), government expenditures for goods and services, and foreign export demand.

In addition to these definitions and identities there is the critical assumption that input flows in any producing sector are used in fixed proportions and that output is proportional to each input. The proportionality factors are -

$$a_{ij} = \frac{x_{ij}}{x_j}$$

The a_{ij} are technical constants that show the amount of the i^{th} input required for each unit of the j^{th} output. That the inputs are assumed to be used in fixed proportions can be seen from the ratio -

$$\frac{a_{ij}}{a_{kj}} = \frac{x_{ij}}{x_{kj}}$$

Substitution of the input-output ratio into the identities above yields -

$$x_i = \sum_{j=1}^{n} a_{ij} x_j + F_i , \quad i=1,2,\ldots,n,$$

which is a system of linear equations with constant coefficients associating n output flows to each other and to the bill of final demand $F_1 ,\ldots,F_n$. This can be rewritten as:

$$x_1 = a_{11} x_1 + a_{12} x_2 + \ldots\ldots + a_{1n}x_n + F_1 ,$$

$$x_2 = a_{21} x_1 + a_{22} x_2 + \ldots\ldots + a_{2n}x_n + F_2 ,$$

$$\vdots$$

$$x_n = a_{m1} x_1 + a_{n2} x_2 + \ldots\ldots + a_{nn}x_n + F_n .$$

By solving the equations, we have -

$$(1-a_{11})x_1 - a_{12}x_2 - \ldots\ldots - a_{1n} x_n = F_1 ,$$

$$-a_{21} x_1 + (1-a_{22})x_2 - \ldots\ldots - a_{2n} x_n = F_2 ,$$

$$\vdots$$

$$-a_{n1} x_1 - a_{n2}x_2 - \ldots\ldots + (1-a_{nn}) x_n = F_n .$$

In matrix form, we can write it as -

$$X = AX + Y$$
$$Y = X - AX$$
$$= (I - A)\,X$$
$$\therefore \quad X = (I - A)^{-1}\,Y.$$

As an example, Table (3) represents the Input-Output table for a state farm.[1]

Table (3).

Input \ Output	Cereals	Fodder	Livestock	Final Demand	Output
1. Cereals	61	14	749	1504	2328
2. Fodder	-	-	581	980	1561
3. Livestock	66	26	170	2710	2972
Material	811	320	687	-	1818
Labour	653	173	817	-	1643
Net Income	737	1028	- 33	-	1732
Gross Output	2328	1561	2971	5194	12054

If the final demand for livestock is to be increased from 2710 to 2737, we have to find out the changes of output in all sectors. This can be easily done by the matrix equation $X = (I - A)^{-1}\,Y$.

---

1 Source: Pavel Kubas a Kolektiv, Matematick e Metody v Riadeni Pol'nohospodarstva, p.132.

$$X = (I - A)^{-1} \cdot Y$$

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 10350 & 00139 & 02796 \\ 00061 & 10035 & 02097 \\ 00311 & 00182 & 10727 \end{bmatrix} \cdot \begin{bmatrix} 1504 \\ 980 \\ 2737 \end{bmatrix}$$

$$= \begin{bmatrix} 2335 \\ 1566 \\ 3001 \end{bmatrix}$$

This results can be fitted into the following table.

Input \ Output	Cereals	Fodder	Livestock	Final Demand	Output
1. Cereals	61	14	756	1504	2335
2. Fodder	-	-	587	980	1567
3. Livestock	66	26	172	2737	3001
Material	814	321	694	-	1829
Labour	655	174	825	-	1654
Net Income	739	1031	- 33	-	1737
Gross Input	2335	1566	3001	5221	12123

The Input-Output Method can solve the problem of finding out the volumes of output for all sectors under different conditions. Therefore this method is quite popular with the planning personnel who are responsible for overall production and financial plans. However, the input-output method cannot point out the optimum combination of different outputs in each sector. In addition, the technical coefficients, whioh are difficult to find out, cannot be established with certain accuracy.

1.5 Mathematical Programming

If the objective of an economic or social entity can be expressed quantitatively, and the objective function of a system can be expressed in equation form, the solution can be computed by means of techniques grouped under a general heading of mathematical programming. It includes Linear Programming, Nonlinear Programming and Dynamic Programming. For special situations, techniques of recursive, stochastic and parametric programming or other variants have been developed. Of the techniques, the simplest and decidedly the most important and widely used is Linear Programming.

1.5.1 Brief Historical Sketch of Linear Programming

Linear Programming is now about 30 years old as an operational tool for problem solving, but its origins go beyond this in the scientific literature of both Mathematics and Economics. Programming problems first arose in Economics, where the optimal allocation of resources has long been of interest to economists. More specifically, however, programming problems seem to be a direct outgrowth of the work done by a number of individuals in 1930's. One outstanding theoretical model developed then was Von Neumann's Linear model of an expanding economy, which was part of the efforts of a number of Austrian and German economists and mathematicians who were studying generalizations of Walrasian equilibrium models of an economy. A more practical approach was made by Leontief, who developed Input-Output models of the economy. Input-Output models did not actually involve any optimization; instead they required the solution of a system of simultaneous linear equations.

During World War II, a group under the direction of Marshall worked on allocation problems for the United States Air Force. Generalizations of Leontief-type models were developed to allocate resources in such a way as to maximize or minimize some linear objective function. George B. Dantzig was a member of the Air Force group; the formulated the general Linear Programming problem and devised the Simplex Method of solution in 1947.

The early applications were primarily those in military operations but in a few short years the scientific journals have become full of innovations of Dr. Dantzig's early work. After 1951, progress in the theoretical development and in practical applications of Linear programming was rapid. Important theoretical contributions were made by David Gale, H.W. Kuhn and A. W. Tucker who had a major share in developing the theory of duality in Linear Programming. A. Charnes, who also did some important theoretical work, and W. W. Cooper took the lead in encouraging industrial applications of Linear Programming.

Problems of the Linear Programming type had been formulated and solved before the pioneering work of Dantzig. In 1941, Hitchcock formulated and solved the transportation problem, which was independently solved by Koopmans in 1947. In 1942, Kantorovitch also formulated the transportation problem but did not solve it. The economist Stigler worked out a minimum-cost diet in 1945. Although this problem can be formulated as a Linear Programming problem, Stigler did not use this technique. It was not until Dantzig's work, however, that the general Linear Programming problem was formulated as such, and a method devised for solving it. The carry over from early military applications to business uses of Linear Programming has been rapid and today thousands of firms make use of this managerial tool.

Its applicability to the practical problems in management and allocative economies has been largely responsible for its development to the present level. Since the end of the war, the technique has experienced remarkable growth and has been increasingly used in industries and agriculture.

1.5.2 Linear Programming

Like any other mathematical tool, mathematical programming itself is a mathematical technique without any economic content. Its sole purpose is to indicate the optimum solution to a problem for a given set of circumstances. To obtain relevant and sensible results, it is important that the reliable data has been collected and the model been precisely formed.

Mathematical programming problems have the following characteristics:-

(1) Solution of the problem has the expressed intent of bettering a current situation; that is, the problem is to be solved in order to reduce cost, to increase profit, to increase output, or for any of a number of statable reasons. The desire found in the problem will be called the objective function or goal.

(2) Within the problem, and directly related to the goal, there are a number of courses of action, any one of which may be satisfactory, but at least one of which will provide the best answer. It is the function of Mathematical Programming to sift through these many alternatives, passing up all but the better ones.

(3) The problem involves certain demands upon the current situation. These are normally referred to as requirements. Demands are the conditions of the problem that must be met.

(4) The problem imposes certain bounds, or limits, which must not be exceeded. These are normally referred to as restrictions.

(5) The choices of action must involve a significant difference in improvement. The difference between choices will be called the rate of efficiency. When the rates of efficiency between choices are not significantly different, the problem is trivial from the standpoint of mathematical programming.

(6) Finally, for solution by mathematical procedures, any problem requires that the data be available in quantitative terms.

Mathematical programming has been applied most widely through Linear Programming models based on assumptions of linear objective and production functions. Linear programming can be used whenever the objective is to optimize subject to certain linear constraints. The usual way of writing a problem in a matrix form is:-

$$\text{Max } Z = c'x$$

$$\text{Subject to } \quad Ax \lesseqgtr B$$

$$\text{where } \quad x \geqslant 0$$

A is an m x n matrix of technical coefficients.

C is an n x 1 vector of prices or other weights for the objective function.

x is an n x 1 vector of activities (commodities to produce)

B is an m x 1 vector of resource or other constraints.

$c'x = Z$ is the objective function.

This problem can be written as -

$$\text{Max } Z = c_1x + c_2x_2 + \ldots\ldots + c_nx_n$$

$$\begin{aligned} \text{Subject to} \quad & a_{11}x_1 + a_{12}x_2 + \ldots\ldots\ldots + a_{1n}x_n \leqslant b_1 \\ & a_{21}x_1 + a_{22}x_2 + \ldots\ldots\ldots + a_{2n}x_n \leqslant b_2 \\ & \vdots \\ & a_{m1}x_1 + a_{m2}x_2 + \ldots\ldots\ldots + a_{mn}x_n \leqslant b_m \end{aligned}$$

$$\text{where } \quad x_1 \geqslant 0, \quad x_2 \geqslant 0 \ldots\ldots\ldots x_n \geqslant 0$$

In a compact form the problem can be rewritten as:-

$$\text{Max } Z = \sum_{j=1}^{n} c_j \, x_j$$

Subject to $\sum_{j=1}^{n} a_{ij} x_j \leq b_i$

$x_j \geq 0$

where $i=1,2 \ldots\ldots, m$

$j=1,2 \ldots\ldots, n.$

The assumptions underlying Linear Programming problem are as follows:-

1. Additivity of resources and activities. The property of additivity means that the sum of resources used by different activities must equal the total quantity of resources used by each activity for all the resources, individually and collectivity. This implies absence of any interaction among the activities of the resources.

2. Linearity of the objective function. If the objective function is not linear, we cannot use this technique as such.

3. Non negativity of the decision variables.

4. Divisibility of activities and resources. This assumption implies continuity of resources and output, i.e., we can use factors in fractional quantities. For problems requiring solutions in whole number, integer programming, a special technique of Linear Programming, is used.

5. Finiteness of the activities and resource restrictions. If there are infinite number of alternative activities and resource restrictions, they cannot be programmed or an optimal solution computed.

6. Proportionality of activity levels to resources. This assumption implies linear relationships between activities and resources.

7. Single-valued Expectations. It means that resource supplies, input-output coefficients, prices of resources and activities, and so forth are known with certainty. For variances of the parameters, we can use sensitivity analysis (or parametric programming).

Linear Programming models serve as tools for determining optimal decisions and patterns of resource allocation. These models specify a set of variables which represent the decision quantities for attainment of objectives under a particular environment represented by technology, prices or their distribution and resource limitation. Then, through design and application of a computational method, they solve the numerical value of these decision variables, thus providing a quantitative potentials, they have great usefulness in agricultural planning.

Linear programming problems can be solved by means of three methods:-

(a) The graphical method

(b) The algebraic method and

(c) The simplex method.

(a) The graphical method. This method can be used only where no more than three variables are involved. Therefore, the graphical method is not generally used to solve real-world linear programming problems. However, the method is very effective in providing a conceptual understanding of the solution process itself. Familiarity with the problems which can occur in the simple cases involving only two or three variables provides a great deal of insight into what can happen in the more realistic case with many variables.

We present a very simple problem of profit maximization below. It involves only two decision variables, Rice and Jute. A farmer has 32 acres of land and proposes to grow rice and jute. He has 36 hours of June and 45 hours of December labour available. He requires .9 hours of June labour per acre and no December labour for rice, and needs 1.5 hour of December labour per acre for jute he grows. The net returns from each acre of rice and jute are K.100/- and K.150/- respectively. This information can be put in the tabular form shown below.

Resources, Input-Output Coefficients, and Profits from Rice and Jute.

Item	Resource Requirements (per acre)			
	June Labor (hr.)	December Labor (hr.)	Land	Profits (per acre)
Rice	.9	0	1	100
Jute	0	1.5	1	150
Total resources available	36	45	32	-

If the objective of the farmer is to maximize his total net returns, what combination of crops should we grow?

Let x_1 = number of acres of rice cultivation and

x_2 = number of acres of jute cultivation.

Then the problem can be written in the following form:

$$\text{Maximize } Z = 100\,x_1 + 150\,x_2$$

Subject to June Labour $.9\,x_1 + 0\,x_2 \leqslant 36$

December Labour $0\,x_1 + 1.5\,x_2 \leqslant 45$

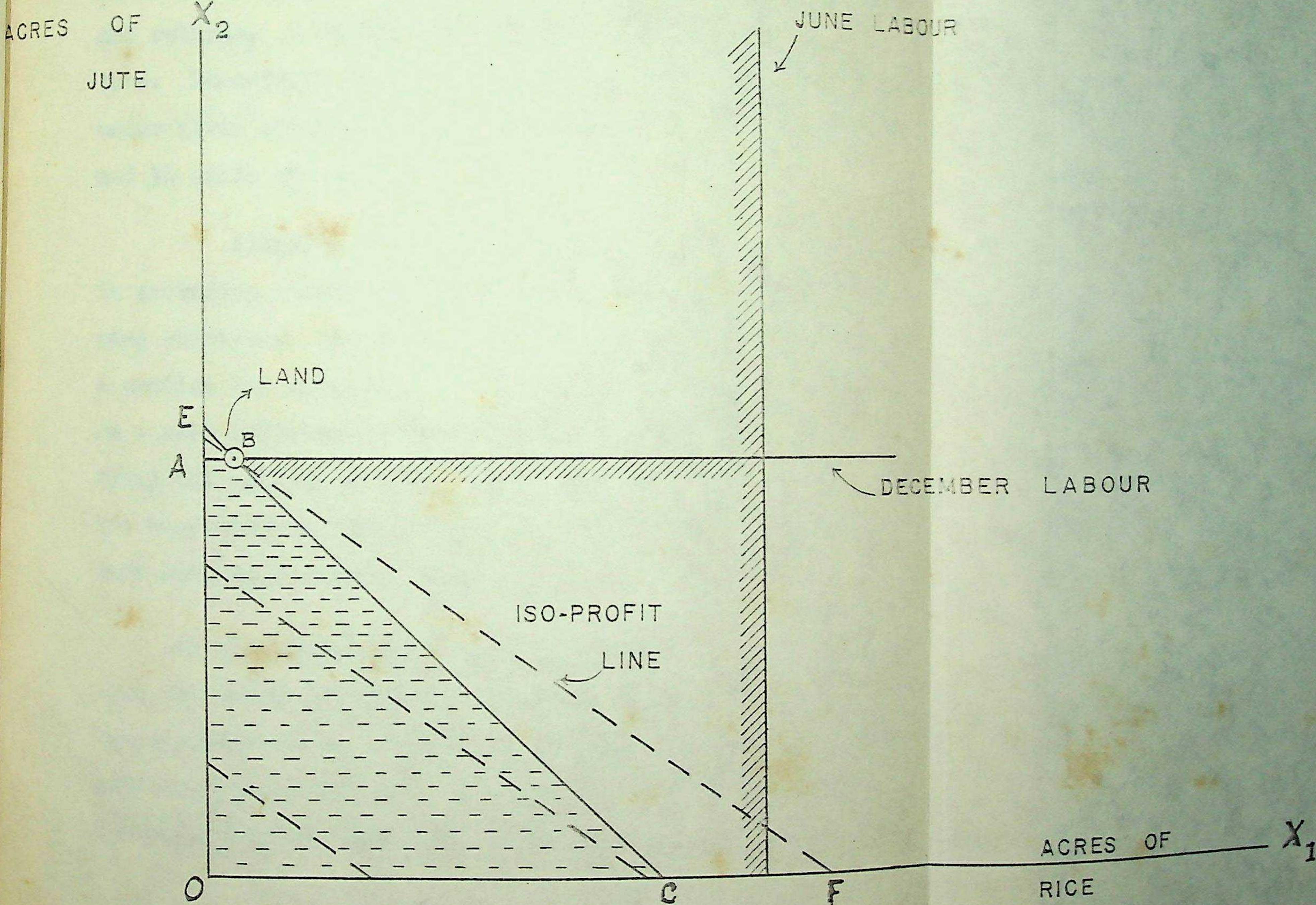
Land $1\,x_1 + 1\,x_2 \leqslant 32$

where $x_1 \geqslant 0, \; x_2 \geqslant 0$

Since we need to solve for only the two variables, x_1 and x_2, we can represent the problem and find the solution with the help of the two-dimensional diagram in Figure (3).

The possibility curves for June Labour, December Labour and Land are plotted in the figure and they represent the feasible region OABC, meeting all the limited conditions. The optimal solution of the problem lies at one of the extreme points of this feasible region or on the lines joining them and the efficiency of the point or points depends on

FIGURE (3).



ACRES OF
JUTE
X_2
JUNE LABOUR
LAND
E
B
A
DECEMBER LABOUR
ISO-PROFIT
LINE
ACRES OF
RICE
X_1
O
C
F

the objective function. Wherever the line representing the ratio of rice to jute (EF in the diagram) is tangent to the production possibility area, we have the most efficient point. Since EF is tangent to OABC at B, B is the point of maximum net returns. B represents 2 acres of rice and 30 acres of jute. Therefore, to get the maximum net returns (Kyats 4700) under given conditions, the farmer must grow 2 acres of rice and 30 acres of jute.

Although the graphical method is very effective in providing a conceptual understanding of Linear Programming solutions, it becomes impractical as the dimensions of a problem are expanded. In this case the algebraic method is a more efficient technique for searching out and identifying the optimal solutions to problems. It does introduce the basic terminology and process of the computationally more efficient simplex method.

(b) The algebraic method. This method is not generally used for solving real-world Linear Programming problems because experience has shown that as computational device it involves excessive time. For example, we will solve the following problem with the algebraic method.

$$\text{Max } Z = 3x + 8y$$

Subject to

$$3x + 4y \leqslant 18 \quad \text{------ (1)}$$

$$3x + 5y \leqslant 21 \quad \text{------ (2)}$$

where $x, y \geqslant 0.$

We have to find the basic combinations or possible solutions to this problem considering the restrictions involved. These combinations may be:-

(a) choose only x

(b) choose only y

(c) choose a combination of x and y.

The maximum profit will be found in one or more of the combinations.

If we choose only x, i.e. $y = 0$

$$3x + 4(0) \leqslant 18 \quad \text{---------- (1)}$$

$$x \leqslant 6$$

$$3x + 5(0) \leqslant 21 \quad \text{---------- (2)}$$

$$3x \leqslant 21$$

$$x \leqslant 7$$

Then, $Z = 3(6) + 8(0)$

$= 18$

If we choose omly y, i.e. $x = 0$

$$3(0) + 4y \leqslant 18 \quad \text{---------} \quad (1)$$

$$4y \leqslant 18$$

$$y \leqslant 4.5$$

$$3(0) + 5y \leqslant 21 \quad \text{---------} \quad (2)$$

$$5y \leqslant 21$$

$$y \leqslant 4.2$$

Then, $Z = 3(0) + 8(4.2)$

$$= 33.6$$

If we solve the equations algebraically to find a combination of x and y, we get -

$$3x + 4y \leqslant 18 \quad \text{--------} \quad (1)$$

$$3x + 5y \leqslant 21 \quad \text{--------} \quad (2)$$

$$y = 3, \quad x = 2$$

Then $Z = 3(2) + 8(3)$

$$= 6 + 24 = 30$$

The maximum profit is found in choosing only y. Using algebraic analysis, we have to check the profit of each combination and find the optimum solution. The above example is very simple and the number of combinations is small. In the case of large problems, checking the profit by trial and error method needs a lot of time. Therefore we will use the Simplex method for computation which is more efficient than the preceding methods.

(c) The Simplex Method. The simplex method consists of the repeated application of the simplex algorithm. An algorithm is a procedure consisting of a set of rules and mathematical operations performed in a specified sequence. This method is an algebraic iterative procedure which will solve exactly any Linear Programming problem in a finite number of steps, or give an indication that there is an unbounded solution.

The simplex method can be given a very simple geometrical interpretation in terms of the concepts, i.e. feasible solution, optimal, and extreme points. If there is an optimal solution, one of the extreme points is optimal. There is only a finite number of extreme points. This method is a procedure for moving step by step from a given extreme point to an optimal extreme point. At each step it is possible to move only to what intuitively are adjacent extreme points. The simplex method moves along an 'edge' of the region of feasible solutions from one extreme point to an adjacent one. Of all the adjacent extreme points, the one chosen is that which gives the greatest increase in the objective function. At each extreme point, the simplex method tells us whether that extreme point is optimal, and if not, what the next extreme point will be. If at any stage the simplex method comes to an extreme point which has an edge leading to infinity, and if the objective function can be increased (or decreased) by moving along that edge, the simplex method informs us that there is an unbounded solution. We will use the previous problem to solve it with the Simplex method. It will prove that with a few iterations, the optimum solution will be achieved.

Simplex Table I

C_j	P.M	3 x	8 y	0 S_1	0 S_2	Qty	
0	S_1	3	4	1	0	18	18/4 = 4.5
0	S_2	3	5	0	1	21	21/5 = 4-2 R.R
	Z_j	0	0	0	0	0	
	C_j-Z_j	3	8	0	0		
			O.e				

Table II

C_j	P.M	3 x	8 y	0 S_1	0 S_2	Qty
0	S_1	3/5	0	1	-4/5	6/5
8	y	3/5	1	0	1/5	21/5
	Z_j	24/5	8	0	8/5	168/5
	$Cj-Z_j$	-9/5	0	0	-8/5	

Since $(C_j - Z_j)$ values are of zeros and negative we obtain the optimum solution. This is the same solution as derived by Algebraic method but it arrives to it with only one iteration. This shows that the simplex method is the most suitable one to handle the real-world problems.

Extensions of Linear Programming

Some of the conditions or assumptions underlying conventional linear programming models occasionally need to be altered or modified to meet special conditions found in agriculture. Frequently we only relax a particular assumption and introduce a specification and computational method to replace it. The assumptions inherent in conventional linear programming models which can be relaxed or replaced to advantage are:-

(1) The values of input-output coefficients Matrix A , resource supplies b vector , or prices of resources and activities c vector may change overtime; or it may be of interest to know within what ranges of the values of the components of b and c vectors, or even of supplies of a specific resource or price of a specific activity, the solution to the original problem remains optimal.

e.g. (a) Suppose the farmer can use 10 acres of land rather than only 7 acres to which the problem applied;

(b) We may wish to examine how the optimal solution will change if the prices of paddy, groundnut, peas are K.12,K.60, K.50 rather than K.10,K.40,K.18 respectively.

In such cases, Sensitivity Analysis can be used to determine the effect of changes in Matrix A, vector b, or vector c on the optimal solution.

In order to make sensitivity analysis, we will refer back to the linear equations stated before.

$$
\begin{array}{lcl}
a_{11}x_1 + a_{12}x_2 + \cdots\cdots + a_{1n}x_n & = & b_1 \\
a_{21}x_1 + a_{22}x_2 + \cdots\cdots + a_{2n}x_n & = & b_2 \\
\vdots & & \vdots \\
a_{n1}x_1 + a_{n2}x_2 + \cdots\cdots + a_{nn}x_n & = & b_n \\
Z - c_1x_1 - c_2x_2 \cdots\cdots - c_n x_n & = & 0
\end{array}
$$

In shorter form, the equation will be rewritten as:-

$$AX = b$$

$$Z - C^TX = 0$$

We can also present it in partition matrix form as follows:

$$\left[\begin{array}{c|c} 0 & A \\ \hline 1 & -C \end{array}\right] \cdot \left[\begin{array}{c} Z \\ \hline X \end{array}\right] = \left[\begin{array}{c} b \\ \hline 0 \end{array}\right]$$

From this initial stage, we can derive by iterations in order to make the necessary variables enter the Basic Matrix (B). The remaining variables will be left in the A_1 matrix, thus we obtain the following format.

$$\left[\begin{array}{c|c|c} 0 & B & A_1 \\ \hline 1 & -C^T & -C^{(1)T} \end{array}\right] \left[\begin{array}{c} Z \\ \hline X \\ \hline X^{(1)} \end{array}\right] = \left[\begin{array}{c} b \\ \hline 0 \end{array}\right]$$

We then multiply both sides by $\left[\begin{array}{c|c} B^{-1} & 0 \\ \hline C^T B^{-1} & 1 \end{array}\right]$ matrix in order to obtain the optimum solution in which all the chosen variables form an Identity matrix.

Thus we have,

$$\left[\begin{array}{c|c|c} 0 & 1 & B^{-1} A_1 \\ \hline 1 & 0 & C^T B^{-1} A - C^{(1)T} \end{array}\right] \left[\begin{array}{c} Z \\ \hline X \\ \hline X^{(1)} \end{array}\right] = \left[\begin{array}{c} B^{-1} b \\ \hline C^T B^{-1} b \end{array}\right]$$

transforming the above partition matrix into equation forms, we obtain:

$$X + B^{-1}A_1 X^{(1)} = B^{-1} b$$

$$Z + C^T B^{-1} A - C^{(1)T} X^{(1)} = C^T B^{-1} b.$$

where X = the variables which enter the basic matrix.

$B^{-1} A_1 X^{(1)}$ = matrix for the coefficients of the remaining variables and slacks.

$B^{-1} b$ = vector for the quantity of chosen variables and the surplus resources.

$C^T B^{-1} b$ = value of the objective function.

$C^T B^{-1} A - C^{(1)T} X^{(1)}$ - this represents $c_j - z_j$ which indicates shadow prices as well as net contribution of the remaining variables.

From these equations we can make post-optimal analysis such as changes in b and changes in C^T. When there is increase or decrease in b (i.e. b, increase or decrease in land, labour and capital) the revised optimum solutions can easily be obtained by multiplying B^{-1} by $(b + \Delta b)$.

$$B^{-1} (b + \Delta b) = B^{-1} b + B^{-1} \Delta b = X + B^{-1} \Delta b.$$

Consequently, the value of objective function will be changed as follows:

$$C^T B^{-1}(b + \Delta b) = C^T B^{-1} b + C^T B^{-1} \Delta b.$$

In the case of changes in C^T (i.e. prices of different variables), we have to find out the net contribution of the remaining variables by using the new prices and their coefficients in the final table. If the net contribution of a variable is positive, this variable should enter the basis. In such cases we can iterate again from the beginning in order to get the new optimal solution.

(2) In some cases the assumption of divisibility of activities and resources may not be practical. Tractors and machines, for example, must come in whole units. It is meaningless to reach a solution requiring purchase of 1.5 tractors and 2.7 ploughs. The technique of Integer Programming can be used for problems requiring the solutions that provide quantities in whole units.

The general integer programming model can be stated as:

$$\text{Maximize:} \quad Z = \sum_{j=1}^{n} c_i X_0$$

$$\text{Subject to} \quad \sum_{j=1}^{n} a_{ij} X_j \leqslant b_i \quad \text{for all} \quad i=1,2,\ldots,m$$

$$\text{and} \quad X_j = 0,1,2,\ldots, \text{ integer } (j=1,2,\ldots n)$$

The only difference between this formulation and that for the general linear programming model lies in the nonnegativity requirement

$$X_j \geqslant 0$$

which has been altered to require that

X_j = 0,1,2,....., integer (that all X_j be integers that are greater than or equal to zero).

(3) The linear programming model rests on the assumption that the relationships between the variables are linear. In practice, either the objective function or some of the constraint relationships, or both, may not be linear. In agriculture the marginal yield of an additional acre of land may not be the same always. So is the cost of labour. In such

cases, the problem is one of Nonlinear programming. Here we have to approximate the objective function with linear segments and build a model using multiple variables. In some cases we may build a model which utilizes multiple tables. Whatever the case may be, the general linear programming model has to be used.

The other technique which offers an integrated management control system which is particularly suited to complex projects and situations with planning uncertainty is Network analysis. The combined diagrammatic and analytical approach to the problems of planning and control eliminates ambiguity and reduce misunderstanding between working groups. It assists all levels of management to:

(1) Define the work to be carried out.

(2) Produce better work schedules based on knowledge of resources required and resources available.

(3) Decide the best way of applying resources to achieve objectives.

(4) Establish budgets for performing the work.

(5) Monitor progress and detect those points, where delays would jeopardize the project objectives, in time to permit corrective action to be applied.

(6) Control project costs by measuring cost progress and predicting final project cost.

The two main network systems are PERT (Programme Evaluation and Review Technique) and CPM (Critical Path Method) which were developed and applied in 1957-58. The general distinction between PERT and CPM is that with PERT the results of the analysis are expressed in terms of events and the results of CPM calculations are shown in terms of activities or operations to be performed. That is, in PERT each activity time can be expressed with multiple time estimates which indicate time uncertainty. The multiple time estimates "optimistic", "pessimistic", and "most likely" are converted to a single time estimate and a statistical variance, and these are used to calculate the probability of achieving the project schedule dates. Thus a PERT-type system is distinguishable by the use of 3 time estimates, and the production of an event type analysis showing probabilities against scheduled dates.

CPM, on the other hand, is based upon the premise that project duration can be shortened by applying extra cost. Thus in this system each activity is given a normal time and normal cost, and a crash time with its associated crash cost. The CPM analysis produces least cost work schedules for each of several project durations and goes on to calculate the project duration which gives the least project cost.

In order to apply the above techniques, the network for paddy farming in Burma can be presented as shown in the following diagram. The necessary activities can be grouped under such topics as preparation of land, preparation of nursery field, preparation of transplanted fields, transplanting, preparation of threshing floor, harvesting and marketing as follows:

(1) Preparation of land

a. carrying and spreading of fertilizer and manure
b. mending bunds and watering

(2) Preparation of nursery field

a. ploughing
b. harrowing
c. sprouting and broadcasting of seeds

(3) Preparation of transplanted fields

a. ploughing
b. harrowing

(4) Transplanting

a. uprooting seedlings
b. carrying seedlings
c. transplanting
d. weeding
e. applying anti-pesticides

(5) Preparation of threshing floor

a. leveling
b. spraying of water

(6) Harvesting

a. bending the plants
b. cutting
c. making sheaves
d. carrying sheaves to the threshing floor
e. threshing
f. winnowing
g. heaping straw
h. burning the stumps of the paddy plant

(7) Marketing

a. carrying paddy to the marketing centres.

Some of the activities can be done concurrently and some are to be carried out independently as it is seen in the network diagram. From this diagram we can continue to apply PERT or CPM taking factors concerned into consideration.[1]

Further, one may be interested in finding optimal solutions over a period of time rather than at a point in time; or there may be situations where multi-stage rather than single-stage decision processes are relevant. These problems are best handled within the framework of dynamic programming in which an additional factor for time is taken into consideration.

In agriculture, time is a dominant factor in the case of double cropping. We may use the following original dynamic form in finding optimal solutions over a period of time.

---

1 One of the application of network analysis in agriculture can be found in the book on "Matematičke Metody liad eni Pol'mohosopodarstva" by Paval Kubas a Kolektiv.

Original dynamic form

$$
\begin{aligned}
& a_{111}x_{11} + a_{121}x_{21} + \dots + a_{1j1}x_{j1} + \dots + a_{1n1}x_{n1} + \dots \\
+ & a_{112}x_{12} + a_{122}x_{22} + \dots + a_{1j2}x_{j2} + \dots + a_{1n2}x_{n2} + \dots \\
+ & a_{11k}x_{1k} + a_{12k}x_{2k} + \dots + a_{1jk}x_{jk} + \dots + a_{1nk}x_{nk} + \dots \\
+ & a_{11t}x_{1t} + a_{12t}x_{2t} + \dots + a_{1jt}x_{jt} + \dots + a_{1nt}x_{nt} + \dots \leqslant S_{11}
\end{aligned}
$$

$$f(x) = c_{11}x_{11} + c_{21}x_{21} + \dots + c_{jk}x_{jk} + \dots + c_{nt}x_{nt} = c_{jk}x_{jk}$$

$i = 1, 2, \dots\dots m$
$j = 1, 2, \dots\dots n$
$k = 1, 2, \dots\dots t$

where a_{ijk} - Coefficient at the time 'K'

S_{ik} - Resources available of i^{th} factor in K^{th} time

When we have to make multi-stage decision process such as differentiating optimal income by seasons, we may use the following new system of equations:

New System of equations for the above dynamic model

$$
\begin{aligned}
a_{111}x_{11} + a_{121}x_{21} + \dots + a_{1j1}x_{j1} + \dots + a_{1rt}x_{rt} &= S_{11} \\
a_{211}x_{11} + a_{221}x_{21} + \dots + a_{2j1}x_{j1} + \dots + a_{2rt}x_{rt} &= S_{21} \\
a_{i11}x_{11} + a_{i21}x_{21} + \dots + a_{ij1}x_{j1} + \dots + a_{irt}x_{rt} &= S_{i1} \\
a_{i12}x_{12} + a_{i22}x_{22} + \dots + a_{ij2}x_{j2} + \dots + a_{irt}x_{rt} &= S_{i2} \\
a_{i1k}x_{1k} + a_{i2k}x_{2k} + \dots + a_{ijk}x_{jk} + \dots + a_{jrt}x_{rt} &= S_{ik} \\
a_{m1t}x_{1t} + a_{m2t}x_{2t} + \dots + a_{mjt}x_{jt} + \dots + a_{mrt}x_{rt} &= S_{mt}
\end{aligned}
$$

$$f(x) = \sum c_{jk}\, x_{jk} \qquad , \; x_{jk} \geqslant 0$$

$i = 1, 2 \dots\dots m$
$j = 1, 2 \dots\dots r$
$k = 1, 2 \dots\dots t$

Chapter II

APPLICATION OF MATHEMATICAL TOOLS IN SELECTING CROP PATTERN IN HENZADA TOWNSHIP

2.1 General Description of Henzada Township and the Sampled Farms[1]

Henzada township is chosen as our experimental area due to the facts that the major crop of this township is Paddy, which is the vital crop of Burma and the productivity of which is quite satisfactory in this township and a variety of other important crops can be found here.

The total population of Henzada township is 283867 in the year 1976-77. About 72% of this population are village dwellers. There are 47472 cultivators who can be classified by type of land on which they work as shown below.

Type of Land	No. of Cultivators		Acres	
Farms	23199	49%	143960	76%
Kaing-land	9891	21%	26241	14%
Garden	14382	30%	19346	10%
	47472		189547	

---

1 Sampled farms in this work mean the ones selected by the Research Department.

The total cultivated acres 189547 includes 490 acres of mix-cropping and there are 12,238 acres of double-cropping.

Type of soil can be classified as follows:[1]

Type of Soil	Acres
Sandy soil	18,955
'Sane' soil	85,296
Rich soil	85,296
	189,547

There are one hundred and three village tracks in Henzada township and a village track is usually composed of three to five villages. Seven villages were chosen to be used in our study. Some important characteristics of the sampled villages are shown in the following table (4).[2]

Table (4)

Villages	Population	Farmers	Sown Acreage	No. of farmers according to farm-size			
				< 5 acres	5-10	10-20	> 20
1. Kunchangone	556	77	510.32	18	54	4	1
2. Kyu Ka Paing	450	98	200.00	7	31	-	-
3. Oatoe	1218	140	1400.00	5	30	100	5
4. Myecha	950	65	300.00	20	42	2	-
5. Bae Chaung	450	25	110.00	25	-	-	-
6. Pe Gyi Kyun	500	250	1300.00[3]	-	95	155	-
7. Oat Shit Gone	1826	400	1560.00	200	200	-	-

1 Estimation by the staff of Township Planning Department.
2 For complete information please see appendices 5,6,7,8,9,10 & 1.
3 Kaing land included.

In order to obtain the farms to be used as our units of study, we list all the farmers in each sampled village and take (3) farmers randomly. Since our sampled farms consist of different sizes, we have to find out the average farm-size to be used as limited land resource which amounts to 7.22 acres.

Capital, the other limited resource, is derived by calculating average cost including cost of labour, cost of inputs and other costs. Labour cost consists of cost for seedbed preparation, plucking seedling, land preparation, transplanting, land maintenance, pest control, harvesting, haulage and cost of 'sayinhngas'. The cost of inputs contains cost for seeds, pesticides, fertilizers, manures, and others. In addition, other costs such as land revenue, interest and depreciations for equipments and animals are also taken into account. The above costs are considered as financial constraint. Furthermore, we classify these costs into (2) types such as imputed cost and out-of-pocket cost. By this way we obtain the total cost 1510 kyats and out-of-pocket cost (in cash) 923 kyats.

The other important resource taken into consideration is labour power. We assume that the labour power available in a family which is working on 7-acre farm is equal to (3) male adults on the ground that there will be (2) male adults, one woman and one helpful youngster. Moreover, we also assume that there are 350 working days in a year as the farm is used throughout the year. Thus, the labour power available is 1050 man days.

The crops cultivated in the sampled farms are 4 types of paddy (Kauk-kyee, Kauk-latt, Kauk-nge and High-yielding varieties), groundnut, chillie and pulses (mainly Pegyi and Peyin). All types of paddy are classified as one group, so are the pulses classified. Therefore, we have four kinds of crops to be considered. For the crops mentioned above we calculate the cost per acre, yield per acre, required man days per acre and net income per acre as shown in the following Table (5).

Table (5).

	Paddy	Groundnut	Chillie	Pulses
1. Cost per acre	249.87 166.92	292.95 97.52	369.21 132.35	110.00 45.39
2. Yield per acre	35.919 baskets	16.16 baskets	60.00 viss	7.7 baskets
3. Man days per acre	23	22	43	16.5
4. Unit Price	9,10,11 kyats	39,40,41 kyats	9,10,11 kyats	17,18,19 kyats
5. Net income(1) (2)	110.13 198.08	387.05 582.48	230.79 467.65	34.00 98.61

Source: Calculation based on the data collected by the staff members of the Research Department of Institute of Economics.

2.2 Application of Cost-benefit Analysis

In order to apply cost-benefit analysis in selecting the crop pattern in Henzada township we have to construct the following Table (6).

Table (6)

Sr. No.	Crops	Cost per acre		Net Income per acre		Ratio of Net Income to Cost		Priorit	
		In cash	Total	"Cash"*	Total	"Cash"*	Total	"Cash"*	[illegible]
1	Paddy	166.92	249.87	198.08	110.13	0.79	0.44	4	3
2	Groundnut	97.52	292.95	582.48	387.05	1.98	1.32	1	1
3	Chillie	132.35	369.21	467.65	230.79	1.26	0.625	2	2
4	Peas	45.39	110.00	98.61	34.00	0.89	0.31	3	4

As shown in the table, the first priority is given to groundnut, the second to chillie, the third to paddy and the fourth to peas in the total column. The first and the second priorities are the same as above, but the third priority is given to peas and the fourth to paddy in the cash column. Whatever the case is, paddy is to be chosen since we have to meet the minimum requirements of paddy, that is 3 acres of

---

* "Cash" = Total Income - Cash Cost.

land, for family consumption, seeds, etc. Furthermore, groundnut also is usually grown on 2 acres of land due to available soil type and high cost of cultivation. Thus, the rest of the land, 2.22 acres, is to be cultivated for chillie. The total net income received from this crop pattern is shown in the following Table (7).

Table (7)

Crop	No. of acres	Net Income Per Acre	Total Income
Groundnut	2.0	K. 387.05	K. 774.10
Chillie	2.2	K. 230.79	K. 512.24
Paddy	3.0	K. 110.13	K. 330.39
			K.1616.73

The total cost for this crop pattern can be calculated as shown in the following Table (8).

Table (8)

Crop	No. of acres	Total Cost per acre	Total
Groundnut	2.0	K. 292.95	K. 585.90
Chillie	2.2	K. 369.21	K. 819.65
Paddy	3.0	K. 249.87	K. 749.61
			K.2155.16

The available capital, the most limited resource, is K.1510, as shown in the appendix, which is much lesser than the total cost needed.[1] Therefore we have to reduce the acres for chillie as its income is lower and its cost is higher than that of groundnut. In order to reduce K.645.16 (i.e. Total Cost 2155.16 less available capital 1510) we are to reduce nearly 1.75 acres (i.e. $\frac{645.16}{369.21}$) of chillie.

Thus the crop pattern and its total net income will be as the following Table (9).

Table (9)

Crop	No. of acres	Net Income per acre	Total
Groundnut	2.00	K. 387.05	K. 774.10
Chillie	0.47	K. 230.79	K. 108.47
Paddy	3.00	K. 110.13	K. 330.39
			K. 1212.96

The weakness of cost-benefit analysis clearly revealed here are as follows: (1) It does not consider the available resources and other constraints in the method itself, and (2) further considerations and calculations are needed to reach the solution which will provide the maximum income.

1 Actually we have also to findout whether available labour hours are sufficient for this crop pattern.

2.3 Application of Budgeting Method

Taking the crop pattern provided by the foregoing analysis, we can easily continue to apply budgeting method as follows:-

Farm Budget

General characteristics

1. Farm size - 7.22 acres
2. Livestock - 1 bullock pair
3. Family size - 5

Physical volume of production

1.	Land use	acre	Yield/acre	Production
	Paddy	3	36	108 baskets
	Groundnut	2	17	34 "
	Chillie	0.47	60	28.2 viss
2.	Labour use	Man days	Rate	Value
	Paddy	69	9*	K 621
	Groundnut	44	9	396
	Chillie	20	9	180
				1197
3.	Cash Inputs			
	Seed			176
	Manure			50
	Fertilizer			40
	Pesticides			44
				310

Receipts, Expenses and Net Income

Receipts	Price	Production	Total
Paddy	10	108	1080
Groundnut	40	34	1360
Chillie	10	28.2	282
			2722
Expenses			
Labour			(-) 1197
Cash inputs			(-) 310
		Net Income	1215

---

* Average Cost

Here we find that the same maximum income can be achieved with the same weakness of the previous method. Moreover, we cannot know the list of priority for the crops without the help of the cost-benefit analysis.

The common weaknesses of both methods, as already explained in chapter one, lie in the facts that some crucial considerations cannot be built in the methods themselves and when changes occur in important factors, we have to start again from the beginning and make tedious effort in order to get the results. Let us see whether these weaknesses can be overcome and what more can be done by applying mathematical programming in the following sections.

2.4 Application of Mathematical Programming

In order to apply mathematical programming in choosing optimum crop pattern, we have first to consider the constraints of available resources or inputs such as land, labour and capital. Then we continue to find out the amount of each input required to produce per unit (basket or viss) of output of each crop. This can be used as the technical co-efficient for each input to produce per unit of output. For example, yield of paddy per acre is 36 baskets, therefore the coefficient for land to produce per basket of paddy is 1/36 acre i.e. .027 acre.

In the same way we calculate the coefficients for other constraints such as labour and capital. The same procedure is repeated for all crops under study.[1] By using these coefficients we form the equations for the constraints of resources. The objective function to maximize the net income can be set by calculating the revenue per unit of output of each crop. Thus the following equations are obtained.

Let x_1 denotes baskets of paddy,

x_2 denotes baskets of groundnut,

x_3 denotes viss of chillie,

x_4 denotes baskets of peas.

Objective function:

$$\text{Max } z = 3.06\, x_1 + 22.77\, x_2 + 3.85\, x_3 + 4.25\, x_4$$

Subject to land - $.027\, x_1 + .058\, x_2 + .017\, x_3 + .125\, x_4 \leqslant 7.22$

Capital - $6.94\, x_1 + 17.23\, x_2 + 6.15\, x_3 + 13.75\, x_4 \leqslant 1510$

Labour - $.64\, x_1 + 1.29\, x_2 + .72\, x_3 + 2.06\, x_4 \leqslant 1050$

where $x_1, x_2, x_3, x_4 \geqslant 0$

---

1 Calculations are shown in Appendix 4(a).

Furthermore, we have to consider the minimum requirement of paddy for family consumption throughout the year. It is assumed that a farmer has to cultivate at least 3 acres of land in order to fulfill the requirement of family consumption, seeds and compulsory sales to government and obligatory payment for advanced sales. Therefore, the minimum requirement in terms of baskets i.e. 108 baskets (36 baskets x 3 acres). In equation form we have:-

$$x_1 \geqslant 108 \quad \text{(minimum paddy requirement)}$$

The other case is of groundnut. The maximum availability of suitable land is generally assumed to be 2 acres because it can be grown only on sandy soil type in lower land which amounts to 3 acres out of the average farm size 7.22 acre. Moreover the cost of cultivating groundnut is too high for a farmer to finance when he cultivates more than this limit. As we have assumed that the yield of groundnut per acre is 17 baskets, this maximum limit in terms of baskets will be 34 baskets (i.e. 17 baskets x 2 acres). In equation form we have:-

$$x_2 \leqslant 34 \quad \text{(Maximum groundnut requirement)}$$

Considering all the above 5 constraints, we can find optimum plan for crop patterns in Henzada township by formulating a full Linear Programming problem as follows:-

2.4.1 Mathematical Formulations

Objective function -

$$\text{Max } z = 3.06x_1 + 22.77x_2 + 3.85x_3 + 4.25x_4$$

Subject to land - $.027x_1 + .058x_2 + .017x_3 + .125x_4 \leqslant 7.22$

Capital - $6.94x_1 + 17.23x_2 + 6.15x_3 + 13.75x_4 \leqslant 1510$

Labour - $.64x_1 + 1.29x_2 + .72x_3 + 2.06x_4 \leqslant 1050$

Min. Paddy - $x_1 \geqslant 108$

Max. Groundnut - $x_2 \leqslant 34$

where $x_1, x_2, x_3, x_4 \geqslant 0$

The results which are computerized by L.P. package can be seen in CRP-0.

2.4.2 Results and Interpretation

According to the results, the optimum crop pattern for Henzada township consist of Paddy, Groundnut and Chillie. In the case of Paddy the number of acres to be cultivated is 3 acres (i.e. 108 baskets $\div$ 36 baskets). This acreage meets first the minimum requirement for family consumption,

```
DUMP,DUMP     3                              RIGHT HAND SIDE  RIGHT
                                             OBJECTIVE        OBJ

COLUMN INFORMATION

   NAME                     VALUE            OBJECTIVE     REDUCED COST
B PADDY       *          108.0000              3.0600               0
B GROUNDNU    *           34.0000             22.7700               0
B CHELLIE     *           28.4000              3.8500               0
  PEGY,PEY    *                 0              4.2500         -4.3577
OBJECTIVE               1214.0000
PROBLEM    YOUR PROBLEM             SOLUTION                                        DATE 1

DUMP,DUMP     3                              RIGHT HAND SIDE  RIGHT
                                             OBJECTIVE        OBJ

ROW INFORMATION

   NAME                     SLACK                         R.H.S.                    PRICE
# OBJ         Z         1214.0000                              0
B LAND        *            1.8492                         7.2200                        0
  CAPITAL     *                 0                      1510.0000                  -0.6260
B LABOUR      *          915.7200                      1050.0000                        0
  MINPAD      -                 0                       108.0000                   1.2846
  MAXGRO      *                 0                        34.0000                 -11.9837
DOCUMENT LOG PRINTOUT, NORM CRP0              LP00 ON 14/09/77 AT 16.59

    ACCOUNT CODE     0000210A                DATE             14/09/77                  TOT

    JOB NAME         CRP0                    START TIME       16/57/40                  INP
    USER NAME        THEIN 00                END TIME         16/59/00                  OUT

    PERIPHERALS USED: 14                                                                MAX
```

seeds and others such as compulsory sales to government and obligatory payment for advanced sales. For groundnut, the number of acres to be sown is 2 acres (i.e. 34 baskets ÷ 17 baskets). This acreage reaches the maximum available acres as it is the most profitable crop. The lowest acreage .475 (i.e. 28.4 viss ÷ 60 viss) is required for growing chillie. If this crop pattern is chosen, our objective to maximize the net income will be fulfilled by 1214 kyats. Of course, any farmer can readily be contented with this net income per annum.

The solutions obtained by Linear Programming method renders not merely the optimum crop pattern but also the important factors for decision making such as the remaining resources and shadow prices. According to the results obtained the remaining resources are land (1.8492 acres) and labour (915.7 man days) and all the capital available are used up. These can be seen in the column headed as 'slack' in the solution. The shadow price for capital is .62 as shown in the column headed as 'price'. If we wish to invest an additional unit of capital we should at least earn .62 as marginal revenue in order to maintain the same level of maximum income.

Since the most flexible constraints, generally assumed or the prices, labour man days, available land and the amount of capital, we vary them in different ways and obtain the results as shown in the following table (10).

From CRP - 0 to CRP - 5 we take land 7.22 acres and labour 1050 man days. CRP - 0, CRP - 2 and CRP - 4 take total cost K.1510 whereas CRP - 1, CRP - 3 and CRP - 5 take cash cost K.923. Prices of crops are K.10,40,18 and 10 for paddy, groundnut, pegyi and chillie respectively in the first two problems. Then we reduce by one kyat in the following two problems and add one kyat in CRP - 5 & 6.

From CRP - 6 to CRP - 13 we take land 8 acres and labour 1400 man days. CRP - 6, CRP - 8, and CRP - 11 take total cost K.2000 whereas CRP - 7, CRP 12 and CRP - 13 take cash cost as K.950. Prices are varied in the same pattern as above.

The mathematical formulations and the results obtained for the different problems solved by L.P. package are explained and analyzed in the following sections.

CRP - 0 - This problem has already been explained in detail. The others can be analyzed by following the same logical reasonings.

Table 10

Problems	Constraints: Land acre	Labour Man Days	Capital: Cash Cost	Capital: Total Cost	Prices: Paddy	Prices: Ground-nut	Prices: Pegyi	Prices: Chillie	Results: Paddy acre	Groundnut acre	Pegyi acre	Chillie acre	Max: Net Income Z	Slacks: Land	Slacks: Labour	Shadow Price of Capit
CRP 0	7.22	1050	-	K1510	K.10	K.40	K.18	K.10	3.00	2.00	-	.4733	1214.0000	1.8492	915.72	.626
CRP 1	7.22	1050	K923	-	10	40	18	10	3.00	2.00	-	1.7205	2549.3077	.5771	862.69	3.524
CRP 2	7.22	1050	-	1510	9	39	17	9	3.00	2.00	-	.4733	1043.6000	1.8492	916.57	.463
CRP 3	7.22	1050	923	-	9	39	17	9	3.00	2.00	-	1.7205	2304.0769	.5771	862.69	3.0724
CRP 4	7.22	1050	-	1510	11	41	19	11	3.00	2.00	-	.4733	1384.4000	1.8492	916.57	.7886
CRP 5	7.22	1050	923	-	11	41	19	11	3.00	2.00	-	1.7205	2794.5385	.5771	862.69	3.9774
CRP 6	8.00	1400	-	2000	10	40	18	10	3.00	2.00	-	1.7205	1520.7480	1.2747	1209.20	.6260
CRP 7	8.00	1400	950	-	10	40	18	10	3.00	2.00	-	1.9241	2644.4796	1.1494	1203.89	3.5249
CRP 8	8.00	1400	-	2000	9	39	17	9	3.00	2.00	-	1.7205	1270.6732	1.2747	1209.20	.4634
CRP 12	8.00	1400	950	-	9	39	17	9	3.00	2.00	-	1.9241	2387.0317	1.1494	1203.89	3.0724
CRP 11	8.00	1400	-	2000	11	41	19	11	3.00	2.00	-	1.7205	1770.8228	1.2747	1209.20	.7886
CRP 13	8.00	1400	950	-	11	41	19	11	3.00	2.00	-	1.9241	2916.5476	1.1494	1203.89	3.0724

DOCUMENT CRP1   NORM[CRP1   : LP01 ON 05/09/77 AT 00.25

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP:DUMP 3

RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

COLUMN INFORMATION

NAME		VALUE	OBJECTIVE	REDUCED COST
B PADDY	+	108.0000	5.3700	0
B GROUNDNU	+	34.0000	34.2700	0
B CHILLIE	+	1034.2308	7.7900	0
PEGYIPEY	+	0	12.3300	-7.6561
OBJECTIVE		2549.3077		

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP:DUMP 3

RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

ROW INFORMATION

NAME		SLACK	R.H.S.	PRICE
# OBJ	Z	2549.3077	0	
B LAND	+	0.5771	7.2200	-0.0000000075
CAPITAL	+	0	923.0000	-3.5249
B LABOUR	+	862.6938	1050.0000	0
MAXGRO	+	0	34.0000	-14.0744
MINPAD	-	0	108.0000	10.9502

CRP - 1 - In this problem we consider only the cash cost as the available capital. Other constraints such as land, labour and prices are the same as CRP 0. Thus we can establish the model as follows:-

Objective function

$$\text{Max } Z = 5.37x_1 + 34.27x_2 + 7.79x_3 + 12.33x_4$$

Subject to -

$$.027x_1 + .058x_2 + .017x_3 + .125x_4 \leqslant 7.22$$
$$4.63x_1 + 5.73x_2 + 2.21x_3 + 5.67x_4 \leqslant 923$$
$$.64x_1 + 1.29x_2 + .72x_3 + 2.06x_4 \leqslant 1050$$
$$x_2 \leqslant 34$$
$$x_1 \geqslant 108$$

where $x_1, x_2, x_3, x_4 \geqslant 0$

The results obtained indicate that the optimum crop pattern is the same as CRP 0 in which we consider the total cost as the available capital. However, CRP 1 indicates that more acres of land should be cultivated for chillie in order to have the maximized net income - K.2549.3077 and that the slacks for land and labour will be reduced to .5771 acre and 862.6938 man days respectively, whereas the shadow price for capital is raised up to K3.5249.

DUMP;DUMP 3 RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

COLUMN INFORMATION

NAME		VALUE	OBJECTIVE	REDUCED COST
IB PADDY	*	108.0000	2.0600	0
IB GROUNDNU	*	34.0000	21.7700	0
IB CHILLIE	*	28.4000	2.8500	0
PEGY;PEY	*	0	3.2500	-3.1420
OBJECTIVE		1043.6000		

PROBLEM YOUR PROBLEM SOLUTION DATE 14

DUMP;DUMP 3 RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

ROW INFORMATION

NAME		SLACK	R.H.S.	PRICE
# OBJ	Z	1043.6000	0	
B LAND	*	1.8492	7.2200	0
CAPITAL	*	0	1510.0000	-0.4634
B LABOUR	*	916.5720	1050.0000	0
MAXGRO	*	0	34.0000	-13.7834
MINPAD	-	0	108.0000	1.1201

DOCUMENT LOG PRINTOUT, NORM;CRP2 , LP00 ON 14/09/77 AT 17/00

ACCOUNT CODE 00CC210A DATE 14/09/77 TOTA

JOB NAME CRP2 START TIME 16/59/06 INPU
USER NAME THEIN OO END TIME 17/00/24 OUTP

PERIPHERALS USED, 14 MAX

CRP - 2 - In this problem we consider the constraints as the same as CRP-0 expept the prices of the crops, which are reduced by one kyat unit each. We can establish this model as follows:-

$$\text{Max } Z = 2.06x_1 + 21.77x_2 + 2.85x_3 + 3.25x_4$$

Subject to

$$.027x_1 + .058x_2 + .017x_3 + .125x_4 \leqslant 7.22$$

$$6.94x_1 + 17.23x_2 + 6.15x_3 + 13.75x_4 \leqslant 1510$$

$$.64x_1 + 1.29x_2 + .72x_3 + 2.06x_4 \leqslant 1050$$

$$x_1 \geqslant 108$$

$$x_2 \leqslant 34$$

$$\text{where } x_1, x_2, x_3, x_4 \geqslant 0$$

Here we find out that the optimum crop pattern, the slacks and the shadow price of capital are nearly the same as CRP - 0.

CRP - 3 - In this case we consider the cash cost as the available capital and the other constraints are the same as CRP - 2. Therefore, the mathematical model is as follows:-

$$\text{Max } Z = 4.37x_1 + 33.27x_2 + 6.79x_3 + 11.33x_4$$

DOCUMENT CRP3 , NORMICRP3 : LP

PROBLEM YOUR PROBLEM SOLUTION

DUMP:DUMP 3 RIGHT HAND
OBJECTIVE

COLUMN INFORMATION

NAME		VALUE	OBJECTIVE
B PADDY	+	108.0000	4.3700
B GROUNDNU	+	34.0000	33.2700
B CHILLIE	+	103.2308	6.7900
REGY,PEY	+	0	11.3300
OBJECTIVE		2304.0769	

PROBLEM YOUR PROBLEM SOLUTION

DUMP:DUMP 3 RIGHT HAND
OBJECTIVE

ROW INFORMATION

NAME		SLACK
# OBJ	Z	2304.0769
B LAND	+	0.5771
CAPITAL	+	0
B LABOUR	+	862.6938
MAXGRO	+	0
MINPAD	-	0

DOCUMENT CRP3 , NORM[CRP3 : LP01 ON 03/

PROBLEM YOUR PROBLEM SOLUTION

DUMP:DUMP 3 RIGHT HAND SIDE RIGH
OBJECTIVE OBJ

COLUMN INFORMATION

NAME		VALUE	OBJECTIVE	REDUCE
B PADDY	+	108.0000	4.3700	
B GROUNDNU	+	34.0000	33.2700	
B CHILLIE	+	103.2308	6.7900	
PEGY,PEY	+	0	11.3300	-6
OBJECTIVE		2304.0769		

PROBLEM YOUR PROBLEM SOLUTION

DUMP:DUMP 3 RIGHT HAND SIDE RIG
OBJECTIVE OBJ

ROW INFORMATION

NAME		SLACK	R.H.S.
# OBJ	Z	2304.0769	0
B LAND	+	0.5771	7.2200
CAPITAL	+	0	923.0000
B LABOUR	+	862.6938	1050.0000
MAXGRO	+	0	34.0000
MINPAD	-	0	108.0000

DOCUMENT CRP3 , NORM[CRP3 : LP01 ON 03/09/77 A

PROBLEM YOUR PROBLEM SOLUTION

DUMP:DUMP 3

RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

COLUMN INFORMATION

	NAME		VALUE	OBJECTIVE	REDUCED COST
B	PADDY	+	108.0000	4.3700	0
B	GROUNDNU	+	34.0000	33.2700	0
B	CHILLIE	+	103.2308	6.7900	0
	PEGY,PEY	+	0	11.3300	-6.0905
	OBJECTIVE		2304.0769		

PROBLEM YOUR PROBLEM SOLUTION

DUMP:DUMP 3

RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

ROW INFORMATION

	NAME		SLACK	R.H.S.
#	OBJ	Z	2304.0769	0
B	LAND	+	0.5771	7.2200
	CAPITAL	+	0	923.0000
B	LABOUR	+	862.6938	1050.0000
	MAXGRO	+	0	34.0000
	MINPAD	-	0	108.0000

$$\text{Subject to} \quad .027x_1 + .058x_2 + .017x_3 + .125x_4 \leqslant 7.22$$

$$4.63x_1 + 5.73x_2 + 2.21x_3 + 5.67x_4 \leqslant 923$$

$$.64x_1 + 1.29x_2 + .72x_3 + 2.06x_4 \leqslant 1050$$

$$x_1 \geqslant 108$$

$$x_2 \leqslant 34$$

$$\text{where } x_1, x_2, x_3, x_4 \geqslant 0$$

The results obtained are nearly the same as CRP - 1.

CRP - 4 - Here, we change the prices of the different crops by increasing Kyat one per unit of output and the constraints are the same as CRP 2. So the mathematical model can be establish as follows:

$$\text{Max} \quad Z = 4.06x_1 + 23.77x_2 + 4.85x_3 + 5.25x_4$$

$$\text{Subject to} \quad .027x_1 + .058x_2 + .017x_3 + .125x_4 \leqslant 7.22$$

$$6.94x_1 + 17.23x_2 + 6.15x_3 + 13.75x_4 \leqslant 1510$$

$$.64x_1 + 1.29x_2 + .72x_3 + 2.06x_4 \leqslant 1050$$

$$x_1 \geqslant 108$$

$$x_2 \leqslant 34$$

$$\text{where } x_1, x_2, x_3, x_4 \geqslant 0$$

DOCUMENT CRP4 , NORMICRP4 : LP01 ON 03/09/77 AT 00.27

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP:DUMP 3

RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

COLUMN INFORMATION

NAME		VALUE	OBJECTIVE	REDUCED COST
B PADDY	*	108.0000	4.0600	0
B GROUNDNU	*	34.0000	23.7700	0
B CHILLIE	*	28.4000	4.8500	0
PEGYIPEY	*	0	5.2500	-5.5935
OBJECTIVE		1384.4000		

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP:DUMP 3

RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

ROW INFORMATION

NAME		SLACK	R.H.S.	PRICE
# OBJ	Z	1384.4000	0	
B LAND	*	1.8492	7.2200	0
CAPITAL	*	0	1510.0000	-0.7886
B LABOUR	*	916.5720	1050.0000	0
MAXGRO	*	0	34.0000	-10.1861
MINPAD	-	0	108.0000	1.4130

The results obtained are generally the same as CRP - 2 except that the maximum net income is increased up to K.1384.40, which is, of course, due to the increase of the prices.

CRP - 5 - In this problem we take the cash cost as the available capital and the other constraints are the same as CRP - 4. The mathematical model is as follows:

$$\text{Max } Z = 6.37x_1 + 35.27x_2 + 8.79x_3 + 13.33x_4$$

$$\text{Subject to } \quad .027x_1 + .058x_2 + .017x_3 + .125x_4 \leqslant 7.22$$

$$4.63x_1 + 5.73x_2 + 2.21x_3 + 5.67x_4 \leqslant 923$$

$$.64x_1 + 1.29x_2 + .72x_3 + 2.06x_4 \leqslant 1050$$

$$x_2 \leqslant 34$$

$$x_1 \geqslant 108$$

$$\text{where } x_1, x_2, x_3, x_4 \geqslant 0$$

The results obtained are the same as CRP - 3 which in turn are similar to the results in CRP - 1 except that the maximum net income is increased up to K.2794.5385 due to the increases in the prices of the different crops.

DOCUMENT CRP5 / NORM:CRP5 : LP01 ON 03/09/77 AT 00:30

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP:DUMP 3 RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

COLUMN INFORMATION

NAME		VALUE	OBJECTIVE	REDUCED COST
B PADDY	+	108.0000	6.3700	0
B GROUNDNU	+	34.0000	35.2700	0
B CHILLIE	+	103.2308	8.7900	0
PEGY,PEY	+	0	13.3300	-9.2217
OBJECTIVE		2794.5385		

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP:DUMP 3 RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

ROW INFORMATION

NAME		SLACK	R.H.S.	PRICE
# OBJ	Z	2794.5385	0	
B LAND	+	0.5771	7.2200	-0.000000075
CAPITAL	+	0	923.0000	-3.9774
B LABOUR	+	862.6938	1050.0000	0
MAXGRO	+	0	34.0000	-12.4796
MINPAD	-	0	108.0000	12.0692

DOCUMENT CRP5 / NORM:CRP5 : LP01 ON 03/09/77 AT 00:30

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP:DUMP 3

RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

COLUMN INFORMATION

NAME		VALUE	OBJECTIVE	REDUCED COST
B PADDY	*	108.0000	6.3700	0
B GROUNDNU	*	34.0000	35.2700	0
B CHILLIE	*	103.2308	8.7900	0
PEGY,PEY	*	0	13.3300	-9.2217
OBJECTIVE		2794.5385		

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP:DUMP 3

RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

ROW INFORMATION

NAME		SLACK	R.H.S.	PRICE
# OBJ	Z	2794.5385	0	
B LAND	*	0.5771	7.2200	-0.000000075
CAPITAL	*	0	923.0000	-3.9774
B LABOUR	*	862.6938	1050.0000	0
MAXGRO	*	0	34.0000	-12.6796
MINPAD	-	0	108.0000	[illegible]

<u>CRP - 6</u> - In this problem we vary the available land, labour and capital by increasing them up to 8 acres, 1400 man days and 2000 kytats respectively, and the prices are taken as same as those of CRP - 0 and CRP - 1. Therefore the following mathematical model can be used.

$$\text{Max } Z = 3.06x_1 + 22.77x_2 + 3.85x_3 + 4.25x_4$$

$$\text{Subject to} \quad .027x_1 + .058x_2 + .017x_3 + .125x_4 \leqslant 8$$

$$6.94x_1 + 17.23x_2 + 6.15x_3 + 13.75x_4 \leqslant 2000$$

$$.64x_1 + 1.29x_2 + .72x_3 + 2.06x_4 \leqslant 1400$$

$$x_2 \leqslant 34$$

$$x_1 \geqslant 108$$

$$\text{where } x_1, x_2, x_3, x_4 \geqslant 0$$

Although the crop pattern obtained is the same as the foregoing problems and the number of acres to cultivate are the same as CRP-1, CRP-3, and CRP-5, the maximum net income is higher than those of the preceding problems which consider the total cost as the available capital. The slacks for labour, and the shadow price of capital have slight differences from those of the CRP-0, CRP-2 and CRP-4 which also consider the total cost as the available capital.

DOCUMENT CRP6 , NORM[CRP6] LP01 ON 03/09/77 AT 00.31

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP:DUMP 3 RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

COLUMN INFORMATION

NAME		VALUE	OBJECTIVE	REDUCED COST
B PADDY	+	108.0000	3.0600	0
B GROUNDNU	+	34.0000	22.7700	0
B CHILLIE	+	108.0748	3.8500	0
PEGYIPEY	+	0	4.2500	-4.3577
OBJECTIVE		1520.7480		

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP:DUMP 3 RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

ROW INFORMATION

NAME		SLACK	R.H.S.	PRICE
# OBJ	Z	1520.7480	0	
B LAND	+	1.2747	8.0000	0
CAPITAL	+	0	2000.0000	-0.6200
B LABOUR	+	1209.2061	1400.0000	0
MAXGRO	+	0	34.0000	-11.9837
MINPAD	-	0	108.0000	1.2846

DOCUMENT GRP7 , NORM:GRP7 : LP01 ON 03/09/77 AT 00.19

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP:DUMP 3 RIGHT HAND SIDE RIGHT

OBJECTIVE OBJ

COLUMN INFORMATION

NAME		VALUE	OBJECTIVE	REDUCED COST
B PADDY	*	108.0000	5.3700	0
B GROUNDNU	*	34.0000	34.2700	0
B PEGYI	*	115.4480	7.7900	0
CHILLE	*	0	12.3300	-7.6561
OBJECTIVE		2644.4796		

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP:DUMP 3 RIGHT HAND SIDE RIGHT

OBJECTIVE OBJ

ROW INFORMATION

NAME		SLACK	R.H.S.	PRICE
# OBJ	Z	2644.4796	0	
B LAND	*	1.1494	8.0000	0
CAPITAL	*	0	950.0000	-3.5249
B LABOUR	*	1203.8975	1400.0000	0
MAXGRO	*	0	34.0000	-14.0724
MINPAD	-	0	108.0000	10.9802

CRP - 7 - Here we take increased cash cost as the available capital and the other constraints are the same as CRP-6. The mathematical model is as follows:

$$\text{Max } Z = 5.37x_1 + 34.27x_2 + 7.79x_3 + 12.33x_4$$

$$\text{Subject to} \quad .027x_1 + .058x_2 + .017x_3 + .125x_4 \leqslant 8$$

$$4.63x_1 + 5.73x_2 + 2.21x_3 + 5.67x_4 \leqslant 950$$

$$.64x_1 + 1.29x_2 + .72x_3 + 2.06x_4 \leqslant 1400$$

$$x_2 \leqslant 34$$

$$x_1 \geqslant 108$$

$$\text{where } x_1, x_2, x_3, x_4 \geqslant 0$$

Although the other results are nearly the same as CRP-6, the maximum net income and the shadow price of capital are almost equal to those of CRP-5 which shows the highest in both of them.

CRP - 8 - The prices of the different crops, in this problem, are reduced by one kyat compared to CRP - 6. The mathematical model for this problem can be formulated as follows:

$$\text{Max } Z = 2.06x_1 + 21.77x_2 + 2.85x_3 + 3.25x_4$$

DOCUMENT LOG PRINTOUT, NORM;CRP8 ; LP00 ON

ACCOUNT CODE 00CC210A DATE

JOB NAME CRP8 START TIME

USER NAME THEIN 00 END TIME

PERIPHERALS USED; 14

PROBLEM YOUR PROBLEM SOLUTION

DUMP;DUMP 3 RIGHT HAND SIDE
OBJECTIVE

COLUMN INFORMATION

NAME		VALUE	OBJECTIVE	RE
B PADDY	+	108.0000	2.0600	
B GROUNDNU	+	34.0000	21.7700	
B CHILLIE	+	108.0748	2.8500	
PEGYIPEY	+	0	3.2500	
OBJECTIVE		1270.6732		

PROBLEM YOUR PROBLEM SOLUTION

DUMP;DUMP 3 RIGHT HAND SIDE
OBJECTIVE

ROW INFORMATION

NAME		SLACK	R.H.S
# OBJ	Z	1270.6732	
B LAND	+	1.2747	8.0
CAPITAL	+	0	2000.0
B LABOUR	+	1209.2061	1400.0
MAXGRO	+	0	34.0
MINPAD	-	0	108.0

DOCUMENT LOG PRINTOUT, NORM:CRP8 : LP00 ON 03/09/77 AT 00.34

ACCOUNT CODE	00CC210A	DATE	03/09/77	TU
JOB NAME	CRP8	START TIME	00/32/41	IN
USER NAME	THEIN 00	END TIME	00/34/12	OU
PERIPHERALS USED: 14				MA

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP:DUMP 3 RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

COLUMN INFORMATION

NAME		VALUE	OBJECTIVE	REDUCED COST
B PADDY	+	108.0000	2.0600	0
B GROUNDNU	+	34.0000	21.7700	0
B CHILLIE	+	108.0748	2.8500	0
PEGYIPEY	+	0	3.2500	-3.1420
OBJECTIVE		1270.6732		

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP:DUMP 3 RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

ROW INFORMATION

NAME		SLACK	R.H.S.	PRICE
# OBJ	Z	1270.6732	0	
B LAND	+	1.2747	8.0000	0
CAPITAL	+	0	2000.0000	-0.4634
B LABOUR	+	1209.2061	1400.0000	0
MAXGRO	+	0	34.0000	-13.7834
MINPAD	-	0	108.0000	1.1501

$$\text{Subject to} \quad .027x_1 + .058x_2 + .017x_3 + .125x_4 \leqslant 8$$

$$6.94x_1 + 17.23x_2 + 6.15x_3 + 13.75x_4 \leqslant 2000$$

$$.64x_1 + 1.29x_2 + .72x_3 + 2.06x_4 \leqslant 1400$$

$$x_2 \leqslant 34$$

$$x_1 \geqslant 108$$

$$\text{where } x_1, x_2, x_3, x_4 \geqslant 0$$

The results obtained are the same as CRP 6 with an exception that the maximum net income is reduced to K.1270.6732.

<u>CRP - 12</u> - Here again we consider only the cash cost as the available capital and the other constraints are the same as CRP-8. The model for this problem is formulated as below:

$$\text{Max } Z = 4.37x_1 + 33.27x_2 + 6.79x_3 + 11.33x_4$$

$$\text{Subject to} \quad .027x_1 + .058x_2 + .017x_3 + .125x_4 \leqslant 8$$

$$4.63x_1 + 5.72x_2 + 2.21x_3 + 5.67x_4 \leqslant 950$$

$$.64x_1 + 1.29x_2 + .72x_3 + 2.06x_4 \leqslant 1400$$

$$x_2 \leqslant 34$$

$$x_1 \geqslant 108$$

$$\text{where } x_1, x_2, x_3, x_4 \geqslant 0$$

PROBLEM YOUR PROBLEM SOLUTION DATE 14

DUMP;DUMP 3

RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

COLUMN INFORMATION

NAME		VALUE	OBJECTIVE	REDUCED COST
B PADDY	*	108.0000	4.3700	0
B GROUNDNU	*	34.0000	33.2700	0
B CHILLER	*	115.4480	3.7900	0
PEGYIPEY	*	0	11.3300	-6.0905
OBJECTIVE		2387.0317		

PROBLEM YOUR PROBLEM SOLUTION DATE 14

DUMP;DUMP 3

RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

ROW INFORMATION

NAME		SLACK	R.H.S.	PRICE
# OBJ	Z	2387.0317	0	
B LAND	*	1.1494	8.0000	0
CAPITAL	*	0	950.0000	-3.0744
B LABOUR	*	1203.8975	1400.0000	0
MAXGRO	*	0	34.0000	-15.6652
MINPAD	*	0	108.0000	9.8552

DOCUMENT LOG PRINTOUT, NORM CRP12 I LP00 ON 14/09/77 AT 17.01

ACCOUNT CODE 0000240A DATE 14/09/77 TOTA

JOB NAME CRP12 START TIME 17/00/25 INPU
USER NAME THEIN OO END TIME 17/01/44 OUTP

PERIPHERALS USED: 14 MAX.

Except for the maximum net income, other results are not much different from the preceding problem.

CRP - 11 - In this problem we assume the highest prices for all the crops as in CRP - 4 and CRP - 5 and the other constraints are the same as CRP - 8. The formulation of mathematical model for this problem is as follows:

$$\text{Max } Z = 4.06x_1 + 23.77x_2 + 4.85x_3 + 5.25x_4$$

Subject to

$$.027x_1 + .058x_2 + .017x_3 + .123x_4 \leqslant 8$$

$$6.94x_1 + 17.23x_2 + 6.15x_3 + 13.75x_4 \leqslant 2000$$

$$.64x_1 + 1.29x_2 + .72x_3 + 2.06x_4 \leqslant 1400$$

$$x_2 \leqslant 34$$

$$x_1 \geqslant 108$$

$$\text{where } x_1, x_2, x_3, x_4 \geqslant 0$$

The results obtained are generally in the same pattern as CRP-1, CRP-3, CRP-5, CRP-7 in the cases of slack and shadow prices. The maximum net income is the highest among those problem which considers the total cost as available capital.

DOCUMENT CRP11   , NORM:CRP11   , LP01 ON 03/09/77 AT 04.36

PROBLEM YOUR PROBLEM   SOLUTION   DATE

DUMP:DUMP 3   RIGHT HAND SIDE RIGHT
        OBJECTIVE OBJ

COLUMN INFORMATION

	NAME		VALUE	OBJECTIVE	REDUCED COST
B	PADDY	+	108.0000	4.0600	0
B	GROUNDNU	+	34.0000	23.7700	0
B	CHILLIE	+	108.0748	4.8500	0
	PEGYIPEY	+	0	5.2500	-5.5935
	OBJECTIVE		1770.8228		

PROBLEM YOUR PROBLEM   SOLUTION   DATE

DUMP:DUMP 3   RIGHT HAND SIDE RIGHT
        OBJECTIVE OBJ

ROW INFORMATION

	NAME		SLACK	R.H.S.	PRICE
#	OBJ	Z	1770.8228	0	
B	LAND	+	1.2747	8.0000	0
	CAPITAL	+	0	2000.0000	-0.7866
B	LABOUR	+	1209.2061	1400.0000	0
	MAXGRO	+	0	34.0000	-10.1841
	MINPAD	-	0	108.0000	1.4130

CRP - 13 - Here we consider the cash cost as the available capital and all the other constraints are the same as CRP - 11. The model for this consideration is as follows:

$$\text{Max } Z = 6.37x_1 + 35.7x_2 + 8.79x_3 + 13.33x_4$$

$$\text{Subject to} \quad .027x_1 + .058x_2 + .017x_3 + .125x_4 \leq 8$$

$$4.63x_1 + 5.73x_2 + 2.21x_3 + 5.67x_4 \leq 950$$

$$.64x_1 + 1.29x_2 + .72x_3 + 2.06x_4 \leq 1400$$

$$x_2 \leq 34$$

$$x_1 \geq 108$$

$$\text{where } x_1, x_2, x_3, x_4 \geq 0$$

The results obtained are nearly the same as CRP-11 except that the maximum net income and the shadow price for capital are the highest.

Generalization of the results for different problems

First of all it is obvious that all the problems give the same crop pattern for paddy, groundnut and chillie. Paddy, the income of which is low, is shown only to fulfill the minimum requirement, whereas groundnut, the income of which is the highest, is sown by using all the maximum available acres. Pegyi (Peas) does not enter into the crop pat-

DOCUMENT CRP13 , NORM[CRP13 : LP01 ON 03/09/77 AT 09.21

PROBLEM YOUR PROBLEM SOLUTION DATE

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OBJECTIVE OBJ

COLUMN INFORMATION

	NAME		VALUE	OBJECTIVE	REDUCED COST
B	PADDY	+	108.0000	6.3700	0
B	GROUNDNU	+	34.0000	35.7000	0
B	PEGYI	+	115.4480	8.7900	0
	CHILLE	+	0	13.3300	-0.2217
	OBJECTIVE		2916.5476		

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP;DUMP 3 RIGHT HAND SIDE RIGHT

OBJECTIVE OBJ

ROW INFORMATION

	NAME		SLACK	R.H.S.	PRICE
#	OBJ	Z	2916.5476	0	
B	LAND	+	1.1494	8.0000	0
	CAPITAL	+	0	950.0000	-3.9776
B	LABOUR	+	1203.8975	1400.0000	0
	MAXGRO	+	0	34.0000	-12.9096
	MINPAD	-	0	108.0000	12.0[illegible]

tern because of its lowest net income.

In the first six problems, from CRP-0 to CRP-5, we assume that the land and labour are 7.22 acres and 1050 man days respectively. Whenever we take the cash cost as the available capital, the slacks for land and labour are reduced and the shadow prices of capital are increased together with the increase in net income which is, of course, the natural consequence of the reduction in the cost ignoring the imputed cost.

The same results can be found in the problems from CRP-6 to CRP-13 although the acres of chillie and the slacks for land and labour are not much different from those problems, which take total cost as the available capital.

Among the problems the maximum net incomes are rendered by those problems which consider the cash cost as the available capital. All these problems also point out that the slacks for land and labour are lower and the shadow prices of capital are higher than those of the problems which consider the total cost as the available capital. We can conclude that there will be surplus of land and labour and shortage of capital in the agricultural sector in the process of maximizing the net income of the farmers.

2.4.3 Post-optimal Analysis

As stated before, post-optimal analysis or sensitivity analysis can be done when there are changes in available resources (b) and changes in prices (CT). Such type of analysis is very useful for us when there is no stability in prices and when there exist different amount of resources available to individual farmers.

2.4.3a Changes in available resources

Changes in resources available can be denoted by (Δ b). If the farm size is changed from 7.22 acres to 10 acres, the available capital from Kyats 1510 to Kyats 2000, and other factors remain constant, (Δ b) will be as follows:

$$\Delta b = \begin{bmatrix} 2.78 \\ 490.00 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

In order to get the new optimal solution with these changes, we have to find out the inverse matrix of B, i.e. B^{-1}, first. By using the program 'PROGRAM LISTING', available at the University Computer Centre to form the last solution table for the previous problem, B^{-1} can be formed

$$B^{-1} = \begin{bmatrix} 1 & 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & .1626 & 1 & 1.12 & -2.8 \\ 0 & -.0028 & 0 & .007 & -.0104 \\ 0 & -.122 & 0 & -.206 & .8112 \end{bmatrix}$$

Then, multiplying B^{-1} by Δb, we can get the incremental effect, i.e. $B^{-1}\Delta b$.

$$B^{-1} \cdot \Delta b = \begin{bmatrix} 2.78 \\ 0 \\ 79.67 \\ -1.372 \\ -59.78 \end{bmatrix}$$

To obtain the new optimal solution, the incremental effect is added to the previous optimum solution, $B^{-1}b$.

$$B^{-1}(b + \Delta b) = \begin{bmatrix} 108.00 + 2.78 \\ 34.00 + 0 \\ 28.40 + 79.67 \\ 1.8492 - 1.372 \\ 915.72 \quad -59.78 \end{bmatrix} = \begin{bmatrix} 110.78 \\ 34.00 \\ 108.07 \\ 0.4772 \\ 855.94 \end{bmatrix}$$

Since the above optimal solutions are in terms of baskets/viss, we can transform them into acres as follows:-

Paddy	-	110.78 baskets	=	$\frac{110.78}{36}$	= 3.07 acres
Groundnut	-	34 baskets	=	$\frac{34}{17}$	= 2.00 acres
Chillie	-	108.07 viss	=	$\frac{108.07}{60}$	= 1.80 acres

Here, we find that the acreage for paddy and chillie have increased and the acreage for groundnut remains as before since it has already reaches its maximum available acres. In addition, the slacks for land and labour reduced to .4772 acres and 855.94 man days respectively.

With these changes, the objective function of the new optimal solution becomes K.1529.22. This can be obtained by multiplying $B^{-1}(b+\Delta b)$ by C^T.

Paddy	-	110.78 baskets	x K 3.06	= K 338.98
Groundnut	-	34.00 baskets	x K22.77	= K 774.18
Chillie	-	108.07 viss	x K 3.85	= K 416.06
			Total --	K1529.22

2.4.3b Changes in Prices

Changes in prices of crops will occur often in actual situation. If these changes occur after the optimum solution has been calculated, we may use the post optimal analysis in order to find the new optimum solution. Here, we have to reconsider the net contribution of the crop by using its new price and its coefficients from the final table. If the net contribution is positive, this crop should enter the basis (B) if it has not been before, or the crop should remain in the basis with new values if it has been before. For example, the prices of paddy, groundnut and peas rise up to K.12, K.60 and K.50 per basket respectively but the price of chillie remains constant, i.e. K.10/-. It does increase the net income per basket of paddy to K.5.059, groundnut to K.42.76 and peas to K.36.25.

In order to get the new optimal solution with these changes, we may calculate as follows:-

C^T		Peas $(B^{-1}A)$		$C^TB^{-1}A$
5.059	⟶	0		0
42.76	⟶	0		0
3.85	⟶	2.2358	=	8.6078
0	⟶	.0870		0
0	⟶	.3832		0
				8.6078

Net Contribution $C^{(1)T} - C^{T} B^{-1} A$ $= 36.25 - 8.6078$

$= + 27.6422$

Because of its positive value in Net contribution, it shows that the crop, i.e. peas, should enter the Basis (b). For simplicity, we can easily formulate the new equations and iterate by L.P. package to get the new optimal solution.

Let x_1 be acres of paddy,

x_2 be acres of groundnut,

x_3 be acres of chillie,

x_4 be acres of peas.

<u>CRP - 17</u>

Objective function -

$$\text{Max } Z = 182.13x_1 + 727.05x_2 + 230.79x_3 + [illegible]x_4$$

Subject to land $x_1 + x_2 + x_3 + x_4 \leq$ [illegible]

Labour $23x_1 + 22x_2 + 43x_3 + [illegible]x_4 \leq$ [illegible]

Capital $249.87x_1 + 292.95x_2 + 369.21x_3 + [illegible]x_4 \leq$ [illegible]

Min. paddy $x_1 \geq$ [illegible]

Max. groundnut $x_2 \leq$ [illegible]

where $x_1, x_2, x_3, x_4 \geq 0$

COLUMN INFORMATION

NAME		VALUE	OBJECTIVE	REDUCED COST
B PADDY	+	3.0000	182.1300	0
B GROUNDNU	+	1.6190	727.0500	0
CHILLIE	+	0	230.7900	-1323.4419
B PEAS	+	2.6010	290.0000	0
OBJECTIVE		2477.7595		

PROBLEM YOUR PROBLEM SOLUTION DATE 1[illegible]

DUMP; DUMP 3 RIGHT HAND SIDE RIGHT

OBJECTIVE OBJ

ROW INFORMATION

NAME		SLACK	R.H.S.	PRICE
# OBJ	Z	2477.7595	0	
LAND	+	0	7.2200	-27.2606
B LABOUR	+	901.1652	1050.0000	0
CAPITAL	+	0	1510.0000	-2.3869
MINPAD	-	0	3.0000	442.0000
B MAXGRO	+	0.3810	2.0000	-0.0000000075

DOCUMENT LOG PRINTOUT, NO CMICRP17 I LP00 ON 14/09/77 AT 17.07

ACCOUNT CODE 00EC300 DATE 14/09/77 T[illegible]

JOB NAME CRP17 START TIME 17/05/34 INP[illegible]

USER NAME TIN WIN AUNG END TIME 17/07/09 OUTP[illegible]

PERIPHERALS USED: 14 MAX[illegible]

The results obtained indicate that 3 acres of land should be used for paddy, 1.619 acres for groundnut and 2.601 acres for peas. Here we find that peas with higher net income than chillie, enter the basis (B) in place of chillié. With this new optimal crop pattern, the maximum net income rises up to K.2477.75.

2.4.4. Comparison between the Application of Mathematical Tools and Mathematical Programming

As we have seen in the previous section, the crop patterns attained by certain mathematical tools and mathematical programming are the same and the maximum income rendered by them also are not different. However, it is obvious that such mathematical tools as cost-benefit method and budgeting method cannot be directly applied, and further calculations are needed in order to choose the optimum crop pattern. Moreover, it has been shown that post-optimal analysis can easily be made in the case of mathematical programming whereas it would be necessary to srart again from the beginning if we apply cost-benefit analysis and budgeting method, when there are changes in available resources and prices of the produce.

Although the same crop patterns and equal maximum amounts of income are obtained by using the mathematical tools or the mathematical programming in the previous problem where only single cropping is considered and surplus labour man days are available, we cannot have such luck if we consider double cropping where simple logical reasonings used before would not be much helpful.

For example, if we double-crop paddy, which must be considered for minimum requirement, with winter groundnut and chillie, which are given the first and the second places in the priority list, we have to wrigh the marginal contributions of capital and labour concurrently for both crops, groundnut and chillie.[1] The problem may seem not very difficult at the first stage since the maximum limit of groundnut is known. However, it is difficult to consider to what extent the acreages of chillie and groundnut should be reduced to keep both labour and capital within the available limits and at the same time maximize the total net income. The problem will become more complex if certain crops such as peas for which no maximum or minimum limit is set. We can handle such problems effectively and efficiently with the help of mathematical programming.

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1 Not only capital but also labour can probably be used up in the case of double-cropping.

Chapter III

APPLICATION OF MATHEMATICAL PROGRAMMING FOR POSSIBLE CROP PATTERNS AND DOUBLE-CROPPING

In this chapter we would introduce the additional crops other than those found in our samples and consider the most suitable crop pattern for double-cropping in Henzada township. By observing the general condition of the Henzada township, we find out that Jute is an important crop recently introduced as a planned-crop. Although there is no cultivator of jute in our samples, it is possible to grow jute in the sampled farms since any land where paddy is sown is also suitable for jute if water is available. Sessamum too is a popular crop since it can be sown on any type of land and the cost of cultivation is the lowest among the crops found in the Henzada township.

3.1 Possible Crop Patterns

There are two types of jute such as pre-monsoon jute and monsoon jute. Similarly sessamum has also two types, one is short life crop known as Hnan-yin, and the other is grown in early monsoon and known as Hnan-gyi, i.e. long life crop. The main crops other than paddy, taken into consideration in the previous chapter will be divided into two groups; the first group includes those crops which are suitable for the monsoon weather and the second group includes those crops which are suitable for winter. Paddy is to be included in both groups since it can be double-cropped with others by choosing proper types such as the combination of pre-monsoon jute and late-monsoon paddy. CRP-18 deals with the first group in which jute is introduced and CRP-19 deals with the second one in which sessamum is introduced.

CRP 18 - In this problem we try to find out the optimum pattern for monsoon crops such as paddy, pre-monsoon jute, monsoon jute and monsoon groundnut. The mathematical model is as follows:

Let x_1 be acres of paddy,
x_2 be acres of premonsoon jute,
x_3 be acres of monsoon jute,
x_4 be acres of monsoon groundnut.

Objective function -

$$\text{Max } Z = 110.13x_1 + 187.50x_2 + 187.50x_3 + 387.05x_4$$

```
PROBLEM   YOUR PROBLEM            SOLUTION                                        DATE 14

DUMP:DUMP    3                           RIGHT HAND SIDE  RIGHT
                                         OBJECTIVE        OBJ

COLUMN INFORMATION

     NAME                  VALUE          OBJECTIVE      REDUCED COST
B PADDY        *          3.0000          110.1300              0
B JUTEP        *          0.6980          187.5000              0
  JUTEM        *               0          187.5000              0
B GROUNDNU     *          2.0000          327.0500              0
OBJECTIVE              1255.3575
PROBLEM   YOUR PROBLEM            SOLUTION                                        DATE 14

DUMP:DUMP    3                           RIGHT HAND SIDE  RIGHT
                                         OBJECTIVE        OBJ

ROW INFORMATION

     NAME                 SLACK                    R.H.S.                    PRICE
# OBJ          Z       12356.3575                       0
B LAND         *          1.6220                   7.2200                        0
B LABOUR       *        900.0877                1050.0000                        0
  CAPITAL      *               0                1510.0000                  -0.7500
  MINPAD       *               0                   3.0000                  77.2745
B PJUTE        *          1.5020                   2.0000                        0
B MJUTE        *          2.0000                   2.0000                        0
  MAXGRD       *               0                   2.0000                -167.3375
DOCUMENT LOG PRINTOUT, NORM:CRP18           : LP00 ON 14/09/77 AT 17:05

     ACCOUNT CODE     0080300             DATE          14/09/77              TOTA

     JOB NAME         CRP18               START TIME    12/04/21              INPU
     USER NAME        TIN WIN AUNG        END TIME      17/05/33              OUTP

     PERIPHERALS USED; 14                                                     MAX
```

Subject to land	x_1	$+ x_2$	$+ x_3$	$+ x_4$	7.22
labour	$23x_1$	$+ 43x_2$	$+ 43x_3$	$+ 22x_4$	1050
capital	$249.87x_1$	$+ 250x_2$	$+ 250x_3$	$+ 292.95x_4$	1510
Minimum Paddy Requirement	x_1				3
Maximum jute (P.M.)		x_2			2
Maximum jute (M)			x_3		2
Maximum groundnut				x_4	2

where $x_1, x_2, x_3, x_4 \quad 0$

The results obtained indicate that the optimum crop pattern consist of paddy, groundnut and pre-monsoon jute. In the case of paddy, the number of acres to be cultivated is 3 acres. This acreage, as it is explained before, meets the minimum requirement for family consumption, seeds and others. For groundnut, the number of acres to be sown is 2 acres. This acreage, as usual, reaches the maximum available acres as it is the most profitable crop. The lowest acreage .698 is required for growing pre-monsoon jute. If this crop pattern is chosen, our objective to maximize the net income will be fulfilled by 1235.35 kyats. The slacks for land and labour are 1.52 acres and 906.98 man-days respectively.

OBJECTIVE OBJ

COLUMN INFORMATION

NAME		VALUE	OBJECTIVE	REDUCED COST
B X1	+	24.0000	387.2500	0
X2	+	0	230.7900	-50.4100
X3	+	0	139.7300	-150.4700
B X4	+	54.2200	290.0000	0
X5	+	0	110.1300	-179.8700

OBJECTIVE 2288.3000

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP; DUMP 3 RIGHT HAND SIDE RIGHT

OBJECTIVE OBJ

ROW INFORMATION

NAME		SLACK	R.H.S.	PRICE
# OBJ	Z	2288.3000	0	
LAND	+	0	7.2200	-290.0000
B LABOUR	+	917.2600	1050.0000	0
B CAPITAL	+	349.0000	1310.0000	0
MAXGRO	+	0	2.0000	-97.2500

DOCUMENT LOG PRINTOUT, NORM:CRP19 , LP00 ON 14/09/77 AT 17:04

ACCOUNT CODE 00EC300 DATE 14/09/77 TOT

JOB NAME CRP19 START TIME 17/03/10 INP
USER NAME TIN WIN AUNG END TIME 17/03/20 OUT

PERIPHERALS USED; 14 MAX

CRP - 19

In this case we consider the optimum pattern for winter crops such as winter groundnut, chillie, sessamum and peas, together with paddy of short life assuming that water is available for paddy during winter. Since paddy is usually grown in monsoon, we would not set the constraint for minimum requirement of paddy in this case. The mathematical formulation is as shown below:-

Let x_1 be acres of winter groundnut,
x_2 be acres of chillie,
x_3 be acres of sessamum,
x_4 be acres of peas,
x_5 be acres of paddy.

Objective function -

$$\text{Max. } Z = 387.05x_1 + 230.79x_2 + 139.73x_3 + 290x_4 + 110.13x_5$$

Subject to land - $x_1 + x_2 + x_3 + x_4 + x_5 \leqslant 7.22$

Labour $22x_1 + 43x_2 + 21x_3 + 17x_4 + 23x_5 \leqslant 1050$

Capital $292.95x_1 + 369.21x_2 + 97.65x_3 + 110x_4 + 249.87x_5 \leqslant 1510$

Max. groundnut $x_1 \leqslant 2$

where $x_1, x_2, x_3, x_4, x_5 \geqslant 0$

Here we find out that the optimum crop pattern is to grow winter groundnut and peas. The acreage for groundnut, the most profitable crop, here again reaches the maximum limit, i.e. 2 acres, and the remaining acres are available to grow peas, since it contributes the second largest income and there is no minimum limit for paddy. Using this crop pattern we will achieve the maximum income of 2288.30 kyats. In this problem, all the available acres of land are used up and there remain slacks for labour and capital. This is the first case where slack for capital is left and available land is fully used up. At the same time, we have to note that this is also the first case where no minimum requirement for paddy is considered.

3.2 Double-cropping - Model I

After thinking about the possible crop patterns by differentiating seasonal crops, we have to consider crop pattern for double-cropping throughout the year. From the static point of view we cannot merely combine the results obtained from CRP-18 and CRP-19, which are considered separately by allowing the use of all available inputs for each case. It is necessary to form the possible pairs of crops for the whole year. CRP-20 deals with the following combinations of important crops in Henzada township.

CRP - 20

x_1 denotes the acre of any kind of paddy and chillie.

x_2 denotes the acre for the combination of paddy and groundnut.

x_3 denotes the acre for the combination of paddy and peas.

x_4 denotes the gcre for the combination of paddy and sessamum.

x_5 denotes the acre for the combination of premonsoon jute and paddy of short life.

x_6 denotes the acre for the combination of monsoon jute and chillie.

The mathematical model for double cropping is as follows:-

$$\text{Max } Z = 340.92x_1 + 497.18x_2 + 400.13x_3 + 249.08x_4 + 297.63x_5 + 418.29x_6$$

Subject to land $x_1 + x_2 + x_3 + x_4 + x_5 + x_6 \leqslant 7.22$

labour $66x_1 + 45x_2 + 40x_3 + 44x_4 + 66x_5 + 86x_6 \leqslant 1050$

capital $619.08x_1 + 542.82x_2 + 359.87x_3 + 347.52x_4 + 499.87x_5 + 619.21x_6 \leqslant 1510$

Min. paddy recuirement $x_1 + x_2 + x_3 + x_4 + x_5 \geqslant 3$

Max. groundnut $x_2 \leqslant 2$

Max. jute (P.M.) $x_5 \leqslant 2$

Max. jute (M.) $x_6 \leqslant 2$

where $x_1, x_2, x_3, x_4, x_5, x_6 \geqslant 0$

DUMP= DUMP 3 OBJECTIVE= 2485.2775

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP;DUMP 3 RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

COLUMN INFORMATION

	NAME		VALUE	OBJECTIVE	REDUCED COST
	X1	*	0	340.9200	-344.8489
B	X2	*	1.6255	407.1800	0
B	X3	*	4.0974	400.1300	0
	X4	*	0	249.8800	-141.4293
	X5	*	0	297.6700	-267.7040
	X6	*	0	448.2900	-285.8914

OBJECTIVE 2485.2775

PROBLEM YOUR PROBLEM SOLUTION DATE

DUMP;DUMP 3 RIGHT HAND SIDE RIGHT
OBJECTIVE OBJ

ROW INFORMATION

	NAME		SLACK	R.H.S.	PRICE
#	OBJ	Z	2485.2775	0	
B	LAND	*	1.4031	7.2200	0
	LABOUR	*	0	1050.0000	-0.9141
	CAPITAL	*	0	1510.0000	-1.0103
B	MINPAD	=	2.0109	3.0000	0
B	MAXGRO	*	2.0000	2.0000	0
B	PJUTE	*	2.0000	2.0000	0
B	MJUTE	*	0	0	0

DOCUMENT LOG PRINTOUT, NORMLCRP20 ; LP00 ON 14/09/77 AT 17.03

ACCOUNT CODE 00EC300 DATE 14/09/77

JOB NAME CRP20 START TIME 17/01/43
USER NAME TIN WIN AUNG END TIME 17/03/09

PERIPHERALS USED: 14

From the results obtained we can conclude that the optimum crop pattern for double-cropping is the combination of paddy and winter groundnut on 1.63 acres of land and the combination of paddy and peas on 4.19 acres. In other words, 5.82 acres of paddy is to be double-cropped with 1.63 acres of winter groundnut and 4.19 acres of peas. This pattern will provide the farmers with the yearly income of Kyats 2485.28 which is an attractive amount for a farmer working on 7.22 acres of land. In addition, it is satisfactory to find out that labour and capital are utilized fully and only 1.4 acres of land are left as slack. This surplus of land is to be left unused for a few years to enrich the soil before another cropping begins, since there is no more labour and capital. This is not contradictory to the current practice of many farmers.

The results obtained from CRP-20 are in line with those results rendered by CRP-18 and CRP-19, except that premonsoon jute, the acreage of which is quite negligible, is excluded in double-cropping. It is also found out that winter groundnut is preferable to monsoon groundnut in the case of double-cropping. These facts can be clearly observed in the following Table (11).

Table (11). Possible Crop Patterns & Double-cropping.

	Crop Pattern				Maximum Net Income
	Monsoon	Acres	Winter	Acres	
CRP-18	Paddy Groundnut Pre-monsoon Jute	3.00 2.00 0.69			K.1235.35
CRP-19			Groundnut Peas	2.00 5.22	K.2288.30
CRP-20	Paddy Paddy	1.62 4.19	Groundnut Peas	1.62 4.19	K.2485.24

Although the results offered by CRP-20 are quite satisfactory, it should be noted that we have considered the present costs and incomes for different crops as the constraints for our model for double-cropping. There may be changes in cost and income patterns if double-cropping proposed here is introduced in the area under study. Moreover, we need to think of the problem of double-cropping with dynamic conception with respect to the available capital and labour.

3.3 Double-cropping - Model II

The obvious weakness of model one is that we think of available capital and labour in a static sense without considering the dynamic aspects of available capital and labour in double-cropping. Additional capital will be available for the second crops from the first crop and additional labour whether owned or hired, can be obtained in the agricultural sector where unemployment or underemployment is common. Therefore we need to introduce another model which applies dynamic conception.

We might assume that the amounts of capital and labour for the second season are the same as those for the first season. Alternatively, we can estimate the available capital for the second season on the basis of average income per acre of the first season less cost of family consumption,[1] and also assume that half of the owned labour is available in each season. The former is

---

1 Net income per acre	from paddy	- K 110.13
" " " "	from jute	187.50
" " " "	from groundnut	387.05
		K 684.68

$\therefore$ Average Net Income per acre = $\frac{684.68}{3}$ = K.228.22

Total Income = K.228.22 x 7.22 = K.1648.47

Total income - family consumption = K.1648.47 - 648.47

Available capital = K.1000.

tried in CRP-21 and the latter is tested in CRP-22. Different assumptions, of course, can be made according to the likes of different persons with certain logic.

CRP-21

The mathematical formulations for CRP-21 is as follows:-

Let x_1 denotes acres of paddy,
x_2 denotes acres of jute,
x_3 denotes acres of monsoon-groundnut,
x_4 denotes acres of winter-groundnut,
x_5 denotes acres of chillie,
x_6 denotes acres of sessamum,
x_7 denotes acres of peas,
x_8 denotes acres of paddy.

Objective function -

$$\text{Max } Z = 110.13x_1 + 187.50x_2 + 387.05x_3 + 387.05x_4 + 230.79x_5 + 139.73x_6 + 290.00x_7 + 110.13x_8$$

Subject to

$$\begin{array}{lllllllll}
x_1 & + x_2 & + x_3 & + 0 & + 0 & + 0 & + 0 & + 0 & \leq 7.22 \\
23x_1 & + 43x_2 & + 22x_3 & + 0 & + 0 & + 0 & + 0 & + 0 & \leq 1050 \\
249.87x_1 & + 250x_2 & + 292.95x_3 & + 0 & + 0 & + 0 & + 0 & + 0 & \leq 1510 \\
x_1 & + 0 & + 0 & + 0 & + 0 & + 0 & + 0 & + 0 & \geq 3 \\
0 & + x_2 & + 0 & + 0 & + 0 & + 0 & + 0 & + 0 & \leq 2 \\
0 & + 0 & + x_3 & + 0 & + 0 & + 0 & + 0 & + 0 & \leq 2 \\
0 & + 0 & + 0 & + x_4 & + x_5 & + x_6 & + x_7 & + x_8 & \leq 7.22 \\
0 & + 0 & + 0 & + 22x_4 & + 43x_5 & + 21x_6 & + 17x_7 & + 23x_8 & \leq 1050 \\
0 & + 0 & + 0 & + 292.95x_4 & + 369.21x_5 & + 97.65x_6 & + 110x_7 & + 249.87x_8 & \leq 1510 \\
0 & + 0 & + 0 & + x_4 & + 0 & + 0 & + 0 & + 0 & \leq 2
\end{array}$$

where $x_i \geq 0 \quad (i=1,2,\ldots\ldots,8)$.

DOCUMENT CRP21 , NORM[CRP21 ; LP01 ON 12/09/77 AT 14:58

PROBLEM YOUR PROBLEM SOLUTION

DUMP;DUMP 3 RIGHT HAND SIDE RHS

OBJECTIVE OBJ

ROW INFORMATION

	NAME		SLACK	R.H.S.	
#	OBJ	Z	3523.1179	0	
B	R1	+	1.5220	7.2200	
B	R2	+	906.6877	1050.0000	
	R3	+	0	1510.0000	-
	R4	=	0	3.0000	7
B	R5	+	1.3020	2.0000	-0,0000
	R6	+	0	2.0000	-1
	R7	+	0	7.2200	-2
B	R8	+	917.2600	1050.0000	
B	R9	+	349.0000	1510.0000	
	R10	+	0	2.0000	-

PROBLEM YOUR PROBLEM SOLUTION

DUMP;DUMP 3 RIGHT HAND SIDE RHS

OBJECTIVE OBJ

COLUMN INFORMATION

	NAME		VALUE	OBJECTIVE	REDUCED COST
B	X1	+	3.0000	110.1300	0
B	X2	+	0.6980	187.3000	0
B	X3	+	2.0000	387.0500	0
B	X4	+	2.0000	387.0500	0
	X5	+	0	230.7900	-50.2100
	X6	+	0	139.7300	-150.2700
B	X7	+	5.2200	200.0000	0
	X8	+	0	110.1300	-6550.8700
OBJECTIVE			3523.1179		

From the results obtained, we find out that the optimum crop pattern is the combination of paddy (3.00 acres), jute (.698 acres) and monsoon-groundnut (2.00 acres) in Monsoon and winter-groundnut (2.00 acres) and peas (5.22 acres) in Winter. The maximum income available is K.3523.12 which is the highest amount among the problems studied in this work. There are slacks for land and labour whereas capital is used up as usual in Monsoon. However, there remain slacks for capital and labour where land is used up in Winter. These conditions point out that capital is used up more faster than land in Monsoon and conversely land is used up more faster than capital in Winter. These effects are caused by the influence of high costs of jute and groundnut in Monsoon and low cost of peas in Winter.

CRP-22

The mathematical formulations are as follows: (See page 97).

The results indicate the same pattern as before with a few differences in the acreages of Winter-groundnut (1.124 acres) and peas (6.0951 acres). In this problem capital is used up in both seasons because the amount of capital available is less than that in the former problem.

From the results obtained, we find out that the optimum crop pattern is the combination of paddy (3.00 acres), jute (.698 acres) and monsoon-groundnut (2.00 acres) in Monsoon and winter-groundnut (2.00 acres) and peas (5.22 acres) in Winter. The maximum income available is K.3523.12 which is the highest amount among the problems studied in this work. There are slacks for land and labour whereas capital is used up as usual in Monsoon. However, there remain slacks for capital and labour where land is used up in Winter. These conditions point out that capital is used up more faster than land in Monsoon and conversely land is used up more faster than capital in Winter. These effects are caused by the influence of high costs of jute and groundnut in Monsoon and low cost of peas in Winter.

CRP-22

The mathematical formulations are as follows: (See page 97).

The results indicate the same pattern as before with a few differences in the acreages of Winter-groundnut (1.124 acres) and peas (6.0951 acres). In this problem capital is used up in both seasons because the amount of capital available is less than that in the former problem.

<u>CRP-22</u>

Objective function -

$$\text{Max } Z = 110.13x_1 + 187.50x_2 + 387.05x_3 + 387.05x_4 + 230.79x_5 + 139.73x_6 + 290.00x_7 + 110.13x_8$$

Subject to -

$$\begin{array}{rcrcrcrcrcrcrcrcl}
x_1 & + & x_2 & + & x_3 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & \leqslant & 7.22 \\
23x_1 & + & 43x_2 & + & 22x_3 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & \leqslant & 525 \\
249.87x_1 & + & 250x_2 & + & 292.95x_3 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & \leqslant & 1510 \\
x_1 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & \geqslant & 3 \\
0 & + & x_2 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & \leqslant & 2 \\
0 & + & 0 & + & x_3 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & \leqslant & 2 \\
0 & + & 0 & + & 0 & + & x_4 & + & x_5 & + & x_6 & + & x_7 & + & x_8 & \leqslant & 7.22 \\
0 & + & 0 & + & 0 & + & 22x_4 & + & 43x_5 & + & 21x_6 & + & 17x_7 & + & 23x_8 & \leqslant & 525 \\
0 & + & 0 & + & 0 & + & 292.95x_4 & + & 369.21x_5 & + & 97.65x_6 & + & 110.00x_7 & + & 249.87x_8 & \leqslant & 1000 \\
0 & + & 0 & + & 0 & + & x_4 & + & 0 & + & 0 & + & 0 & + & 0 & \leqslant & 2
\end{array}$$

where $x_i \geqslant 0 \quad (i=1,2,......,8)$.

n.b. The notations of x_i $(i=1,2,......,8)$ are the same as CRP-21.

DOCUMENT CRP22 , NORM[CRP22 : LP01 ON 12/09/77 AT 10.56

PROBLEM YOUR PROBLEM SOLUTION

DUMP:DUMP 3

RIGHT HAND SIDE RHS
OBJECTIVE OBJ

COLUMN INFORMATION

	NAME		VALUE	OBJECTIVE	REDUCED COST
B	X1	+	3.0000	110.1300	0
B	X2	+	0.6980	187.5000	0
B	X3	+	2.0000	387.0500	0
B	X4	+	1.1249	387.0500	0
	X5	+	0	230.7900	-196.7139
	X6	+	0	139.7300	-143.7187
B	X7	+	6.0951	290.0000	0
	X8	+	0	110.1300	-254.0072
OBJECTIVE			3438.3288		

PROBLEM YOUR PROBLEM SOLUTION

DUMP:DUMP 3

RIGHT HAND SIDE RHS
OBJECTIVE OBJ

ROW INFORMATION

	NAME		SLACK	R.H.S.
#	OBJ	Z	3438.3288	0
B	R1	+	1.5220	7.2200
B	R2	+	381.0877	525.0000
	R3	+	0	1510.0000
	R4	=	0	3.0000
B	R5	+	1.3020	2.0000
	R6	+	0	2.0000
	R7	+	0	7.2200
B	R8	+	396.6335	525.0000
	R9	+	0	1000.0000
B	R10	+	0.8751	2.0000

3.4 Comparison between Model I and Model II

CRP - 20 is Model I where the available resources for the whole year are taken constant and generally acceptable pairs of crops are preconsidered. CRP 21 & 22 are formed by Model II in which we apply the dynamic conception for the available resources with the chance of freedom in pairing crops. The crop patterns and maximum net incomes for the different models are shown in the following Table (12).

Table (12)

Crop Pattern

Models	Monsoon	Acre	Winter	Acre	Max. Net Income
Model I	Paddy	1.62	Groundnut	1.62	K.2485.24
CRP-20	Paddy	4.19	Peas	4.19	
Model II	Paddy	3.00	Winter-		
CRP-21	Jute	0.698	Groundnut	2.00	K.3523.12
	Monsoon-		Peas	5.22	
	Groundnut	2.00			
CRP-22	Paddy	3.00	Winter-		
	Jute	0.698	Groundnut	1.1249	K.3438.32
	Monsoon-		Peas	6.0591	
	Groundnut	2.00			

It is not surprising that the maximum incomes of model two are much greater than that of model one, since more resources are available and freedom of choice in pairing crops can be enjoyed in the former case. However, such a fortunate farmer whose land and soil types are suitable for any way of combination of all the crops under consideration is rare to be found. Moreover, if a farmer chooses model one, he has to handle only three types of crops such as paddy, winter-groundnut and peas, whereas if he chooses model two he has to handle five types of crops such as paddy, jute, monsoon-groundnut, winter-groundnut and peas. Then tradition and skill may become limiting factors. Consequently, although model two is theoretically far better than model one, the reverse is generally found in actual practice. Nevertheless, we expect that model two can be applied practically if we make some modifications according to the conditions of individual farmers.

Modified Model

Actually, the division of the available capital among two agricultural seasons poses a problem. It can neither be said that K 755 would be available in each season, as the whole amount of K 1510 could possibly be utilized in Monsoon, nor it is possible to assume that the amount of capital invested in the production of Monsoon crops would be replenished by the sale of these crops at the end of the season and hence would be available for reinvestment in Winter. It is, therefore, decided that the whole sum of K 1510 is to be made available for use in Monsoon and that no capital is reserved specifically for Winter. Those crops which are harvested at the end of the Monsoon season would become a capital supplying activity for the Winter season. These crops would have a negative capital coefficient in the Winter capital restriction. In order to facilitate the transfer of capital from Monsoon to Winter, a seperate activity (X_9) has to be included in the programme. This activity would have a coefficient of plus (+1) in the Mosoon capital restriction and minus one (-1) in the Winter capital equation.

The restrictions :-

b_1 = available land in Monsoon = 7.22 acres

b_2 = available labour hours in Monsoon = 525 hours

b_3 = available capital in Monsoon = K 1510

b_4 = Minimum requirement of Paddy = 3 acres

b_5 = Maximum cultivatable area for groundnut = 2 acres

b_6 = Maximum cultivatable area for Jute = 2 acres

b_7 = available land in Winter = 7.22 acres

b_8 = available labour hours in Winter = 525 hours

b_9 = available capital in Winter = 0

The alternatives:-

x_1 denotes acres of Monsoon-paddy

x_2 denotes acres of Jute

x_3 denotes acres of Monsoon-groundnut

x_4 denotes acres of Winter-groundnut

x_5 denotes acres of Chillie

x_6 denotes acres of Sessamum

x_7 denotes acres of Peas

x_8 denotes acres of Paddy (winter)

x_9 denotes activity for transferring Monsoon-capital to Winter-capital

The Model:-

$$\text{Max } Z = \sum_{j=1}^{9} c_j x_j$$

subject to -

$$\sum_{j=1}^{9} a_{ij} x_j \leqslant b_i \quad (i = 1,2,3,5,6,7,8,9)$$

$$\sum_{j=1}^{14} a_{ij} x_j \geqslant b_i \quad (i = 4)$$

where $x_j \geqslant 0 \quad (j=1,\dots\dots\dots\dots,9)$

Objective function -

$$\text{Max } Z = 110.13\,x_1 + 187.50\,x_2 + 387.05\,x_3 + 387.05\,x_4 + 230.79\,x_5 + 139.73\,x_6 + 290\,x_7 + 110.13\,x_8 + 0\,x_9$$

subject to -

$$\begin{array}{rcrcrcrcrcrcrcrcrcl}
x_1 & + & x_2 & + & x_3 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & \leqslant & 7.22 \\
23x_1 & + & 43\,x_2 & + & 22\,x_3 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & \leqslant & 525 \\
249.87\,x_1 & + & 250\,x_2 & + & 292.95\,x_3 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & + & 1 & \leqslant & 1510 \\
x_1 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & \geqslant & 3 \\
0 & + & x_2 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & \leqslant & 2 \\
0 & + & 0 & + & x_3 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & \leqslant & 2 \\
0 & + & 0 & + & 0 & + & x_4 & + & x_5 & + & x_6 & + & x_7 & + & x_8 & + & 0 & \leqslant & 7.22 \\
0 & + & 0 & + & 0 & + & 22\,x_4 & + & 43\,x_5 & + & 21\,x_6 & + & 17x_7 & + & 23\,x_8 & + & 0 & \leqslant & 525 \\
-249.87\,x_1 & + & 250\,x_2 & + & 292.95\,x_3 & + & 292.95\,x_4 & + & 369.21\,x_5 & + & 97.65\,x_6 & + & 110\,x_7 & + & 249.87\,x_8 & - & 1 & \leqslant & 0 \\
0 & + & 0 & + & 0 & + & x_4 & + & 0 & + & 0 & + & 0 & + & 0 & + & 0 & \leqslant & 2
\end{array}$$

where $x_i \geqslant 0$, $(i = 1, \ldots\ldots, 9)$

CONCLUSION

Among the mathematical tools applicable in agriculture, the mathematical programming is the most powerful one in farm planning in finding out the optimal crop-pattern. As described in chapter two, although cost-benefit analysis and Budgeting method can be applied in choosing the optimal crop-pattern in simple cases, these tools cannot be applied as effectively as Mathematical Programming.

By applying Mathematical Programming in choosing optimum crop pattern for the farms in Henzada township, we find out that capital is the most scarce resource and the choice of crop pattern is sensitive enough to changes in prices. Moreover, it is also found that groundnut, which is to be grown all over the maximum available acres, is the most preferable crop whereas paddy, which is to be grown only for the minimum requirements, is the least favourable one. Either chillie or peas are second to groundnut depending upon their prices and one of these crops would be grown by using all the remaining capital.

Furthermore, we find out that slack for labour exists in the case of single-cropping and it disappears in the case of double-cropping, whereas slack for land exists in all cases due to the fact that available acres are not in proportion with the available capital and labour.

Although mathematical programming is a powerful tool in choosing optimum crop-pattern we should not forget that there exist weaknesses or limitations in building the models mostly due to the lack of information. These weaknesses are concerned with forming the constraints and formulating the co-efficients of the variables in our models. We have only considered the input factors such as land, labour and capital, and the output factors such as yield per acre for each crop and the prices mostly on the average basis which are derived from the past data, incidentally neglecting the technology which also is a determining factor in modern agriculture.[1] Therefore, we have to make detail study of each farm, which is the unit of study in this work, if the proposed models are to be made applicable for an individual farmer.

In the case of land, we have assumed that the available land per farmer is 7.22 acres where minimum supply of water is available throughout the year by means

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1 Technology factor is implicitly considered in calculating cost of cultivation.

of nature or irrigation especially for jute cultivation. In addition, we have also assumed that the maximum available acreage for groundnut is only 2 acres. Of course, different farmers would have different sizes of farms with different structure of soil types, and availability of water throughout the year would be a dream to some farmers. Crop pattern mainly depends also on the types of soil and water-supply. However, we can easily fit the conditions into our models if we have enough information about these conditions.

In the case of labour, we have considered only the labour of a family with three working members, and assumed that there would be a custom of offering labour in turn ((Let-sa-lite) during labour peak periods such as transplanting and harvesting periods. Not only the actual available labour of each farmer and the existing custom but also the availability of hired labour should be considered in practical application of the mathematical programming.

Available capital which is the most scarce resource is unfortunately also the weakest estimate in our study due to the lack of reliable information. Although the farmers are willing to inform the amount of agricultural loans they received, they are usually reluctant to reveal the amount of cash available from private sources. Therefore, in most of our cases we have indirectly estimated the available capital from the average cost of cultivation of the sampled farmers. In our last case we have directly estimated the available capital from the average income for all crops under consideration. Only when better education for the farmers can be provided and better rapport between the farmers and the researchers can be established in the future, we will be able to estimate the available capital more accurately.

Yield per acre, which we have taken on average basis, is a combined effect of various factors such as seeds, fertilizers, labour input, technology, type of soil, weather, etc. Except weather, the natural friend and enemy of farmers, other factors can be known beforehand with certain accuracy if we study thoroughly.

In the case of prices, we have taken the market prices of last year for the free crops and the government prices for the controlled crops. As is known price fluctuation is a common event in agricultural sector nowadays. We have to rely on the government pricing policy of agricultural loans they received, they are usually reluctant to reveal the amount of cash available from private sources. Therefore, in most of our cases we have indirectly estimated the available capital from the average cost of cultivation of the sampled farmers. In our last case we have directly estimated the available capital from the average income for all crops under consideration. Only when better education for the farmers can be provided and better rapport between the farmers and the researchers can be established in the future, we will be able to estimate the available capital more accurately.

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In the case of prices, we have taken the market prices of last year for the free crops and the government prices for the controlled crops. As is known price fluctuation is a common event in agricultural sector nowadays. We have to rely on the government pricing policy and scientific research on price forecasting such as trend analysis, seasonal price index, etc. Without proper price mechanism, it is difficult to apply mathematical tools in agricultural sector. Setting up collective bargaining system is a way to establish stable price mechanism in agriculture.

Diffusion of modern technology in agriculture is what the government is striving for, with the view to increase productivity of land and labour. Use of chemical fertilizers such as Urea, Potash, Phosphate and Pesticides is now popular with the farmers. Application of scientific methods in choosing better seeds of high yielding varieties, ploughing and planting is also important to increase the yield per acre. Introduction of modern technology and scientific methods in agriculture to a fuller extent will result in changes of input structure and consequently in cost and income structures. Personnel from the department of agriculture, especially the village managers are playing the key roles as change-agents. To what extent a farmer can have their help will determine the degree of acceptance of modern technology and scientific methods. Input factors and yield should be estimated within the

In addition, we have to note that it will be more practicable to consider township or region as the unit of study in the case of agricultural planning at national level. Then the f unction to be optimized should be the volume of production instead of net income which is the case in this thesis where the farm is the unit of study. Consequently, the constraints might also be changed. The level of output determined by the national requirement and the sucessful cultivation of planned crops might enlarge the scope of constraints to be considered. Moreover, capital available might be considered in line with the government policy which is the crucial factor in determining the availability of the financial requirements. The average farm-size, which we have taken as the land constraint, might be substituted by the cultivatable area.

In general, improvement of agriculture involves multi-disciplines such as accounting, management, marketing, economics, sociology (tradition, cultural level, politics, etc.), chemistry (fertilizers, pesticides, etc.), biology, engineering, geology, geography and so on. This thesis is presented only from the view point of management and economics. Other disciplines should also be applied concurrently with the improved methods in management in agriculture, if we desire to improve the overall system of agriculture. It is high time for us to stride forward to increase the growth rate of our economy, the structure of which is mainly based on agricultural sector.

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Appendices

1. Questionnaire for Cost of Cultivation and Income Data.

2. Questionnaire for Apportionment of Agricultural Cost and Labour Hours.

3. Questionnaire for Household Income Data.

4. Calculations for Coefficients.

4. (a) Technical Coefficients.

5. Cost of Cultivation and Income Data of Bae Chaung Village, Henzada township.

6. Cost of Cultivation and Income Data of Kyu-Ka-Paing Village, Henzada township.

7. Cost of Cultivation and Income Data of Ootoe Village, Henzada township.

8. Cost of Cultivation and Income Data of Pe-Gyi-Kyun Village, Henzada township.

9. Cost of Cultivation and Income Data of Myecha Village, Henzada township.

10. Cost of Cultivation and Income Data of Oat-Shit-Gone Village, Henzada township.

11. Cost of Cultivation and Income Data of Kunchangone Village, Henzada township.

Appendix (1)

Questionnaire for Cost of Cultivation and Income Data

Division ------------------

Township ------------------

Village ------------------

Sample No. ------------------

Year ------------------

Total acreage ------------------

No. of Sayin-hngas (Agri. lab.) ------------------

Wages ------------------

Agricultural Credit ------------------

Advanced payments ------------------

Capital ------------------

Others ------------------

1. Total Cost of Production and Income

No.	Crops	Sown Acreage	Yield Per Acre	Yield	Price	Value

2. Implements and Assets

No.	Item	Qty.	Value
1	Bullock		
2	Plough and Accessories		
3	Harrow and Accessories		
4	Paddy Storage Unit		
5	Bullock Cart		
6	Cow Shed / Farm Shed		
7	Water Pump		
8	Sickle		
9	Knife		
	Total		

3. Yearly Maintenance Expenditure

No.	Item	Cost
1	Paddy Storage Unit	
2	Bullock Cart	
3	Cow Shed	
4	Sickle & Knife Sharpening	
5	Others	
	Total	

Appendix (2)

Questionnaire for Agricultural Cost and Labour Hours.

Sown Acreage ----- Yield ----- Price -----

Items	Own			Bought/Hired		
	Kyats	Man Days	Bullock Days	Kyats	Man Days	Bullock Days
1 Labour Cost						
1. Seedbed Preparation						
2. Plucking Seedlings						
3. Land Preparation						
4. Transplanting						
5. Land Maintenance						
6. Pest Control						
7. Harvesting						
8. Haulage						
9. Sayinngha						
10. Others						
Total						
2 Inputs						
1. Seeds						
2. Pesticides						
3. Fertilizers						
4. Manure						
5. Others						
Total						
3 Others						
1. Land revenue						
2. Interest						
3. Others*						
Total						
Total Cost(1)						
Total Cost(2)						
Total Cost(3)						

Total						
Total						
Total						

Total Cost (1) - includes family labour cost
(2) - includes only hired or purchased cost
(3) - Total Cost (1) without depreciations for equipments

* includes depreciations for equipments and animals, animal feeds etc.

(-) Value of production

Net Income (1)
Net Income (2)
Net Income (3)

Appendix (3)

Questionnaire for Household Income Data

No. of dependents ------

No. of people in the household ------ Monthly average income of household ---- No. of workers -----

Sr. No.	Name	Sex	Age	Religion	NRC FRC	Relationship with the house-hold head	Place of birth	Education	Marital Status	Type of work	Wage	Monthly Income	Other Income	Total Income

Annual average capital ----------

Capital for this year ----------

(a) Owned ----------

(b) Borrowed ----------

Capital for next year ----------

(a) Owned ----------

(b) Borrowed ----------

Appendix (4)

Calculations for Coefficients.

1. Average Farm-size = $\frac{151.58}{21}$ = 7.218 (7.22) Acres.

2. Average Cost (1) = $\frac{31710.75}{21}$ = K.1510.035 (1510)

(2) = $\frac{19384.81}{21}$ = K. 923.086 (923)

3. Labour man-days = 350 days x 3 = 1050 man-days.

4. Cost per acre:-

Paddy (1) = $\frac{25187.41}{100.80}$ = K. 249.87

(2) = $\frac{16826.50}{100.80}$ = K. 166.92

Groundnut (1) = $\frac{1025.42}{3.50}$ = K. 292.95

(2) = $\frac{341.35}{3.50}$ = K. 97.52

Chillie (1) = $\frac{959.97}{2.60}$ = K. 369.21

(2) = $\frac{344.11}{2.60}$ = K. 132.35

Peas (1) = $\frac{4537.95}{25.40}$ = K. 178.65

(2) = $\frac{1872.85}{25.40}$ = K. 73.73

5. Average yield - Paddy = $\frac{754.28}{21}$ = 35.919 = 36 baskets

Groundnut = $\frac{50.00}{3}$ = 16.66 = 17 baskets

Chillie = $\frac{32.00}{3}$ = 10.66 = 11* viss

Peas = $\frac{46.21}{6}$ = 7.70 = 8 baskets

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(1) - Total Cost
(2) - Cash Cost only

* This average yield is low relative to normal yield since there was crop failure at the time when the sample was taken. Normal yield is estimated round about 60 viss.

Cost of Cultivation and Income Data

Division - Irrawaddy   Township - Henzad

Village	Bae Chaung		
Sample No. / Item	424	425	426
1. Total acreage	7.42	7.00	4.00
2. No. of sayinhngas (agri. labourers	2	2	
3. Wages of sayinhngas	630.00	300.00	
4. Agr. credit	225.00	200.00	
5. Advanced payments			
6. Crops			
Paddy I			
(a) Sown acreage		1.00	1.40
(b) Yield/ acre		27.00	17.14
(c) Cost of cultn.			
1		282.14	195.31
2		203.14	95.48
3		215.56	175.45
(d) Income			
1		40.86	92.69
2		120.86	192.52
3		108.44	112.55
Paddy II			
(a) Sown acreage	7.00	6.00	1.00
(b) Yield/ acre	26.42	45.50	20.00
(c) Cost 1	2480.00	1534.87	157.24
2	2016.00	1189.89	70.07
3	1960.00	1129.39	143.04
(d) Income 1	-815.82	922.13	22.76
2	-351.99	1267.11	109.93
3	-295.00	1327.61	36.96
Groundnut			
(a) Sown acre		1.00	
(b) Yield/acre		5.00	
(c) Cost 1		375.04	
2		150.04	
3		307.46	
(d) Income 1		24.96	
2		249.96	
3		92.54	
7. From other activities			
(a) Cost			
(b) Income	1500.00	3000.00	
8. Total cost of productio			
1	2480.00	2193.05	352.55
2	2016.00	1543.07	165.55
3	1960.00	1652.41	318.49

Village	Bae Chaung					
Sample No.	424		425		426	
Item	Qty	Value	Qty	Value	Qty	Value
9. Total net income						
1		684.18		3987.95		115.4
2		1148.01		4637.93		302.4
3		1205.00		4528.59		149.5
10. Implements & assets						
1. Bullock	2	1900	1	1000	2	1400.0
2. Plough & accessories	6	307	7	186.50	3	26.0
3. Harrow & accessories						
4. Paddy storage unit	1	50				
5. Bullock cart	1	1000				
6. Cow shed/ farm shed	1	250	1	300	1	30.00
7. Water pump						
8. Sickle	2	10	2	25	4	20.0
9. Knife (Dah)	2	40	3	30	1	7.0
11. Yearly maintenance expenditure						
1. Paddy storage unit						
2. Bullock cart		80				
3. Cow shed						
4. Scikle & knives sharpening		4				
5. Others						

Cost of Cultivation and Income Data

Division - Irrawaddy | Township - Henzada

Village	Kyu	Ka	Paing
Sample No. / Item	430	431	432
1. Total acreage	3.37	6.36	7.60
2. No. of sayinhngas (agri. labourers)	1	1	2
3. Wages of sayinhngas	90.00	360.00	725.00
4. Agri. credit	165.00	655.00	370.00
5. Advanced payment			
6. Crops			
Paddy II			
(a) Sown acres	3.37	6.36	7.60
(b) Yield/acre	53.41	23.58	34.21
(c) Cost			
1	1012.55	1411.99	2044.75
2	800.88	1180.49	1137.40
3	983.02	1399.61	1952.25
(d) Income			
1	607.45	- 61.49	295.25
2	819.20	169.51	1202.60
3	637.08	49.61	387.75
7. From other activities			
(a) Cost			
(b) Income	200.00	200.00	
8. Total cost of production			
1	1012.65	1411.99	2044.75
2	800.88	1180.49	1229.90
3	988.02	1366.61	1952.25
9. Total net income			
1	807.45	138.01	295.25
2	1019.20	369.51	1110.10
3	837.08	249.61	387.75

Village	Kyu		Ka		Paing	
Sample No.	430		431		432	
Item	Qty	Value	Qty	Value	Qty	Value
10. Implements and accessories						
1. Bullock					3	7500.
2. Plough & accessories	4	67.50	1	15.00	2	30.0
3. Harrow & accessories						
4. Paddy storage unit	1	13.50				
5. Bullock cart					1	750.0
6. Cow shed / farm shed					1	40.00
7. Water pump						
8. Sickle	2	6.00	1	2.00	2	10.00
9. Knife (Dah)	3	15.00	1	5.00		
11. Yearly maintenance expenditure						
1. Paddy storage unit						
2. Bullock cart						
3. Cow shed				15.00		
4. Sickle & knives sharpening						
5. Others						

Appendix (7)

Cost of Cultivation and Income Data

Division - IRRAWADDY

Township - HENZADA

Village / Item	Ootoe		
Sample No.	436	437	438
Total acreage	11.00	10.75	9.94
No. of sayin-hngas (agr. labourers			1
Wages of sayin-hngas			180.00
Agr. credit	550.00	520.00	450.00
Advanced payments			
Crops			
Paddy II			
(a) Sown acreage	9.00	8.00	7.00
(b) Yield/acre	34.44	41.75	34.28
(c) Cost 1	1991.45	2079.58	1566.27
2	870.58	1450.24	972.03
3	1919.92	1945.20	1448.67
(d) Income 1	1798.55	926.43	593.73
2	1919.42	1555.76	1187.97
3	2718.47	1060.80	711.33
Paddy III			
(a) Sown acres	2.00		
(b) Yield/acre	40.00		
(c) Cost 1	403.85		
2	190.85		
3	387.95		
(d) Income 1	316.15		
2	529.15		
3	704.10		
Paddy IV			
(a) Sown acres		2.00	2.00
(b) Yield/acre		90.00	40.00
(c) Cost 1		621.64	513.44
2		435.31	313.75
3		588.05	479.76
(d) Income 1		998.36	206.56
2		1184.69	406.25
3		1031.95	240.24
From other activities (b) Income 1	200.00		500.00
Total cost of production 1	2395.30	2701.22	2079.71
2	1061.43	1885.55	1285.78
3	2307.87	2083.25	1928.43
Total net income 1	1314.70	1924.78	1300.29
2	2648.57	2740.45	2094.22
3	3622.57	2092.75	1451.57

Village / Item	Ootoe					
Sample No.	436		437		438	
	Qty	Value	Qty	Value	Qty	Valu-
10. Implements and assets						
1. Bullock	1	1800	1	1000	2	3850
2. Plough & accessories	2	13.50	6	106	6	90
3. Harrow & accessories		-		-		-
4. Paddy storage unit		-		-		-
5. Bullock cart	1	300	1	450	1	1500
6. Cow shed/ farm shed	1	150	1	200	1	150
7. Water pump		-		-		-
8. Sickle	3	13	3	6	2	8
9. Knife (Dah)	1	5		-	3	17
11. Yearly maintenance expenditure						
1. Paddy storage unit						
2. Bullock cart						
3. Cow shed		130				100
4. Sickle & knives sharpening						
5. Others						

Appendix (8)

Cost of Cultivation and Income Data

Division - IRRAWADDY Township - HENZADA

Village	Pe	Gyi	Kyun
Sample No.	445	446	447
Item			
1. Total acreage	4.00	1.90	10.00
2. No. of sayinhngas (agri.labourers)			
3. Wages of sayinhngas			
4. Agr. credit			
5. Advanced payments			
6. Crops			
Chillie			
(a) Sown acres	0.50	0.60	1.50
(b) Yield/acre	5.00	2.00	25.00
(c) Cost 1	283.99	191.86	484.12
2	24.11	30.13	289.87
3	262.11	144.81	447.25
(d) Income 1	-198.99	-111.86	515.88
2	60.89	49.87	710.13
3	-177.11	-64.81	552.75
Peyin			
(a) Sown acres	3.00	2.00	8.50
(b) Yield/acre	1.00	2.50	4.71
(c) Cost 1	744.01	460.54	1669.51
2	144.73	145.44	597.43
3	612.72	404.14	1460.58
(d) Income 1	-624.01	-260.54	-69.51
2	- 24.73	54.56	1002.57
3	492.72	-204.14	139.42
7. From other activities			
(a) Cost			
(b) Income			
8. Total cost of production			
1	1028.00	652.40	2153.63
2	168.84	175.57	887.30
3	874.83	548.95	1907.83
9. Total net income 1	-823.00	-372.40	446.37
2	36.16	104.43	1712.70
3	-669.83	-268.95	692.17

Village	Pe		Gyi		Kyun	
Sample No.	445		446		447	
Item	Qty	Value	Qty	Value	Qty	Value
10. Implements & assets						
1. Bullock	3	4700	2	3500	3	4000
2. Plough & accessories	5	180	3	90	12	135
3. Harrow & accessories						
4. Paddy storage unit					6	50
5. Bullock cart					1	800
6. Cow shed/ farm shed	1	250	1	45	1	200
7. Water pump						
8. Sickle	2	5	2	10	4	20
9. Knife (Dah)	2	22	2	10.30	2	10
11. Yearly maintenance expenditure						
1. Paddy storage unit						
2. Bullock cart						
3. Cow shed	1	100				
4. Sickle & knives sharpening						
5. Others						

Cost of Cultivation and Inco...

Division - IRRAWADDY

Township

Village	MYECHA		
Sample No. / Item	469	470	471
Total acreage	6.71	6.25	7.07
No. of sayin-hngas (agr. labourers)			
Wages of sayinhngas			
Agr. credit			
Advanced payments	325.00	175.00	350.00
Crops			
Paddy I			
(a) Sown acreage			1.00
(b) Yield/acre			30.00
(c) Cost of cultn. 1			290.32
2			227.32
3			276.96
(d) Income 1			159.68
2			222.68
3			173.04
Paddy II			
(a) Sown acre-age	5.31	6.25	4.00
(b) Yield/acre	44.26	48.00	45.00
(c) Cost 1	1592.10	1225.51	941.28
2	672.06	561.84	782.28
3	1502.33	1144.50	887.85
(d) Income 1	522.90	1474.49	678.72
2	1442.94	2188.16	837.72
3	612.67	1555.50	732.15
Paddy IV			
(a) Sown acre	1.00		2.00
(b) Yield/acre	65.00		40.00
(c) Cost 1	374.21		541.64
2	145.11		450.64
3	350.44		514.93
(d) Income 1	30.79		178.36
2	259.89		269.36
3			205.07
7. From other activities			
(b) Income 1	500.00	500.00	1500.00
Total cost of production			
1	1966.31	1225.51	1773.24
2	817.17	561.84	1460.24
3	1852.77	1144.50	1679.74

Village	MYECHA					
Sample No.	469		470		471	
Item	Qty	Value	Qty	Value	Qty	Value
10. Implements & assets						
1. Bullock	2	5000	3	4300		
2. Plough & accessories	7	116.50	2	24	4	90
3. Harrow & accessories						
4. Paddy storage unit						
5. Bullock cart	1	300				
6. Cow shed/ farm shed	1	100	1	80	1	50
7. Water pump						
8. Sickle	4	11	3	10.50	3	12
9. Knife (Dah)	3	16	2	12	3	20
11. Yearly maintenance expenditure						
1. Paddy storage unit						
2. Bullock cart						
3. Cow shed		150				
4. Sickle & knives sharpening						
5. Others						

Appendix (10)

Cost of Cultivation and Income Data

Division - IRRAWADDY Township - HENZADA

Village	Oat Shit Gone		
Sample No. / Item	481	482	483
1. Total acreage	8.00	4.00	15.30
2. No. of sayin-hngas (agr. labourers			
3. Wages of sayinhngas			
4. Agr. credit			
5. Advanced payments			
6. Crops			
Pe Gyi			
(a) Sown acre	2.00	4.50	5.40
(b) Yield/acre	5.00	18.00	15.00
(c) Cost 1	466.66	620.70	576.53
2	241.27	434.70	309.28
3	354.39	531.00	395.28
(d) Income 1	- 66.66	207.30	113.47
2	218.73	393.30	380.72
3	105.61	297.00	294.72
7. From other activities			
(a) Cost			
(b) Income			
8. Total cost of production			
1	466.66	620.70	576.53
2	241.27	434.70	309.28
3	354.39	531.00	395.28
9. Total net income			
1	- 66.66	207.30	113.97
2	218.73	393.30	380.72
3	105.61	297.00	294.72

Village	Oat Shit Gone					
Sample No.	481		482		483	
Item	Qty	Value	Qty	Value	Qty	Value
10. Implements & assets						
1. Bullock	2	1600			2	2000
2. Plough & accessories	8	83	2	28	3	46
3. Harrow & accessories						
4. Paddy storage unit	2	16			3	30
5. Bullock cart	1	350	1	450	1	450
6. Cow shed/ farm shed	1	15	1	80		
7. Water pump						
8. Sickle	5	17.50	3	15	4	18.50
9. Knife (Dah)	2	10.00	3	13.50	1	7.00
11. Yearly maintenance expenditure						
1. Paddy storage unit						
2. Bullock cart		25				
3. Cow shed				150		
4. Sickle & knives sharpening						
5. Others						

Appendix (11)

Cost of Cultivation and Income Data

Division - IRRAWADDY   Township - HENZADA

Village	KUNCHANGONE		
Sample No. / Item	496	497	498
. Total acreage	7.08	7.06	6.27
. No. of sayin-hngas (agr. labourers)			
Wages of sayin-hngas			
Agri. credit	250.00	250.00	210.00
. Advanced payments			
. Crops Paddy II			
(a) Sown acre-age	7.08		6.27
(b) Yield/acre	24.01		39.87
(c) Cost 1	1467.38		1514.44
2	1018.08		1326.44
3	1361.53		1475.50
(d) Income 1	62.62		735.56
2	511.92		923.56
3	168.47		774.50
Paddy IV			
(a) Sown acres		7.06	
(b) Yield/acre		35.41	
(c) Cost 1		944.35	
2		624.18	
3		860.34	
(d) Income 1		1305.65	
2		1625.82	
3		1389.66	
Groundnut			
(a) Sown acres	0.50	2.00	
(b) Yield/acre	30.00	15.00	
(c) Cost 1	229.69	420.69	
2	88.00	103.31	
3	222.22	396.82	
(d) Income 1	170.31	1439.31	
2	312.00	1756.69	
3	177.78	1463.18	
. From other activities (b) Income 1	200.00		
Total cost of production			
1	1697.07	1365.04	1514.44
2	1106.08	727.49	1326.44
3	1583.75	1257.16	1475.50
. Total net			

Village	KUNCHANGONE					
Sample No.	496		497		498	
Item	Qty	Value	Qty	Value	Qty	Value
10. Implements & assets						
1. Bullock	2	3000	2	2800		
2. Plough & accessories	3	58	4	89	7	75
3. Harrow & accessories						
4. Paddy storage unit						
5. Bullock cart	1	250	1	800		
6. Cow shed/ farm shed	1	150	1	150		
7. Water pump						
8. Sickle	4	24	1	7	5	23.5
9. Knife (Dah)	1	5	2	10	2	6
11. Yearly maintenance expenditure						
1. Paddy storage unit						
2. Bullock cart						
3. Cow shed		200		150		
4. Sickle & knives sharpening						
5. Others						