APPLICATIONS OF LINEAR PROGRAMMING TO CORPORATE FARM PLANNING IN DEVELOPING COUNTRIES: A CASE STUDY FOR NAFCO FARMS IN TANZANIA

A thesis
presented in partial fulfilment
of the requirement for the degree
of
Master of Agricultural Business and Administration
at
Massey University
by
ERNEST ALEONASAA SWAI

Palmerston North
1980

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ACKNOWLEDGEMENTS

This study was carried out under the supervision of Dr A.D. Meister, Senior Lecturer, Dept. of Agricultural Economics and Farm Management, Massey University.

I wish to record my sincere appreciation of the dedicated guidance given by Dr Meister throughout the study and the patience shown, especially when reading the scripts.

I also wish to thank Professor R.J. Townsley, Dept. of Agricultural Economics and Farm Management, Massey University, for the invaluable advice offered from the initial stages of planning the course of my study, right through the stage of building the computer model and for generously giving his time to read over my script.

I am also very much indebted to Bruce Wilson, Reader, Faculty of Business Studies, Massey University, for his comments on the financial aspects of the model; to Professor Wilfred Candler of the World Bank, N.Y. for his comments on the computer model during its initial stage of development.

I am grateful to many staff members of NAFCO who readily sent me some of the basic data through the mail.

My thanks are also due to the Massey University Computer Centre staff for their co-operation during the computer analysis.

I wish to thank Mrs Veronica Lobb for her superb job of typing the thesis.

Finally, I would like to extend my sincere thanks to the New Zealand Government for sponsoring my study in New Zealand under the Bilateral Aid Programme. Thanks are also due to the Tanzanian Government for offering me the opportunity to undertake the study.

Any errors found in this thesis are entirely mine.

ABSTRACT

The economic development of most of the developing countries depends, almost entirely, on the agricultural industry. Measures to speed-up the development of the agricultural sector to increase productivity in such countries are therefore imperative.

In Tanzania, one of the actions the government has taken to achieve this is the establishment of agricultural Corporations which operate large scale mechanized farms. To achieve maximum productivity from scarce resources, such Corporations must be operated efficiently and this can only be achieved with appropriate planning of the corporate farms.

This study has dealt with one such Corporation in Tanzania called National Agricultural and Food Corporation (NAFCO). The objective of the study has been to illustrate how such a Corporation can be operated efficiently so that maximum food production can be achieved from scarce resources. Linear programming has been evaluated as a planning tool for a single representative farm of NAFCO. The aim was to develop a suitable LP model for the farm, use this model to determine the optimal farm plans and associated information and evaluate whether the technique would form a suitable planning tool for NAFCO farms.

The linear programming model developed demonstrated that the profits of the farm under study could be increased substantially by allocating the farm scarce resources more optimally. Repeating the optimisations of the model by changing the various assumptions proved to be quite useful in providing additional information on which to base management decisions. These results provided a better understanding of the effects and implications on what would happen if the anticipated yields, prices and certain policy decisions were changed. These are discussed in detail.

The optimum plan computed should with minor changes be both acceptable and realizable. It is argued that, because under corporate farm structure, specific data relevant to individual farms is more readily available than under peasant farm

situations and that because of the large scale nature of the corporate farms, the availability of wide choice of activities and resources as well as the necessary skills and defined objectives; linear programming would form a suitable planning tool for NAFCO farms.

CHAPTER ONE

CHAPTER ONE

1. INTRODUCTION

1.1 Agriculture and Economic Development in Tanzania

Agriculture is the backbone of Tanzania's economy and therefore this makes land one of the most important resources for the economic growth of the country. Agricultural products contribute more than 80% of the foreign exchange earnings and resources like minerals, forests and wildlife together contribute about 8-10%. The agricultural sector represents about 41.9% of the gross domestic product (GDP).

Tanzania has an area of about 945,200 sq kms (364,940 sq mils) out of which about 50,000 sq kms are covered by water. With a population of about 17.5 million people (1978) the average population density is about 19.5 people per kilometre. More than 90% of the population live in rural areas and are heavily dependent upon direct exploitation of land for the greater part of their livelihood. Throughout the greater part of the country the nature of the terrain and soils is such that crop and livestock farming are not only possible but also economically viable. However, this potential has yet to be fully exploited.

Tanzania unlike those countries which already are highly industrialized, depends in part on the availability of products (usually raw materials) suitable for export. This is necessary for payment of imported machineries, food stuffs, certain raw materials as well as the manufactured goods which make domestic resource exploitation in part possible. In this context, cash crops, food surpluses and forest products play an important role in the economic development of the country.

Given the fact that Tanzania has very few known untapped resource endowments apart from agricultural land; and industrialization as a major emphasis for economic development is far from reality; it is evident that for years to come the country's economic development will rely mainly on agriculture.

Before describing further the measures the government has taken in order to develop this industry it will be in order to explain the farm tenure system in Tanzania.

1.2 Exchange of Ownership in Land in Tanzania

In Tanzania land is in principle owned by the state. The Arusha Declaration (1967) which defines the policy of the country in broad terms states that: "All citizens together possess all the natural resources of the country in trust for their descendants ...". Individuals are not allowed to profit from land transactions and thus land cannot be treated as an ordinary asset controlled by individuals and subject to the pressures of the market. According to the policy of the country of 'socialism and self reliance', private land ownership is considered as a means of accumulation and concentration of wealth to a few privileged individuals and therefore contributes to social injustice. One cannot therefore sell land as such but only the investment on the land.

Exchange of land ownership has been changing over years according to different land tenure systems which have come into existence in Tanzania. These include the native custom and law (traditional) land tenure which was the only form of land tenure which existed before the colonial era. To adequately describe Tanzanian traditional land tenure system is extremely difficult due to existence of numerous tribal and intertribal forms of tenure. Other forms of land tenure systems which have existed since the colonial era and which still exist to some degree include leaseholds arising out of German freehold alienation, right of occupancy arising out of African customary law, and right of occupancy by grant. However, a few years back the government passed an Act of parliament to convert leaseholds to rights of occupancy and this has been taking place fairly rapidly. Most of the large scale agricultural farms held under 33 or 99 years lease have now been nationalized and handed over to co-operative ventures and/or public corporations.

Most of the land is held under the traditional patterns of land tenure by the smallholder farmers. Such land carries no formal right of occupancy. One has the right to a piece of land as long as he uses it. In sparsely populated areas a family may acquire a piece of land easily, and as long as they use it, their right to it is recognised. In densely populated areas rights are more clearly defined and formal but still there is no register of rights in writing. In most traditional systems of tenure, planting perennial crops is held to carry a permanent right to the land. The owner can sell his/her 'land' in such a case, but he is only paid or compensated for actual investment on the land and not for the land itself. Grazing rights are held almost everywhere to be communal, although in some areas rights may be associated with families, villages or units of a tribe.

Land is traditionally passed from father to son(s) and thus land fragmentation is a normal pattern, especially in densely populated areas. This is infact a limiting factor to agricultural development in densely populated areas.

The advent of 'Ujamaa' villages (village communities) has had great impact on the present land tenure farms. One objective of developing 'Ujamaa' villages is to obtain the economic advantages of large scale farming through the introduction of modern agricultural techniques and by farming village land collectively. The majority of 'Ujamaa' villages have been started on newly cleared land where there were no established traditional tenure rules. The rest have however been established on traditional village land which belonged to individuals but has now been taken over by the village communities. Land owned by 'Ujamaa' villages is however, given formal right of occupancy unlike that owned by individual peasant farmers. The rights are given under the name of the village. Part of the village farm is cultivated collectively by the members of the village and the rest of the land is allocated to individual village members for their personal use.

The issue of land tenure in 'Ujamaa' villages, although important, has not been well defined. Whether traditional African land tenure will be extinguished entirely or remain as part of new tenure regulations, which hopefully will be developed in due course, is hard to say. However, the chances are that the native custom and law which has been in existence will greatly be altered. The disappearance of this type of tenure will likely not occur in the near future.

Public corporations can similarly acquire unutilized farm land for agricultural development and in order for them to be able to obtain loans and other credit facilities from banks, they too must obtain the right of occupancy for the land they farm.

1.3 Measures Taken to Develop the Agricultural Industry

Because of the importance of agriculture in the national economy the government has taken steps towards speeding up the development of the agricultural sector. In particular it has urged all farmers to develop their land to the full and where practicable to expand their holdings. The campaign of the government to repatriate unemployed people from urban areas to the rural areas and the introduction of 'Ujamaa' villages (village communities) in which large scale farming is done communally, is geared towards this goal. Subsidized farm inputs, credit facilities and extension services, offered to farmers has to some extent accelerated land development and hence agricultural output. However, because peasant farmers are considered by commercial lenders (banks etc) as a great risk, for they have little wealth and inadequate skills to manage large scale farms, they can not easily obtain loans for agricultural development. For this reason, and as a means of accelerating agricultural development faster the government has formed various state owned Corporations and Crop Authorities which are responsible for the development of particular crops. Since these Corporations can employ the necessary skills and technology required for operating large scale farms more efficiently than the peasant farmers or the villages and can obtain loans (if required) more easily, they are therefore, more capable of making agricultural development proceed much faster and thus contributing more towards total economic development of the country. Their role in crop production is therefore very important.

In addition to producing cash crops for export, the country aims to be self-sufficient in food crops by 1982 as well as to have surplus for strategic reserves to meet unexpected natural disasters (such as droughts) and also surplus for export.

Cereals (rice, wheat, maize and sorghum) and beans are consumed by the greatest majority of Tanzanians. One Corporation responsible for production of these food crops, among others, is the National Agricultural and Food Corporation (NAFCO) - (whose functions, aims, etc are explained in detail in the next chapter). Because of the importance of this Corporation and other similar ones, it is of paramount importance that they are operated efficiently so that maximum food production is achieved from scarce resources. To achieve this, appropriate planning of the corporate farms is essential. In this study, the National Agricultural and Food Corporation (NAFCO) has been chosen to illustrate how this can be achieved. The study will only concentrate on resource planning aspects for food production.

The planning tool which will be evaluated in this study is linear programming. It is thought that linear programming might be a more appropriate planning tool than the methods currently in use in NAFCO (i.e. budget analysis and gross margin analysis) because most of the NAFCO subsidiaries have the potential to produce numerous crops and livestock products, and most resources are limited and can be allocated among production possibilities in thousands of ways. Therefore, the number of alternative plans in one subsidiary could thus run to millions because of the diverse resources available and the wide range of production alternatives that are feasible. Linear programming makes it possible to select the plan(s) which can utilize the available scarce resources optimally. Using more sophisticated planning methods may create problems because of lack of specialist staff with skills for applying the methods satisfactorily in NAFCO.

1.4 Objectives of the Study

The objectives of this study are: -

(1) to develop a linear programming model for a typical farm of NAFCO,

(2) to use this model to determine optimal farm plans and associated information, and

(3) to evaluate the technique as to its suitability as an aid in Corporate farm planning.

However, before looking into the development of linear programming (LP) model, a review of functions, the set-up (structure), the planning methods and problems of NAFCO will be discussed to emphasize the need for better resource planning.

1.5 Plan of the Study

The study consists of seven chapters, the first chapter being the introduction. The second chapter gives a review of the functions, the set-up, the planning methods and the problems of NAFCO mainly to emphasize the need for better planning for its subsidiaries. Proposed solutions to these problems are also discussed. In the third chapter, the theory underlying the linear programming technique is presented. Further in this chapter, some farm planning studies using LP models are reviewed. The purpose of this review is to show that linear programming could also be suitable for corporate farm planning. Of course it is the aim of this study to evaluate this for a specific example. In chapter four, a description of a typical representative farm of NAFCO and the basic data are given and an LP model is developed for this farm. In chapter five, the method used for the data analysis, the delimitations of the model and the results of the model are presented. This is followed by a detailed interpretation of the results and a discussion of their effects and implications. In chapter six, the sensitivity analysis results are presented and a detailed interpretation and discussion of these results, is given. The summary and conclusions drawn from the results of the study as a whole are given in chapter seven.

CHAPTER TWO

CHAPTER TWO

2. A REVIEW OF THE FUNCTIONS, THE SET-UP, THE PLANNING METHODS AND PROBLEMS OF NAFCO

2.1 Objectives of NAFCO

National Agricultural and Food Corporation (NAFCO) is a parastatal Corporation in Tanzania established by an act of Parliament in 1969 and charged with the responsibility of promoting agricultural development and food production on large scale mechanized farms within Tanzania.

Within five years of establishment, the activities of the Corporation expanded very rapidly to an unmanageable scale. In 1974 a re-organization was carried out whereby Sugar Development Corporation (SDC), Livestock Development Authority (LIDA) and Tanzania Fisheries Corporation (TAFICO) were formed by detaching operations formally under NAFCO. Since then the prime objective of NAFCO has been to promote and develop mainly the basic food crops, namely, rice, maize, wheat and sorghum etc. However, most NAFCO farms have other side-line crops suitable for large scale production and livestock enterprises, (mainly dairy cattle, poultry and piggery).

At present NAFCO has 14 subsidiary companies with share holdings ranging between 74% to 100% [1]. There are also 3 associated companies with shareholdings of 30%, 39% and 50%. The Corporation also has 7 on-going farm projects and 12 new projects at various stages of implementation. Each subsidiary or associated company or project[2] operates one or more large scale farms, and these are scattered throughout the country.

The main aim of NAFCO as a Holding Company is to start as many viable and financially self-supporting subsidiaries (companies and on-going projects) as possible, each producing its own

1) The shareholding in 12 of these subsidiaries is 100% and in the other two it is 74% and 88%.

2) In the subsequent sections the word "subsidiaries" will be used for actual subsidiaries, associated companies and farm projects.

target crops. That is to say it aims to: -

(a) develop the existing weak subsidiaries to the stage where they are financially self-fupporting.
(b) start new viable projects, each growing at least one of the major food crops as its target crop,
(c) provide the subsidiaries and new projects with the required managerial and technical skills,
(d) support them by other means to make them financially self-supporting as far as possible, and
(e) contribute significantly to the economic development of the country by utilizing the available scarce resources most efficiently for maximum food production through its subsidiaries. This is the aspect which will be dealt with in this study.

The objective of NAFCO subsidiaries is to produce their target crops most economically taking the advantage of:

(a) the large scale nature of the operation,
(b) the high level of managerial and technical skills they obtain from the Holding Company, and
(c) the available resources (land), labour, etc).

Tanzania still imports some of the basic food crops. NAFCO's duty is to fill the gap between the demand and the supply especially of the three most important food crops, wheat, rice and maize.

The average annual short fall in wheat production in Tanzania during 1972/75 was about 30,000 tons. According to the third National Five Year Development Plan (1978/82), the annual demand for wheat in 1981/82 will be about 127,000 tons and the production estimates in the plan shows that the national short-fall in domestic wheat supply will be about 50,000 tons. NAFCO being the major producer of wheat in Tanzania has to contribute a bigger share in closing up this gap.

The average annual short-fall in maize production during 1970-76 was about 100,000 tons. The Third Five Development Plan estimates maize demand in 1981/82 to be 1,360,000 tons which is 57% more than the 1970/71 level. NAFCO has plans

Table 2.1: SUMMARY OF PRODUCTION TARGETS OF NAFCO DURING 1977/78 - 1981/82

	1977/78	1978/79	1979/80	1980/81	1981/82
FOOD CROPS & THEIR SEEDS:					
Wheat (1,000 tons)	19.0	22.5	27.1	31.5	35.9
Rice "	10.9	13.7	16.3	21.1	27.5
Maize "	5.7	10.1	18.6	28.7	36.5
Soya benas "	3.5	4.0	4.6	5.6	6.0
Sorghum "	10.3	10.5	9.6	10.6	12.2
Navy beans "	1.2	1.1	1.1	1.1	1.2
Other beans"	1.6	2.3	2.7	3.4	3.7
SEED PROCESSING:					
Wheat (tons)	1300	1900	2200	2600	3200
Maize "	7600	10900	12400	13600	15000
Others "	2200	3100	4600	7200	9700
LIVESTOCK PRODUCTS:					
Milk (ton)	2600	3500	4100	4400	4500
Steers & cow culls (heads)	500	600	850	950	1050
Porkers (heads)	3300	4000	5600	6000	6100
Eggs (millions)	3.6	5.6	7.3	7.9	8.8
Broilers & layer culls (1000 birds)	90	100	120	125	135
OTHER PRODUCTS:					
Coffee (tons)	500	560	640	660	820
Cocoa "	100	120	140	165	185
Lime juice "	370	430	530	590	650
Coconut oil "	830	990	1230	1450	1700
Copra cake "	430	510	590	750	900

Source: National Agricultural and Food Corporation Corporate Plan (1977/78 - 1981/82), 1977.

to produce 36,500 tons of maize in 1981/82 which will be 3% of the estimated demand at that time.

During 1977, five year development plans for NAFCO subsidiaries were made. Although the plans were made on an ad hoc basis they however, reflect a good picture of the development potential of the subsidiaries.

On the assumption that only 80% of the development targets for the new projects would materialize, the production of the major crops and their seeds and livestock products for the existing subsidiaries and the new projects were expected to develop as shown in Table 2.1.

According to the development plans 13 subsidiaries which were unprofitable in 1977 would become profitable during the plan period. Two subsidiaries would still be making losses by 1981/82. With better planning these subsidiaries could be making profits within a shorter period.

Twenty two subsidiaries would need new loans or equity during the plan period. Seven of them would need the funds mainly for re-investments in their existing operations. The summarized need of funds for the operations and development of the existing subsidiaries and new projects were estimated as shown in Table 2.2 below:

Table 2.2: REQUIREMENT OF FUNDS FOR OPERATIONS AND DEVELOPMENT (EXISTING AND NEW FARMS)

Year		Existing Farms		New Farms	
1977/78	shs	87.4	million	22.3	million
1978/79	"	116.0	"	37.9	"
1979/80	"	93.1	"	65.5	"
1980/81	"	78.7	"	80.8	"
1981/82	"	11.4	"	76.6	"

During the plan period NAFCO would also study about 20 new potential project areas (for wheat, rice and maize). Feasible plans would be implemented during the next plan period. According to the plan only those areas with the greatest potential in terms of productivity and national economic benefit, will be selected for implementation. The national policy of equal horizontal distribution of investments will be followed only if it won't affect the feasibility of corporate production.

At the time when this study was undertaken no actual figures on the results of implementation of the plan were available for comparison with the planned targets. Nevertheless, to achieve these targets, better planning for optimal allocation of resources will be required.

2.2 The Structure of NAFCO

NAFCO has its Head Office in Dar-es-Salaam. The Head Office is divided into three directorates. They are: Planning and Development, Finance and Operations and Administration and Manpower Development. Each is headed by a Director under the General Manager. The organizational structure of NAFCO is shown in Figure 2.1.

At present NAFCO has one Zonal Office situated in Arusha - the Northern Zone. There are plans to open two other Zonal Offices - in the Central Zone and Southern Zone.

The Zonal Managers are directly under the General Manager and have the same status as the Directors. The Zonal Office is a decentralization to which the functions of the Head Office have been devolved. It therefore carries out similar functions as the Head Office for the NAFCO subsidiaries within its zone. This is to reduce the problem of poor communication between Head Office and the subsidiaries and poor existing communication links.

The main function of NAFCO Head Office and Zonal Offices is therefore to plan and control the activities of the subsidiaries. At the same time the role of the management of NAFCO is to ensure that the Directorates and the Zonal Offices perform their functions efficiently. The process involves continous handing over of responsibilities in a systematic way through the following stages: -

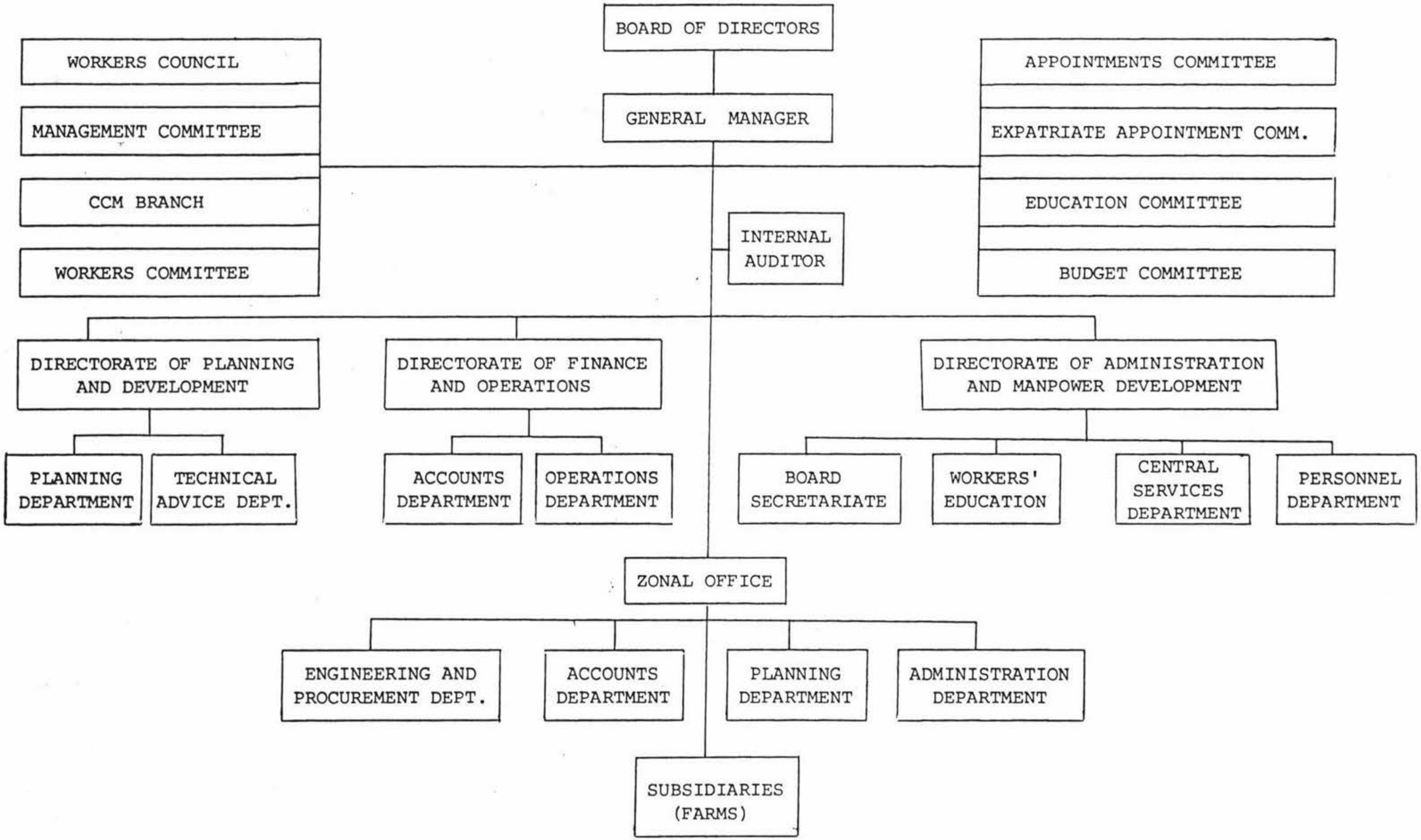


Figure 2.1: THE ORGANISATIONAL STRUCTURE OF NAFCO

(1) The Government, the Board of Directors and the General Manager set up the growth guidelines (targets) which guide the Directorate of Planning and Development as to which are the long and medium term priority development plans for NAFCO investment.

(2) The Directorate of Planning and Development prepares plans in **consultation** with Zonal Offices and the subsidiaries.

(3) The Directorate of Finance assists the Planning and Development directorate in the planning and identification of sources of funds and the necessary planning of capital and financial structure including the processing of the actual financing.

(4) The Directorate of Finance in consultation with the Zonal Offices and the farms prepare matching standards (e.g. budgets) and the appropriate accounting and feed back information systems for effective control. As the responsibilities shift to Zonal Offices they supervise the actual data processing.

(5) The Zonal Offices take up the responsibility of implementing those plans financed and the supervision of on-going projects by preparing (in close co-operation with the directorate of Planning and Development and in consultation with the subsidiaries) operational and project implemenatation programmes and timing the subsidiary activities.

(6) The Operations department in close co-operation with the Zonal Offices continuously collect information and prepare reports for analysis and presentation to top management for decision making. The top management makes decisions on corrective measures suggested. These decisions are taken up by the directorate of Planning and Development to start the process again by making improved plans.

The above procedures are not strictly applied in all cases for two main reasons. First, the Head Office and the Zonal Office do not have enough competent staff to do all the functions required to be undertaken by them. Secondly, the two more Zonal Offices required are not yet in operation. Therefore, at farm level, if the management of the farm is competent, then they are left to make the farm plans subject to the guidelines laid down by the Corporation and subject to the approval of the Head Office before implementation. For those subsidiaries with poor performance or lack of management with planning skills, the planning staff of NAFCO or Zonal Office make the farm plans in conjunction with the management and other farm personnel. Even then, 'minor' decisions such as on what other side-line enterprises to include in the plans in addition to the target ones is made by the management of the farms. The plans are then submitted to the Board of Directors of NAFCO for approval.

Nearly all NAFCO farms are mixed farms with both cropping and livestock activities. A few have cropping activities only, but in the long run they also expect to incorporate livestock activities wherever feasible. Each farm can produce any combination of activities, but this must include a certain minimum acreage of the target crop(s) for the farm.

2.3 The Current Planning Techniques in Use

There are two major planning methods currently in use by NAFCO. They are: -

(a) budget analysis, and
(b) gross margins analysis.

With budget analysis, a whole farm plan is usually established through an assessment of past performance, using accounts and efficiency ratios, together with future expectations. Two kinds of budgets to suit particular purposes are used. They are cash flow budgets and partial budgets. The cash flow budget is prepared to indicate the financial consequence of the plan for the farm as a whole. The partial budgets are only prepared when the Manager is considering adding a new side-line enterprise, replacing an old one with a new one, or envisaging a change in the production technique(s) for a particular product line.

With gross margins analysis, an estimate of the gross margin for each of the possible enterprises is calculated by subtracting from the enterprise's gross revenue the variable costs which can be allocated to the particular enterprise. Then, the production plan is selected by arranging the enterprises (high gross margin to low) until the available resources are exhausted. This method is adequate for relatively simple problems on small farms with little diversification. Even then, however, it is often not easy to allocate all the available resources to give the highest profit possible.

With the potential to produce numerous crops and livestock products and with a wide range of resources, most, if not all, of the subsidiaries of NAFCO find these planning methods inadequate and burdensome. Because of the load of work involved in arithmetical computations when using these methods, some subsidiaries make their plans mainly based on subjective judgements. Sometimes this is also the case even when the planning is carried out in conjunction with the Head Office or Zonal Office.

Introduction of more suitable planning methods which are less burdensome would certainly eliminate this problem and make planning more systematic.

2.4 The Viability of NAFCO Subsidiaries and the Problems They Face

2.4.1 Viability and Problems

Most of the NAFCO subsidiaries have been making financial losses during their whole lifetime. Although many have been able to cover their operational costs, only a few have been able to generate surplus capital for re-investment in fixed capital items like machinery, etc. To sustain the subsidiaries, NAFCO has been pouring in more and more funds for capital investments.

In most cases unfavourable weather conditions have been given as the reason for poor performances. However, an in-depth examination has shown that this is more of a contributing factor rather than the main cause.

Generally, the losses can largely be attributed to lack of appropriate planning which leads to non-optimal allocation of resources and hence the unprofitability of product lines and small scale of operation with marginally profitable production. There are other problems experienced by some of the subsidiaries which contribute to the losses as well.

In a number of subsidiaries, the situation described above has been aggrevated by frequent mechanical break-down, due mainly to inexperienced handling, lack of adequate spare parts and of skilled machinery/ equipment operators. Consequently, high running costs have been a common phenomena in some subsidiaries.

Also as a result of inaccurate recording systems and inadequate and ineffective control systems in some subsidiaries the management was not in a position to know the amount of inputs used in each production line. It has therefore been difficult for management to assess the level of productivity and overall efficiency of operations for some subsidiaries and their individual production lines. Even though some subsidiaries now have adopted an accurate recording system, the data compiled is not used effectively in control and planning due to lack of skill to use the information.

Low level of motivation and limited skills or experience of the management and other personnel sometimes contribute to the unprofitability of some subsidiaries.

The Head Office and Zonal Office have been offering the subsidiaries some supporting services such as: -

(a) recruiting and training of personnel,
(b) assisting in applying for loans and bank overdrafts,
(c) assisting in development planning,
(d) giving technical advice on operations, and
(e) assisting in the purchasing of machinery spare parts and materials.

However, the central organization has not been able to fulfil all these obligations very well because of practical difficulties, some of which have already been mentioned. The acute shortage of transport facilities (for Head Office and Zonal Office staff) and lack of staff housing (especially guest houses for visiting staff) on remote farms are among the motivational factors which also contribute towards decreasing efficiency at work for Head Office and Zonal Office staff.

Sometimes the management of a subsidiary spends a considerable portion of their resources on unprofitable side-line enterprises instead of the major ones which have been planned. Little effort is made at field level to identify bottlenecks, diagnose the problems and find out timely solutions for them.

In some cases, the major product lines, even though they could be profitable on a larger scale hardly cover the fixed costs due to the small scale nature of their current operation. Such subsidiaries could create surpluses if their scale of operations were increased and the resources available allocated more optimally.

In certain instances some of the subsidiaries have to grow certain crops or start a livestock enterprise (where the Government requires the Corporation to do so for a particular purpose, e.g. for encouraging people in a certain area to adopt a new enterprise or a new production technique) even though the enterprise or technique may fail the test of financial viability for the Corporation.

However, even under such circumstances, income could be improved or losses minimized by using appropriate planning methods.

Furthermore, despite the fact that there is an organizational set-up in NAFCO as described in section 2.2 the following organizational problems still exist:

(1) There is absence of clearly indicated and clearly known responsibilities for management decision among the executives who form the organizational structure.

(2) The lack of clear definition of responsibilities has resulted in too much concentration of mangement decision making into the hands of the General Manager.

2.4.2 Proposed Solutions

To solve some of the problems facing NAFCO subsidiaries, the Corporation has drawn-up strategies which it intends to follow. With regard to the development of its own functions as a holding company, NAFCO intends:

(a) to develop the management policies regulating the relations between the Holding Company and its subsidiaries,

(b) to intensify technical assistance to the subsidiaries and new projects,

(c) to strengthen the supporting services, and

(d) to re-organise the organisational set-up at the Head Office to improve allocation of functions of the various directorates.

NAFCO will manage and control its subsidiaries by following two general principles, namely "Management by Objectives" and "Management by Exceptions". This means that the Corporation: -

(a) will set targets (plans) for a subsidiary in Co-operation with it;

(b) follow the attainment of the targets from periodical reports;

(c) demand explanations to the variances between targets and results actually attained.

The general principle is that NAFCO will delegate appropriate authority to a subsidiary and will avoid all undue control on day to day operations when it is able to attain its targets and is financially self-supporting.

When the subsidiary is unable to attain its targets and is continually making losses, then NAFCO will tighten its control and will increase the amount of management consultancy to it, including temporary take-over of the subsidiary, if it is in danger of collapsing.

To help the management of the subsidiaries to successfully steer their operations, NAFCO will develop for them proper management systems like a budgeting procedure (based on the separate gross margins of the various production lines), farm recording and control systems, etc.

NAFCO will also produce, for subsidiaries, operational guidelines such as how to make systematic trials with different varieties and cultural practices at the farm level and determine suitable amounts of various inputs to be used per producing unit.

The training of personnel of subsidiaries is one of the most important supporting services provided by NAFCO. NAFCO has prepared several training programmes for various key personnel groups of the subsidiaries, the objective being to both improve skills and increase motivation. NAFCO is also studying the possibility of establishing a training centre including an apprentice scheme in connection with one of the operating subsidiaries. To improve the technical services of subsidiaries NAFCO will give the status of 'Zonal workshop' to some of the better operating subsidiary workshops. These workshops will be provided with additional resources so that they are able to serve other workshops with spare parts, exchange units and special services.

NAFCO is also studying the possibility of standardizing the machinery and equipment used by subsidiaries. NAFCO has established a purchasing unit operated from Head Office for more systematic and efficient purchases of machinery, agro-chemicals and spare parts for subsidiaries.

Operational conditions of the Head Office are to be improved by acquiring additional vehicles and staff houses.

Acquisition of development funds entails continuously ensuring their adequacy in conditions of inflation for all aspects of development projects. This applies not only to funds for fixed assets, but also for working capital, operating losses during initial years, debt service coverage, provision for risk due to exceptionally adverse agricultural conditions such as drought, etc. NAFCO will try whenever possible to secure the right kind of funds, primarily non-interest bearing and non-redeemable equity type financing supplemented to a limited extent only by loans on soft terms. Another aspect of fund raising which NAFCO will try to abide to is to ensure acquisition of funds in good time, timeliness of disbursements and especially good co-ordination between project implementation and financing.

With regard to the problems of NAFCO it clearly shows from the above solutions that NAFCO has at least planned lines of actions for solving some of the problems mentioned earlier, even though they might not be the best solutions. However, without proper tools for allocating resources optimally the subsidiaries may still continue to make losses. It is therefore the intention of this study to examine a possible solution to this problem.

In the next chapter a tool for farm or resource planning i.e. linear programming which could be used in NAFCO will be discussed in detail. It should be noted that it is not the aim of this study to plan the whole of the NAFCO operation. Rather, seeing that subsidiaries will have to become self-sufficient, the study will concentrate on resource management at the subsidiary level. That is, linear programming (LP) will be evaluated as a planning tool for a single typical representative farm of NAFCO.

CHAPTER THREE

CHAPTER THREE

3. THEORETICAL ASPECTS OF LP MODEL BUILDING

3.1 Introduction

This chapter is devoted to a discussion of the theoretical aspects of LP Model Building, model analysis and the interpretation of the solution.

3.2 Definition

Linear programming is a planning technique which given suitably formulated data is capable of producing optimal mathematical solution(s) in terms of either maximizing or minimizing some stated objective.[1] According to Yang (1958),

> "LP as applied to farm planning and budgeting represents a systematic method of determining mathematically the optimum plan for the choice and combination of farm enterprises (technically also known as processes, activities and outputs) so as to maximise the income (or to minimize the cost) within the limits of the available resources (also known as production factors, inputs or constraints) on an individual farm."[2]

As the definition indicates, the technique is useful when there are different enterprises and different methods or techniques of producing the enterprises so as to achieve the objective. Also, the technique is important only when resources are restricted or limited. These restrictions set limits on the kind of plans which can be considered.

Linear programming is used as an aid to decision making. According to Meister & Nicol (1975), "Linear programming is mainly a procedure for providing normative answers to problems which are so formulated" (i.e. formulated as in section 3.8). They defined normative as "the course of action which ought to be taken by an individual business unit, area, or other economic sector, when: (a) the end objective takes a particular form and (b) the conditions and restraints, surrounding the action or choice are of a particular form.... The conditions and restraints surrounding the plans which can be followed will be the techniques available, the amount and kind of soil, the amount and quality of labour, the prices, the amount of capital and other specific resources".[3]

3.3 Historical Background and Applications

LP was first used during the second World War to allocate scarce resources when moving supplies to armies. Later, it was applied to solving problems such as blending of petrol from different oilfields, co-ordination of factories, formulation of minimum-cost diets of required nutritive value and transportation problems. Since the 1950's its use has been extended to farm planning and has found widespread application in many other economic problems involving decisions which require a choice among a large number of alternatives. It is for this reason the technique has been selected for testing its suitability for farm planning in Tanzania.

3.4 Computation Methods

The solution of LP problems can be done by mechanical means or by using electronic computers. Simple LP problems can easily be solved manually on a desk calculator. Under practical and more realistic conditions, LP problems consist of a large number of alternative choices and constraints such that it is not practical to obtain solutions on desk calculators. However, with the aid of electronic computer packages, complex LP problems can easily be solved at very little cost and time.

3.5 The Characteristics of LP Problems

All LP problems have four characteristics. These are: -

(i) the method can be described in terms of a sequence of possible activities,

(ii) the planner has to select the most appropriate levels for each of these activities,

(iii) the selection is limited by the availability of scarce resources, and

(iv) there is a well defined objective (e.g. profit, cost, etc) which can be used to rank the suitability of the various alternatives available.

3.6 Assumptions of LP Models

When constructing LP models there are six important assumptions generally made. The planner has to ensure that none of these assumptions are invalidated before applying the technique.

The assumptions are as follows: -

(i) Linearity and Additivity

It is assumed that the physical requirements of each production factor per unit of farm activity is fixed. That is to say, each additional unit of output requires the same quantity of input. Thus, no interaction can occur in the quantity of resources required per unit of output regardless of whether activities are produced alone or in various proportions and hence no adjustment for economies of scale is made.

(ii) Divisibility of Activities and Resources

Activities are assumed to be capable of operation at any positive fraction and that any proportion of each resource can be used in the production. Thus, an optimal solution which included an activity such as 10.246 cows and a resource requirement of 50.409 mandays is possible. However, not all solutions are acceptable. Acceptability depends on the problem. If for example, one of the activities in a problem was buying a tractor and the solution says buy 0.5 of a tractor; since this would not be possible, it would have to be accounted for by setting up the problem differently or using interger programming.

(iii) Non-negativity

It is assumed that no activity can be carried on at a negative level. Thus, a model which includes borrowing and lending activities must treat each activity separately, each being carried out at some positive level.

(iv) Finiteness

It is assumed that the number of alternative activities and resource restrictions which the farmer or planner need to consider are limited. Had the number of alternatives been unlimited, the task of programming them would never get finished.

(v) Single-Value Expectations

It is assumed that the resource supplies, input-output coefficients and prices used in linear programming are known with certainty.

(vi) Accountability of resources

It is assumed that in an LP model it must be possible to account for each of the available resources. For example, if there are 1,000 ha of land, we must be able to account for all the 1,000 ha of land by adding up the number of hectares used by each activity and those not used at all.

Other assumptions related to the above are those of independence of planning period and convexity. All these assumptions are closely obeyed especially with whole farm activities as described in this study.

3.7 Steps for LP Model-Building

Before an LP problem can be solved a model to describe the problem must be built. The process of constructing the model can be divided into five main steps as follows: -

(i) Define the activities

The first step is to analyse the problem to determine what activities are being carried out or could be included in the problem.

In a farm planning LP model, the real activities could take a variety of forms. Beneke (1973) lists the most common ones as follows:

1. Producing or growing crops.
2. Raising and/or feeding livestock.

3. Selling products.
4. Buying or hiring inputs or services including labour and capital.
5. Harvesting crops.
6. Transferring inputs or intermediate products from one activity or time period to another.
7. Paying fixed costs and/or family living expenses.[4]

A number of functions can also be combined within a single activity, but care should be taken to ensure that the range of functions combined is well defined to avoid confusion.

The unit used for measuring the level of each activity should be chosen and used consistently all through the process of model building (i.e. when defining each of the coefficient for that activity). The unit chosen should be practical and convenient to use. For example, the unit for a particular crop could be 1 ha, or 4 ha, or 10 ha, depending on which of the activity units will make formation of the various coefficients more convenient or practical. For a crop activity that included a rotation such as beans, maize, maize, fallow; the unit of activity could conveniently be expressed in 4 ha. - one of beans, two of maize and one of fallow.

(ii) <u>Determine the Scarce Resources</u>
The second step is to enumerate **all** the resources that will be required by the activities included in the model and then determine amongst them which are the scarce resources. These may include land, capital, labour, etc. The unit for measuring each of the scarce resources is chosen. For example, land could be measured in hectares or acres, capital could be measured in dollars or shillings as in this study, and labour could be measured in man-hours or mandays.

(iii) <u>Define the restraints</u>
This third step takes place simultaneously with step (ii) above, however, for clear elaboration they have been treated separately. In this third step restraints (also known as constraints or restrictions) are defined. There are two

major types of restraints which may limit the level of the activities that may enter the optimum plan. These are: -

(a) Resource restraints i.e. the total amount of land, labour, machinery available per period of time.

(b) Activity restraints i.e. the maximum or minimum amount allowable for some activities.

Each resource or activity restraint is designated as a maximum or minimum or equality restraint depending on the purpose of the restriction. For example, the restriction could be due to the maximum amount of resource (such as land, capital, labour, etc) available to the farm; or there could be external restrictions such as government programs or credit limitations; or the farm manager could impose subjective restrictions such as limiting the credit he is willing to use or forcing-in activities which he requires for other than economic reasons, or restrictions designed for risk aversion, etc.

(iv) Determine the Input/Output Coefficients

The fourth step is to determine the relationship between the activities and the resources in the problem in terms of resources needed per unit of output. These are referred to as input/output coefficients.

A positive or negative sign of the coefficient indicates whether the activity is a user or a source of the resource. However, this rule does not apply to the objective function for which, in a maximization problem, a positive coefficient indicates the quantity by which the value of the program can be increased and a negative coefficient indicates the quantity by which the value of the program can be reduced when the activity level is increased by one unit. In a minimization problem the interpretation of the signs in the objective function is exactly the opposite of this.

(v) Define the Objective Function

The next step is to define the objective function and to determine the coefficients in the objective function row. The signs of the coefficient are determined as explained in subsection (iv) above.

In LP models the objective is either to maximize or minimize a certain variable in the model, subject to given restraints. In most farm planning problems the objective is either to maximize some income variable such as total gross margins or to minimize some cost variable such as the cost of making a livestock feed mixture of a desired nutritive value.

(vi) Construction of the Model

Having determined all the possible activities, the resources (or restraints), the input-output coefficients and the objective; the next step is to construct the model layout. The model takes the form of a matrix of coefficients which shows the relationship between the production activities and the resources in the problem. The columns of the matrix represents the production activities and the rows represent the resources (restraints) as well as the objective function.

The values of the resources (or contrainsts) are generally placed on the right-hand side of the matrix and hence referred to as the 'right-hand side' or RHS. The layout of the LP matrix may generally look as shown in Table 3.1.

TABLE 3.1: LAYOUT OF AN LP MATRIX

	ACTIVITIES (COLUMNS) (e.g. producing, selling, buying, transferring, etc).	
	OBJECTIVE FUNCTION (e.g. net revenues made up of gross margins, partial gross margins, variable costs, prices, etc).	
RESOURCES/ CONSTRAINTS (ROWS) e.g. Land Capital Labour Machinery etc	INPUT-OUTPUT MATRIX Resources or constraints consumed or supplied per unit of each activity.	RHS The values of the resources/constraints

The importance of building the model is to enable the planner to set-up the problem in a mathematical relationship for easy computation. As Wagner (1975) puts it, "Constructing a model helps you put the complexities and possible uncertainties attending a decision-making problem into a logical framework amenable to comprehensive analysis. Such a model clarifies the decision alternatives and their anticipated effects, indicates the data that are relevant for analyzing the alternatives, and leads to informative conclusions. In short, the model is a vehicle for arriving at a well structured view of reality."[5]

3.8 Algebraic Formulation of an LP Problem

In a maximization problem involving the planning of the whole farm an LP problem can be expressed algebraically as follows: -

The problem is to find the optimal values of the variables X_1, ----, X_j, ----, X_n which include all the possible enterprises that can be undertaken on the farm and all the various ways of producing them to maximize the objective function.

Objective Function:

(1) Maximize $Z = \sum_{j=1}^{n} C_j X_j$ for $j = 1,2,---,n$.

Where: Z is the farm profit, e.g. total gross margins,
C_j is per unit profit (gross margin) of the jth activity,
X_j is the level of the jth farming activity.

Subject to the conditions given by a set of m linear restraints expressed as:

(2) $\sum_{j=1}^{n} a_{ij} X_j \lesseqgtr b_i$ for $i = 1, 2, ---, m$.

Where: only one of the inequalities ($\leq$ or $=$ or $\geq$) holds for each restraint,

b_i is either the amount of ith resource available or just an accounting identity.

X_j is the level of the jth farming activity.

a_{ij} is the technical input-output coefficient which specifies the amount of the ith resource required to produce one unit of jth activity.

(3) Also, $X_j \geqslant 0$ i.e. each activity level should be nonnegative since production of negative areas of crops or negative numbers of livestock is not possible.

Any selection of values for X, to X_{n+m} is called a 'solution' to the problem. If the solution satisfies all the constraints of the problem it is said to be a 'feasible solution'; and if it is also the solution which gives the highest value of the objective function (in a maximization problem) or the lowest value of the objective function (if it were a minimization problem) is is an 'optimal solution'.

3.9 Information Provided by the Optimal Solution

3.9.1 Routines

Three routines are included in LP solution procedures and each gives a separate interpretation of the system of equations analyzed. These are: -

(i) The basic solution

This shows the levels of the activities and the associated limits, costs, and use of the activities or resources. The solution of an LP problem is given in two separate parts. The first part is an analysis of the restraints (rows section) and the second part is an analysis of the activities (columns section).

(ii) Range analysis (see next sub-section).

(iii) Parametric routines (see next sub-section).

3.9.2 Sensitivity Analysis

(i) Definition

A farm plan developed through LP is assumed to be based on perfect foresight and that the data and other information built into the model are known accurately and with certainty. That is, even tenuous market forecasts, expected costs, estimated profits per unit, labour and machinery efficiency ratings and the like are assumed to be known with accuracy. However, in practice, perfect data are rarely obtainable and none of the data can ever be known accurately. This means then, that an optimal solution to an LP problem cannot be taken as the final plan for implementation without carrying out further tests on the stability of the plan. This testing of the stability of the optimal solution by making small changes in the input data in order to determine whether it depends critically on the exact values of particular data is called sensitivity analysis or postoptimality analysis.

Sensitivity analysis provides answers to many questions which in turn provide useful insights into the planning situation. Beneke (1973) lists some of the questions it answers as follows: -

1. How great is the advantage of the activities which entered the plan over those which did not?
2. How would increasing or decreasing one or more resources affect the optimum mix of activities and the value of the program?
3. How would changes in price relationships affect the solution?[4]

The answers to questions such as these, enables the decision-maker to make appropriate decisions on the final plan to be implemented. In actual fact, in many real applications of LP models, these considerations are even more important than finding the exact optimal production values.[5]

The ability (in LP models) to vary resource levels and input-output coefficients allows for a wide-range analysis of the sensitivity of the optimal solution. This is very advantageous in risky situations or situations where we are not too sure of the data.

(ii) Two routines which give sensitivity analysis can be included in the LP solution procedures. These are: -

(a) Range Analysis

This procedure shows the amount of change (either positive or negative) which is possible before the basic solution is changed. It provides an estimate of the range over which the cost or profit coefficients and right-hand sides may vary without changing the optimum solution. It also indicates the income penalty of deviating from the optimum activity level on either the up or the down side and points out the limiting process.

(b) Change if a non-basic activity is included

This shows the change that will take place in the objective function if a particular non-basic activity is included in the solution.

Parametric routines can be used post-optimally (as the range analysis) to carry out such analysis. These will analyse a series of related problems by replacing either the original objective row or a given column or the original right-hand side or a given row, (or several of these simulteneously) by their original values plus a multiple of desired change intervals in the parameter(s) concerned to determine their effect on the optimum solution.

3.10 Advantages and Limitations of Linear Programming

3.10.1 The Advantages

Compared with other simpler farm planning techniques (such as budgeting, programme planning, gross margin analysis, etc) linear programming has a number of advantages.

One of the main advantages of LP technique is that it can be used in analysing complex planning situations in a more comprehensive and practical way by utilizing computers to carry out the computations rather than the planner. And as Barnard & Nix (1973) put it, "... a greater range of

> plans may be encompassed by changing the assumptions in respect of resource availability, prices and input-output coefficients because of the ease with which fresh data can be incorporated and new solutions obtained. This gives a general picture of the lines along which the farm might develop, instead of just a single solution based on present resources and practices."[1]

Thus, LP provides a means of analyzing a variety of alternative decisions. For example, resources such as labour can be analysed realistically by eliminating the weak concept of working with total labour per annum as a resource. Labour can be treated separately in as many periods as desired.

Also, LP does not require a highly skilled worker or technician to do the computations, as is the case with the other methods, because this can be done by computer. The solution obtained is not prone to arithmetical errors although of course it could be prone to many other errors.

In addition to providing an accurate solution, LP, also provides additional information of value in decision making such as shadow prices, limiting processes, unit costs, etc.

For simple problems, LP involves no more work in data collection and preparation than for planning methods like budgeting. However, while derivation of the best production plan through budgeting may require the preparation of a large number of plans, the procedure followed in LP is quite straightforward and systematic.[1] More complex planning problems will require rigorous specification of restraints and input-output data for solution by LP.

3.10.2 The Disadvantages/Limitations

Like any other planning technique, LP is not without some disadvantages or limitations. The main arguments against LP are some of the assumptions it makes. LP, by definition assumes constant input-output ratios, which is often not true in actual farming conditions.

Another assumption which LP makes which is not technically or economically sound is that a farm enterprise (process or activity) is divisible into infinitesimally small units. Practically, one cannot for example, feed a portion of a pig or economically grow 0.05 ha of a certain crop, although the LP solution may indicate these solution values.

Furthermore, factor and product prices are assumed to be known with certainty and not to vary with level of output or quality of product or factor. This also, is not true in general.

A further limitation of LP is that it may be difficult to specify certain restraints because of the requirement to predict the situation several months or years ahead. For example, it may not be easy to predict the supply of hired labour during the peak periods when certain farm operations have to be performed. And the farm manager may be uncertain as to how much credit can be secured from his creditors.

Unavailability of well tested routines and computers especially in developing countries, is another limitation which may hinder successful application of LP. With large complex LP problems, an electronic computer is essential. However, with the present advance in technology which has lead to manufacture of cheap but very sophisticated micro-computers, inavailability of computers will be a thing of the past in a few years to come, even in developing countries.

3.11 LP Farm Planning Studies

A large number of studies have been done which illustrate the application of linear programming technique to farm planning. However, most have been the application of LP to individual peasant farms in which farmers generally operate fewer activities requiring less resources than large scale corporate farms. Nevertheless, the application of linear programming technique to individual peasant farms is in principle not much different from its application to Corporate farms except in scale, complexity and the treatment of certain restraints as will be discussed in a later part of this section.

Barnard and Smith (1959)[6] studied the application of linear programming to 'resource allocation on an East Anglian Dairy Farm'. They showed how a problem concerned with maximizing the net revenue of a farm in the short-run can be formulated and a model constructed. Using the LP model they were able to show that there was considerable scope for economic expansion on farms by better allocation of resources among already existing opportunities. In formulating the problem, they assumed that the resources available to the farmer were those currently committed on the farm. Further, no changes were permitted from existing practices and levels of yield and only those opportunities about which it was reasonable to suppose the farmer had the necessary knowledge and skills were included in the model. They noted that although the study showed the gain resulting from better use of current opportunities, it did not in any way mean there were no other advantages to be had from improved techniques. They noted further that although the farm under study was a representative of many others, it did not suggest that the optimum programme could be applied to them without modification, but that the value of the solution lay mainly in its indication of certain principles that could be capable of application to similar farms. In addition they noted that the increase in net income did not result from any one change, but was the sum effect of a number of changes together.

McFarquhar (1960) formulated a similar problem but also involving flexibility in seasonal labour inputs. The summary of his study was as follows: -

1. "Alternative farm plans show the increased returns to be expected from more detailed consideration of seasonal labour problems.
2. This involves an illustration of the fact that linear programming methods can be used to specify the actual amount of labour to be used in each month per unit of the activity, given other practical limitations. This is a partial answer to the critism of the technique that the linear programme must assume fixed monthly labour coefficients.
3. Allowance is made for the effect of seasonal

uncertainty about time when jobs might have to be carried out in any year.

4. The practical value of linear programming as a technique which could be used forthwith for planning individual farms is discussed. Comparison is drawn with an alternative method such as programme planning which is likely to be severely limited in practice because of the burden of arithmetic involved. Where conscientious consideration of a planning problem does not involve much time spent in arithmetic calculation, techniques based on gross margins or partial budgeting are satisfactory and appropriate in practice.
5. It is argued that the case that linear programming is too costly to use in practice is not proven. No real estimates of cost appear to have been made. On the contrary, tentative estimates presented here suggest that the advantage lies with linear programming which may give better use of skilled resources as well as better farm plans than methods now in use."[7]

In another study using linear programming Simpson (1960) showed that it 'can be used within the context of a fairly complex farm situation to indicate ways to considerably increase profits through better use of the available resources. This increase was achieved without any improvement in technical performance.'[8] However, with regard to the use of LP on the individual farm Simpson concluded that 'the use of linear programming solely to improve profits is likely to be the exception rather than the rule'. This, he says, is because activity data is difficult to prepare: that coefficients (the input-output coefficients) must be relevant to the particular farm - but few farms can supply these details. He stated further that, 'the future of linear programming as regards farm management would seem, therefore, to be firstly as a research method rather than in application to individual farms.'

In objection to this, McFarquhar (1960) stated that, "This seems to be unduly pessimistic and the reverse of Simpson's view may well be the more accurate one to take". Certainly this would be the more appropriate case with corporate farms because they are supposedly more organized and hence data for planning can more readily be derived from the specific farms being planned rather than using group average data.

Regarding the question of which technique gives the best results, McFarquhar (1960) stated that, "it can hardly be contested that LP will always give the better technical results from any given data. Other methods of planning such as programme planning are academically interesting but their practical use is likely to be limited...."[9]

In their earlier work McFarquhar & Evans (1957), noted that, "one of the greatest disadvantages of LP as applied in farm planning is that the technique is much more refined than the data to which it is likely to be applied at present."[9] Again, in corporate farms this may not be as serious a problem as would be with peasant farms where farmers can hardly provide most of the needed information accurately.

In a linear programming model of peasant farmer behaviour, LOW (1974) noted that in developing countries,

> "Villagers have no real interest in making a cash income out of farming.... They are cultivators because that is the way to live and that is the way their fathers lived. They are much involved in village affairs and take the social demands of traditional village life seriously. They sell any surplus of production that may occur in a good year, and indeed, as a precaution, they may normally aim to produce slightly more than their subsistence needs, so that in a bad year they will not starve. But they do not view their farming as a source of income and they are not anxious to expand production."[10]

By contrast, corporate farms endeavour to produce at a profit in order to survive in business over an extended period and thus making linear programming a more appropriate planning tool for them.

A model slightly similar to the one in this study is that of McCarl, et al (1977) known as the 'Purdue Top Farmer Cropping Model B'. This model was designed for large commercial farms for cropping activities only. As with the model in this study, the model did not explicitly consider price, yield, or weather risk. An added, feature of this model was that crop planting and harvesting dates were incorporated into the activity definition in order to assure that yield and moisture content of the crop were consistent with the planting and harvesting dates. Other important features of this model relating to individual farm applications are the input form and output reports. Given that Purdue did not want to spend analyst time on each and every run of the model, the input and output was designed to be understandable by the farmer. A specific input and output format was developed which asked questions and reported answers in a form which the farmer could understand.[11] Also, resources were given realistic minimum productivity so that they conformed with the farmer preferences - (that resources are not to be used until they are exhausted or their marginal contribution is zero). Although restraints such as these would have been appropriate to include in the model in this study, they have not because of the difficulty of determining a realistic minimum productivity of resources.

In the next chapter a detailed description of the farm under study will be given and a linear programming model for the farm will be developed following the basic theory described in this chapter. The type of model developed will only be an example but one which can easily be applied to most other NAFCO farms.

CHAPTER FOUR

CHAPTER FOUR

4. THE LP MODEL FORMULATION

4.1 Introduction

In the previous chapter, theoretical and practical aspects of the linear programming technique were discussed. In this chapter the general features of a typical representative farm of NAFCO will be described and development of a linear programming model for the farm and the derivation of the various matrix coefficients for the model will be discussed.

The LP problem as formulated in this study is designed to create a static equilibrium cropping and livestock plan. The LP solution represents the maximum profit plan which can either be repeated year after year (if the resource availability and the input-output coefficients remains unchanged) or can be reviewed annually.

4.2 The Farm Under Study

4.2.1 General Features

The representative farm-chosen for study is called NAFCO Ruvu Rice Farm and is typical of many other NAFCO farms in Tanzania. The farm is situated in Bagamoyo District, Coast Region, some 80 kms west of Dar-es-Salaam, at 38^{O} 40' East longitude and 6^{O}45' South latitude. The farm covers an area of nearly 4000 ha, of which about 3000 ha is arable land, 500 ha is permanent grassland suitable for grazing and the rest is bushland with very low fertility. The arable land can be sub-divided into three distinct classes based on soil types as shown in section 4.2.3.

4.2.2 Climate

(i) Rainfall: According to the farm records from 1968-1977, the annual mean rainfall is 1063 mm concentrating on 104 days. The major rainy season is from March to May, with 12-19 rainy days per month and consisting of 48% of the annual rainfall.

The minor rainy season is from mid October to mid December, with 5-10 rainy days per month and consisting of 25% of the annual rainfall. The dry season, totalling 6-7 months occurs from January to February and from June to mid October with 3-6 rainy days per month and consisting of 27% of the annual rainfall.

(ii) Temperature: According to the 1968-1977 farm records, the mean annual temperature is 26.8^{o}C, with the maximum monthly temperature of 31.2^{o}C (March) and the minimum monthly temperature of 23.9^{o}C (August). The absolute maximum temperature is 39^{o}C, and the absolute minimum temperature is 12^{o}C.

(iii) Evaporation: Farm records show that the annual evaporation is 2278.5mm, the maximum being 2434.6mm in 1970 and the minimum 2046.2 mm in 1972. The maximum monthly evaporation is 232.8mm in January; and the minimum monthly evaporation is 138.8 mm in May.

(iv) Relative Humidity: Seven year records show that the average annual relative humidity is 79.2% with a maximum in September to December.

(v) Wind: The records of Kurasini station in Dar-es-Salaam indicate that low wind velocity prevails all year round. The north-east wind prevails mostly from November to March and south easterlies from April to August.

The above meteorological data show that the abundant rainfall and adequate heat suit the growth of crops all year round. However, the uneven distribution of rain and the long dry season require irrigation for the growth of water loving or long maturing crops. The data also give an indication of possible enterprises which can be carried out on the farm and how the scheduling of the field operations can be designed to suit the climate and other prevailing conditions.

4.2.3 Soils

The soils of the farm can be classified as follows: -

1. Ordinary meadow (mainly clay-loam): This type of soil spreads over the valley close to the river bank, covering an area of about 1450 ha. The clay profile shows that the subsoil is not well stratified. The cultivated land of the farm is mainly of this type.

   The flat topography of the valley meadow favours mechanized farming. With the high humus content, the high fertility of the top soil layer and its high water holding capacity suit the growth of paddy rice and other crops. But the poor water penetration and poor aeration of the clay easily provoke drought. For this reason about 1000 ha of this area is supplied with irrigation facilities for paddy rice.

2. Gray lime loam: This type of soil covers an area of about 1500 ha of sloping land (gradient of about 1/300). The soil contains a considerable amount of colloid particles, loosened while getting wet and hardened while drying up, making a considerable portion of this unsuitable for growth of crops if no irrigation facilities are available. About 900 ha is croppable land, about 500 ha has flourishing grass and serve as grazing pasture, and the rest is unsuitable for any use.

3. Sandy-loam and loamy laterite: This type of soil covers an area of about 1050 ha of hilly area (gradient of about 1/120). About 650 ha of this is croppable land which mainly suits the growth of fruit trees and deep-rooted crops. Poor water and fertility retaining capacity of the soil requires water and soil conservation measures for raising soil fertility. The remaining area is waste bushland.

4.2.4 Past Production Pattern

In accordance with the "agreement" and "Notes of Talks" regarding the government's objectives in establishing the farm in 1965, paddy rice is and will remain, the main crop.

Other major crops and livestock enterprises conducted on the farm are shown in Table 4.1 giving the production pattern during the season 1976/77.

Table 4.1: Ruvu Rice Farm: 1976/77 Production Pattern

Activity	Area or Numbers
Rice	860 ha
Maize	80 ha
Sorghum	80 ha
Cashewnut	36 ha
Poultry	6600 layers
Piggery	50 sows
Dairy cattle	110 cows

Seed maize has also been occasionally grown on contract for the Tanzania Seed Company. However, this requires more labour and capital than food maize because the crop requires more attention in various operations to produce the required quality of seeds.

Crop yields differ depending on land type. For this reason, each of the crops which can be grown on more than one soil type are treated as different activities in the model.

Pig-keeping is rather restricted both by limited accomodation and reliable markets, but up to 100 sows can be housed, each capable of farrowing twice per year. Porkers are sold at an average dressed weight of 50 kgs at shs 11 per kilo.

There is a poultry unit with 6600 layers in battery cages and up to 3000 more birds could be raised (with the same results) in a deep-litter system utilizing available empty houses. Also in 1976/77 there was a herd of 110 dairy cattle of which about 70 were lactating.

The farm has 115 regular men employed and casual labour can be employed, except that during peak seasons there is often a scarcity of such labour.

4.3 Construction of the Model

4.3.1 Features of the LP Model

The model is essentially a static single period linear programming model except that monthly cashflows of income are explicitly included.

4.3.2 Structure of the Model

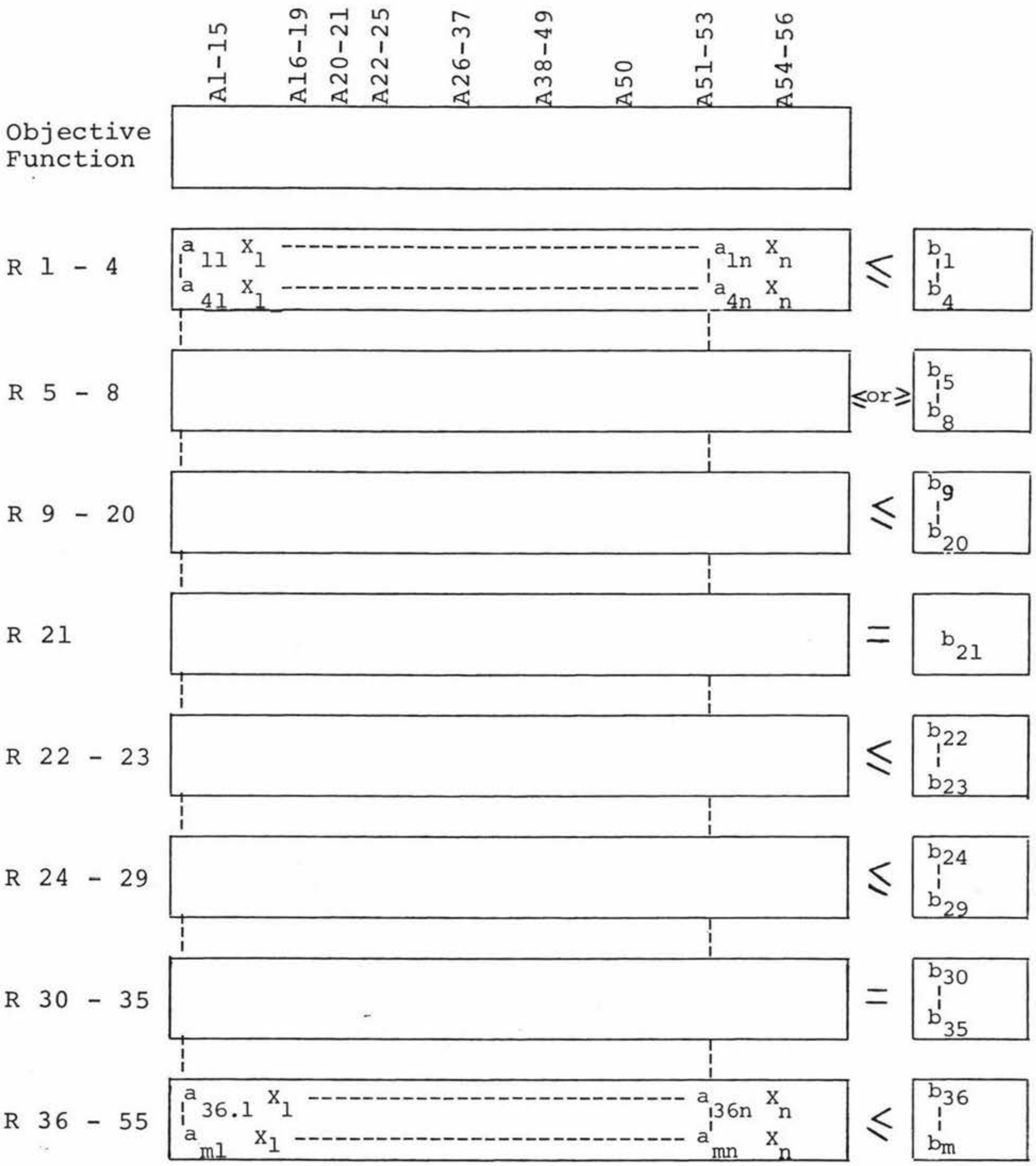
The general structure of the LP model is shown in schematic form in Figure 4.1. The model consists of 9 major sets of activities: -

(a) Cropping activities (A1-15)
(b) Livestock rearing activities (A16-19)
(c) Livestock buying activities (A20-21)
(d) Livestock selling activities (A22-25)
(e) Capital transfer activities (A26-37)
(f) Capital borrowing activities (A38-49)
(g) Capital inventory activity (A50)
(h) Tractor borrowing activities (A51-53)
(i) Permanent labour transfer activities (A54-56)

Figure 4.1 also shows that the model consists of 8 major groups of constraints: -

(a) Land constraints (R1-4)
(b) Minimum and maximum constraints on various activities (R5-8)
(c) Financial/capital constraints (R9-20)
(d) Accounting constraint (R21)
(e) Poultry building and feed constraints (R22-23)
(f) Livestock transfer constraints (R24-29)
(g) Labour constraints (R30-35)
(h) Field-machinery time constraints (R36-55)

A pictorial matrix of the model is presented on pages 44-47 Figure 4.2 and the symbols used in this figure are explained on pages 49-53.



Where: A = Activities/column numbers (1 to n). n = 56
R = resources/row numbers (1 to m). m = 55

a_{mn} = specifies the input-output coefficient in column n row m.

X_n = the activity level in column n.

Thus a_{mn} X_n = the matrix coefficient for the activity in column n row m.

b_m = the amount of resource available in row m.

≤ = ≥ equal to or less than; equal to; and greater than or equal to respectively.

<u>Figure 4.1</u>: <u>SCHEMATIC STRUCTURE OF THE LP MODEL</u>

FIGURE 4.2: A PICTORIAL REPRESENTATION OF THE LP MATRIX

Row	TYPE	RICE	RCEH	RCDP	MZE1	MZE2	MZES	SRG1	SRG2	SRG3	CSH1	CSH2	CSH3	LEY1	LEY2	LEY3	POU	PIG	DAIR	REPC	BUYS	BUYC	SLBC	SLHC	SLCC	SLCS	CPT1	CPT2	CPT3	CPT4	CPT5	CPT6	CPT7	CPT8	CPT9	CPT10	CPT11	CPT12	BCP1	BCP2	BCP3	RANGE	SCALE	
SCALE																																												
UPPER BOUND																																							F	F	F			
LOWER BOUND																																												
GRMA	N																																											GRMA
LAF1	L	1	1	1	1			1			1			1																														LAF1
LAF2	L					1	1		1			1			1																													LAF2
LAF3	L									1			1			1																												LAF3
GRSL	L													-1	-1	-1			A	A																								GRSL
MINR	G	1	1	1																																								MINR
MINCW	G											1																																MINCW
MAXS	L																	1																										MAXS
MINC	G																		1																									MINC
JACP	L	C	C	-C	B	B	B	C	C	C				B	R	B	-B	C	-C	B					-B		1												-1					JACP
FECP	L	-B	C	C	C	C	C	C	C	C				B	B	B	-A	C	-C	B					-B		-1	1											A	-1				FECP
MACP	L	B	C	-B	C	C	C	C	C	C				B	B	B	-A	C	-C	B					-B			-1	1											A	-1			MACP
APCP	L	C	C	C	C	C	C	B	B	B				B	B	B	-A	C	-C	B					-C				-1	1											A			APCP
MYCP	L	C	C	C	B	B	C	A	A	A				B	B	B	-A	-D	-C	B					-B					-1	1													MYCP
JNCP	L	B	B	B	B	B	B	C	C	C	A	A	A	B	B	B	-A	-D	-C	B					-B						-1	1												JNCP
JYCP	L	-C	-C	B	C	C	C	B	B	B	B	B	B	B	B	B	A	C	-B	B	C				-B	-C						-1	1											JYCP
AUCP	L	-C	-C	-C	C	C	C	-C	-C	-C	B	B	B	B	B	B	-A	C	-A	C			-B	-B	-B								-1	1										AUCP
SECP	L	-C	-C	-C	-D	-D	C	-D	-D	-D	B	B	B	B	B	B	-A	C	-A	C			-B	-B	-B									-1	1									SECP
UCCP	L	-C	-C	-C	-D	-D	-D				B	B	B	B	B	B	-A	C	-B	B		D			-B										-1	1								UCCP
NUCP	L	-C	-C	-C			-D				-C	-C	-C	B	B	B	-A	-D	-C	B		C			-B											-1	1							NUCP
DECP	L	-C	-C	-C	B	B	B				B	B	B	B	B	B	-A	-D	-C	B	C				-C	-C											-1	1						DECP
ACTR	E																																					-1						ACTR
PUUB	L																1																											PUUB
PUUF	L																B																											PUUF
LPDJ	L	A	B	B	A	A	B	A	A	A	A	A	A				1	B	B	B																								LPDJ
LPFM	L	B	B	B	B	B	B	B	B	B	A	A	A	A	A	A	1	B	B	B																								LPFM
LPJS	L	B	B	B	A	A	B	A	A	A	A	A	A	A	A	A	1	B	B	B																								LPJS
LCDJ	L	B	B	B	A	A	A	A	A	A	B	B	B				T	B	B																									LCDJ
LCFM	L	C	C	C	B	B	C	B	B	B	B	B	B	A	A	A	T	B	B																									LCFM
LCJS	L	B	B	B	B	B	C	B	B	B	B	B	B	A	A	A	T	B	B																									LCJS
BUCA	E																		-T				1																					BUCA
HECA	E																		-T	1				1																				HECA
CSTR	E																	-T								1																		CSTR
REPG	E																	T			-1																							REPG
CCTR	E																		-T						1																			CCTR
REPH	E																		T	-1		-1																						REPH

JAD5	L	1	1	T										JAD5
FED5	L	1	1	A										FED5
MAD5	L	T	T	1										MAD5
AUD5	L	T	T	T										AUD5
SED5	L	T	T	T										SED5
OCD5	L		T	T							T	T	T	OCD5
NOD5	L	T	T	T										NOD5
DED5	L	T	T	T										DED5
JASLT	L	A	A	A	A	A	A	A	A	A				JASLT
FESLT	L	A	A	A	A	A	A	A	A	A				FESLT
MASLT	L	T	T	T	A	A	A	A	A	A				MASLT
AUSLT	L	1	1	T	T	T								AUSLT
SESLT	L	A	1	1	T	T	T							SESLT
OCSLT	L	T	T	T			T							OCSLT
NOSLT	L	A	A	T										NOSLT
DESLT	L	A	A	1	A	A	A							DESLT
JNCH	L	T	T											JNCH
JYCH	L	1	T	T										JYCH
AUCH	L	T	T	A										AUCH
SECH	L	T	T	T										SECH

		BCP4	BCP5	BCP6	BCP7	BCP8	BCP9	BCP10	BCP11	BCP12	CPIN	JATB	FETB	MATB	OJPL	FMPL	JSPL	RHS	RANGE	SCALE	
	SCALE																				
UPPER	BOUND	F	F	F	F	F	F	F	F	F		C	C	C							
LOWER	BOUND																				
	TYPE																				
GRMA	N										1										GRMA
LAF1	L																	D			LAF1
LAF2	L																	C			LAF2
LAF3	L																	C			LAF3
GRSL	L																	C			GRSL
MINR	G																	C			MINR
MINCW	G																	B			MINCW
MAXS	L																	B			MAXS
MINC	G																	B			MINC
JACP	L											U									JACP
FECP	L												U								FECP
MACP	L													U							MACP
APCP	L	-1																			APCP
MYCP	L	A	-1																		MYCP
JNCP	L		A	-1																	JNCP
JYCP	L			A	-1																JYCP
AUCP	L				A	-1															AUCP
SECP	L					A	-1														SECP
OCCP	L						A	-1													OCCP
NOCP	L							A	-1												NOCP
DECP	L								A	-1											DECP
ACTR	E									A	1										ACTR
POUB	L																	D			POUB
POUF	L																	F			POUF
LPOJ	L														1			E			LPOJ
LPFM	L															1		E			LPFM
LPJS	L																1	E			LPJS
LCOJ	L														-1			E			LCOJ
LCFM	L															-1		F			LCFM
LCJS	L																-1	E			LCJS
BUCA	E																				BUCA
HECA	E																				HECA
CSTR	E																				CSTR
REPG	E																				REPG
CCTR	E																				CCTR
REPH	E																				REPH

2

JAD5	L				D	JAD5
FED5	L				D	FED5
MAD5	L				C	MAD5
AUD5	L				D	AUD5
SED5	L				D	SED5
OCD5	L				D	UCD5
NOD5	L				D	NOD5
DED5	L				D	DED5
JASLT	L	-1			D	JASLT
FESLT	L		-1		D	FESLT
MASLT	L			-1	D	MASLT
AUSLT	L				D	AUSLT
SESLT	L				D	SESLT
OCSLT	L				D	UCSLT
NOSLT	L				D	NOSLT
DESLT	L				D	DESLT
JNCH	L				C	JNCH
JYCH	L				D	JYCH
AUCH	L				D	AUCH
SECH	L				D	SECH

4.3.3 The Model

(a) The Equations

Subscripts Used

i = 1 ... 56 where i denotes the resource row.
j = 1 ... 56 where j denotes the activity column.
n = 56 which is the number of activity columns.
m = 56 which is the number of resource rows.

Input-Output Coefficients

a_{ij} denotes the technical input-output coefficient which specifies the amount of the i^{th} resource required to produce one unit of j^{th} activity.

Revenue Coefficients

Cj denotes the net revenue (gross margin shown implicitly in the cashflow) of the j^{th} activity.

Constraints

b_i which denotes the amount of the i^{th} resource available or just an accounting identity for the i^{th} resource.

Activities

X_j denotes the level of the j^{th} farming activity.

The Objective Function

Maximize Z = the net farm income given as the total gross margins of all the activities in the optimal solution (plan).

The objective function equation then becomes:

(1) Maximize $Z = \sum_{j=1}^{n} C_j X_j$ For j = 1,2,....,n.

Subject to:

(2) $\sum_{j=1}^{n} a_{ij} X_j \leqslant b_i$ For i = 1,2,...,m. and j = 1,2,...,n.

and:

(3) $X_j \geqslant 0$ for j = 1,2,....,n

(b) Explanation of Symbols Used in Figure 4.2

1. Objective function:

GRMA = Gross margin

2. The Activities in the Model are Defined as follows:

RICE = Rice growing activity on land type one. Activity unit is 1 ha.

RCEH = Rice growing activity (extended harvesting). Activity unit is 1 ha.

RCDP = Rice growing activity (delayed planting). Activity unit is 1 ha.

MZE1 = Maize growing activity on land type one. Activity unit is 1 ha.

MZE2 = Maize growing activity on land type two. Activity unit is 1 ha.

MZES = Seed maize growing activity on land type two. Activity unit is 1 ha.

SRG1 = Sorghum growing activity on land type one. Activity unit is 1 ha.

SRG2 = Sorghum growing activity on land type two. Activity unit is 1 ha.

SRG3 = Sorghum growing activity on land type three. Activity unit is 1 ha.

CSH1 = Cashewnut growing activity on land type one. Activity unit is 1 ha.

CSH2 = Cashewnut growing activity on land type two. Activity unit is 1 ha.

CSH3 = Cashewnut growing activity on land type three. Activity unit is 1 ha.

LEY1 = Ley (transfer activity) on land type one. The activity unit is 1 ha.

LEY 2= Ley (transfer activity) on land type two. The activity unit is 1 ha.

LEY3 = Ley (transfer activity) on land type three. The activity unit is 1 ha.

POU = Poultry (layer raising activity). The activity unit is one laying bird.

PIG = Piggery (porker raising activity). The activity unit is one sow together with two litters each of 6 porkers, per annum.

DAIR = Dairy cow production activity. The activity unit is one cow.

REPC = A heifer growing and breeding activity for replacement of cull cows. The activity unit is one heifer.

BUYS = A replacement gilt buying activity. The activity unit is one gilt.

BUYC = A replacement heifer buying activity. The activity unit is one heifer.

SLBC = A bull calf selling activity. The activity unit is one bull calf - a few days old.

SLHC = A heifer calf selling activity. The activity unit is one heifer calf - a few days old.

SLCC = A cull cow selling activity. The activity unit is one cow.

SLCS = A cull sow selling activity. The activity unit is one sow.

CPT1, CPT2, CPT3, CPT4,
CPT5, CPT6, CPT7, CPT8,
CPT9, CPT10, CPT11, and CPT12 = are activities which transfer capital between months in one production cycle. CPT1 transfers capital from January to February, CPT2 from February to March and so forth.

BCP1, BCP2, BCP3, BCP4,
BCP5, BCP6, BCP7, BCP8,
BCP9, BCP10, BCP11, BCP12 = are capital borrowing activities for each month from January to December respectively. In all the activities each unit borrowed represents Tz sh 1.00 for a period of one month.

CPIN = is an activity to accumulate capital at the end of the planning cycle. The activity unit is Tz. sh 1.00.

JATB = is a January tractor 'borrowing' activity. Tractors can be borrowed from other Corporation farms free of charge. The activity unit is one hour (of field machinery time).

FETB = is a February tractor 'borrowing' activity. Tractors can be borrowed from other Corporation farms free of charge. The activity unit is one hour (of field machinery time).

MATB = is a March tractor 'borrowing' activity. Tractors can be borrowed from other Corporation farms free of charge. The activity unit is one hour (of field machinery time).

DJPL, FMPL, JSPL = are permanent labour transfer activities. The activity unit is one man-hour.

3. <u>The Restraints in the Model are Defined as Follows:</u>

LAF1 = Land type one restraint. The RHS column unit is one hectare.

LAF2 = Land type two restraint. The RHS column unit is one hectare.

LAF3 = Land type three restraint. The RHS column unit is one hectare.

GRSL = Grassland (pastureland) restraint. The RHS column unit is one hectare.

MINR = Minimum restraint on rice. The RHS column unit is one hectare.

MINCW = Minimum restraint on cashewnut. The RHS column unit is one hectare.

MAXS = Maximum restraint on the number of sows. The RHS column unit is one sow.

MINC = Minimum restraint on the number of dairy cows. The RHS column unit is one cow.

JACP = is the January capital restraint. The RHS column unit represents Tz.sh 1.00.

FECP = is the February capital restraint. The RHS column unit represents Tz.sh 1.00 etc up to December (DECP).

ACTR = is an equality restraint which transfers accumulated capital at the end of the planning cycle (1 year) to a capital inventory activity. The transfer unit is Tz. sh 1.00.

POUB = Poultry building capacity restraint. The RHS column unit represents one laying bird.

POUF = Poultry feed restraint. The RHS column unit represents one kilogram.

LPOJ, LPFM and LPJS = are permanent labour restraints. LPOJ restraints permanent labour during the period October to January, LPFM restrains permanent labour during the period February to May, LPJS restrains permanent labour during the period June to September. For all the restraints, each unit in the RHS column represents one man-hour.

BUCA = is a bull-calf transfer row. The transfer unit is one bull-calf a few days old.

HECA = is a heifer-calf transfer row. The transfer unit is one heifer-calf a few days old.

CSTR = is a cull-sow transfer row. The transfer unit is one sow.

REPG = is a replacement gilt transfer row. The transfer unit is one gilt.

CCTR = is a cull-cow transfer row. The transfer unit is one cow.

REPH = is a replacement heifer transfer row. The transfer unit is one heifer.

JAD5 = a restraint on suitable crawler tractor field-time, January.

FED5 = a restraint on suitable crawler tractor field-time, February.

MAD5 = a restraint on suitable crawler tractor field-time, March.

AUD5 = a restraint on suitable crawler tractor field-time, August.

SED5 = a restraint on suitable crawler tractor field-time, September.

OCD5 = a restraint on suitable crawler tractor field-time, October.

NOD5 = a restraint on suitable crawler tractor field-time, November.

DED5 = a restraint on suitable crawler tractor field-time, December.

For all the crawler tractor field-time restraints above, the RHS column unit is hours.

JASLT = a restraint on suitable tractor (60-100hp) field-time, January.

FESLT = a restraint on suitable tractor (60-100hp) field-time, February.

MASLT = a restraint on suitable tractor (60-100hp) field-time, March.

AUSLT = a restraint on suitable tractor (60-100hp) field-time August.

SESLT = a restraint on suitable tractor (60-100hp) field-time, September.

OCSLT = a restraint on suitable tractor (60-100hp) field-time, October.

NOSLT = a restraint on suitable tractor (60-100hp) field-time, November.

DESLT = a restraint on suitable tractor (60-100hp) field-time, December.

For all the tractor (60-100hp) field-time restraints above, the RHS column unit is hours.

JNCH = a restraint on suitable combine harvester field-time, June. The RHS column unit is hours.

JYCH = a restraint on suitable combine harvester field-time, July. The RHS column unit is hours.

AUCH = a restraint on suitable combine harvester field-Time, August. The RHS column unit is hours.

SECH = a restraint on suitable combine harvester field-time, September. The RHS column unit is hours.

UP BND =forms a series of bounds on capital borrowing activities which have the effect of restraining each borrowing activity to Tz. shs. 125,000/-.

= Also supplies the bounds on the tractor 'borrowing' activities which has the effect of restraining the borrowing activities to 998, 828 and 915 hours during January, February and March respectively.

4.3.4 The Constraints

As mentioned in section 4.3.2 the major constraints included in the model may be grouped as follows: -

(i) Land constraints
(ii) Minimum and maximum constraints
(iii) Financial constraints
(iv) Accounting constraints
(v) Poultry building and feed constraints
(vi) Labour constraints
(vii) Field machinery constraints

(i) The land constraints (LAF1, LAF2, LAF3 and GRSL).

Four land rows based on land type,constrain land utilization to no more than the area available in each land type.

The farm has an area of nearly 4000 ha out of which about 3000 ha is arable land, 500 ha is permanent grassland suitable for grazing and the rest is occupied by buildings, roads and useless bushland.

The 3000 ha croppable land can be subdivided into 3 different land types according to productive capability: -

about 1450 ha are clay-loam (ordinary meadow) with good fertility (designated LAF1 in the model), about 900 ha are gray lime loam with medium fertility (designated LAF2 in the model), and 650 ha are sandy-loam with low fertility (designated LAF3 in the model). About 1000 ha of clay-loam land (LAF1) is supplied with an irrigation system for rice.

The 500 ha of permanent grassland (pasture) (designated GRSL in the model) is suitable for grazing and has a holding capacity of 0.4 and 0.5 (cows and replacement heifers respectively) per hectare.

(ii) Minimum and maximum constraints (MINR, MINCW, MINC, MAXS).

Three minimum constraints were included in the model. One limiting rice crop (MINR) to a minimum of 1000 ha, the second limiting cashewnuts (MINCW) to a minimum of 36 ha, and the third limiting the number of dairy cows (MINC) to a minimum of 30 cows.

The rice crop is constrained at a minimum of 1000 ha in the model because this area is supplied with an irrigation system for rice and it is the Corporation/government policy that this farm should be predominantly a rice farm.

There are 36 ha planted in cashewnuts. This crop is a perennial crop which takes very little effort to look after when fully established. There are no plans to uproot the crop, even if it proves to be uneconomic, therefore a minimum restraint of 36 ha has been incorporated into the model.

The dairy cows are constrained at a minimum of 30 cows because this is the number of cows required to meet the milk demand for the farm workers since there is no other milk source close-by.

One maximum constraint (MAXS) limiting the number of sows to 100 was also included in the model. This is the maximum number of sows which can be housed using the available buildings. Also there is no desire to increase the capacity beyond this level because of lack of reliable markets for the porkers.

(iii) <u>The financial constraints (JACP, FECP, ..., DECP)</u>

The model shows a 12 monthly cash profile - which is important for farm planning. Twelve financial constraints (one for each month) were set up to facilitate cash flow accounting in each month. Each constraint limits total expenditure to no more than the cash generated during that month and that brought forward from the previous months plus a maximum bank overdraft of shs 125,000 at any one time. The model is capable of carrying forward the excess capital in one period (month) to the next.

The concern is with working capital rather than fixed capital and hence the cash flow shown is the difference between sales and working capital (equal to variable costs in this case) during the period .

(iv) <u>The accounting constraint (ACTR)</u>

The LP model used a 'non-computational' constraint (ACTR) to transfer the accumulated capital to a common pool at the end of the planning period so as to determine the aggregate gross profit of the farm in a full production cycle.

(v) <u>Poultry building and feed constraints (POUB, POUF)</u>

Availability of livestock buildings is an important factor in limiting the number and type of stock which can be kept. On the farm under study it appears these would not permit an increase of layer numbers above 9600. Also because of frequent shortage of poulty feeds which even at times leads to rationing, it has been estimated that only about 180,000 kgs of poultry feeds could be available to the farm per year.

Therefore, one building constraint (POUB) and one feed constraint (POUF) were included in the model to constrain the numbers of layers to 9600 and 9000 respectively. The inclusion of the building constraint may appear superfluous but this has been included intentionally in order to have a more realistic constraint in the model to constrain POU activity when carrying out sensitivity analysis on the effect of feed supply variation on the optimum plan. The poultry feed supply is known to vary widely from one year to another.

(vi) Labour constraints (LPOJ, LPFM, LPJS, LCOJ, LCFM, LCJS)

Two sets of labour constraints were included in the formulation of the model. The sets are: -

(a) permanent labour (staff employed on permanent basis) (LPOJ, LPFM and LPJS), and
(b) casual labour (employed as and when required) (LCOJ, LCFM and LCJS).

The planning period (year) was divided into 3 periods to reflect the major farm operations and seasonal labour availability: These periods together with the operations falling within them are listed below: -

Period	Principal Operations
October - January	2nd ploughing, harrowing, levelling, rice milling.
February - May	Levelling, planting; insecticide, fertilizer and herbicide application, irrigation, drainage and bird control.
June - September	Drainage, harvesting, 1st ploughing, rice winnowing, drying and milling.

Note: Work on cattle, pigs and poultry occurs in all periods and rice milling goes on all the time except in the months April, May and June when milling machine repairs and maintenance are carried out.

Since labour in each period is divided into permanent and casual labour, the number of labour constraints is therefore six.

The various periods have been subdivided to correspond as far as possible with the periods during which certain operations are undertaken and the availability of labour is reasonably even during the period.

Although there are periods when work on crops is relatively slack, these periods have not been ignored. During such periods there are other essential activities which require labour and it is thought that labour availability in such periods could likely be an effective restriction because it is at such times people in the area are busy with their own farms.

Labour availability has been based on the permanent labour which was employed by the farm during 1976/77 season and the average possible available casual labour (based on three years) for each of the major farm operation seasons.

The farm has 115 permanent employees working 40 hours per week each for 48 weeks a year. It is estimated that only 85% of the total working time available is effective. The remaining 15% covers sick leave non-allocatable jobs and other eventualities which may reduce the working time.

The available casual labour force has been estimated from the monthly average number of people registered as seeking temporary work at the farm during the period 1974/75 to 1976/77 seasons.

The computation of casual and permanent labour availability is shown in Appendix D1.

(vi) The livestock transfer activities (BUCA, HECA, CSTR, REPG, CCTR and REPH)

Bull calf and heifer calf transfer constraints were included in the model. The calving rate is estimated at 40% bull calves and 40% heifer calves. The BUCA constraint transfers the bull calves to the bull calf selling activity (SLBC) and the HECA constraint transfers the heifer calves to the heifer calf selling activity (SLHC) and/or to the replacement heifer activity (REPC). Of the 40% of the heifer calves produced the model may transfer 20% from the REPC activity to the replacement heifer transfer constraint (REPH) which in turn transfers 15% of these to the DAIR activity to replace the cows which are culled. The remaining 5% is an allowance for calf mortality. The REPH constraint can also transfer purchased replacement heifers from the BUYC activity to the DAIR activity. The cull cow transfer constraint then transfers 15% of the cows to the cull cow selling activity (SLCC). The 15% cow replacement rate assumes the productive life of a dairy cow to be about 6.6 years on average.

The cull sow transfer constraint (CSTR) transfers the culled sows to the cull sow selling activity (SLCS). It is estimated that the sows are culled every 3 years and therefore the culling rate is 33% per annum.

The replacement gilt transfer constraint (REPG) transfers the purchased replacement gilts from BUYS activity to the PIG activity to replace the sows which are culled.

All six constraints described in this sub-section are equality restraints whose values are determined by the level of DAIR and/or PIG activity level which enters the solution.

(viii) Field machinery constraints (JAD5, ..., DED5; JASLT, ..., DESLT; JNCH, ..., SECH)

The farm has a wide range of field machinery and equipment but only those machines which could be limiting have been included in the model. Three sets of field machinery constraints based on machinery type were included in the model. The machinery types included are: -

(a) Crawler tractors (D5),
(b) Wheel tractors (60-100 hp), and
(c) Combine harvesters for rice.

The farm has 4 crawler tractors, 11 wheel tractors (60-100hp) and 6 combine harvesters. Provision for borrowing (free of charge) up to 3 wheel tractors from other NAFCO farms is also given.

The crawler tractor and wheel tractor constraint sets were each sub-divided into eight monthly constraints, and the combine harvester set was sub-divided into four monthly constraints.

Only the periods with high level of field machinery activity were included in the model. For both the tractor types the periods used to define the field machinery constraints were January, February, March, August, September, October, November and December and for the combine harvester the periods were June, July, August and September. The field-machinery time availability for each of these periods is shown in Appendix E.

4.3.5 The Activities

The model represents production possibilities for rice, maize, sorghum, cashewnuts, ley, poultry (layers), piggery (porkers), dairy cattle and raising of replacement heifers. The production of each of these activities takes place within the yearly availability of resources.

As mentioned in section 4.3.2, the activities included in the LP model can be divided into 9 main categories. They are: -

(i) cropping activities
(ii) livestock activities
(iii) buying activities
(iv) selling activities
(v) capital transfer activities
(vi) capital borrowing activities
(vii) tractor borrowing activities, and
(viii) permanent labour transfer activities
(ix) capital inventory activity

(i) Cropping acitivites

There were five sets of cropping activities each consisting of one crop sub-divided into three distinct activities based either on the schedule of operations or production method of the crop or on the land type on which the crop is grown.

The cropping activities included in the model were as follows: -

(a) Rice activities (RICE, RCEH, RCDP)

Three rice activities which differ from each other by having different schedule of operations (which in turn cause differences in the input-output coefficients) were included in the model. The schedule of operations for the activity RICE (Appendix B1) is the optimum one followed under ordinary conditions. However, because of bad weather and other uncertainties in some years even a tightly defined schedule can be thrown out of gear and/or even in an average year conditions are likely to be such as to prevent the specified task being undertaken. Thus for example, the planting operation may be delayed or the harvesting period may have to be extended. Either of these would cause large variation in the input-output coefficients. For this reason the late planted rice (RCDP) and extended harvested rice (RCEH) have been treated as additional and different rice activities in the model to provide a safeguard against an over-optimistic plan (by forcing these into the plan).

(b) Maize activities (MZE1-2, MZES)

Three maize activities were included in the model. The MZE1 and MZE2 are food maize activities grown on land type one (LAF1) and two (LAF2) respectively, and MZES is a seed maize activity grown on land type two (LAF2). The MZES activity differs from the other maize activities in the production methods used. Seed maize requires additional inputs such as fertilizers and labour (see Appendices A4, A5 and A6). Also about 60% of seed maize yield (i.e. grade A) fetches a higher price than the food maize (see Appendix A6).

(c) Sorghum activities (SRG1-3)

Three sorghum activities were included in the model. Each activity is grown on a different land type. Activities SRG1, SRG2 and SRG3 are grown on land type one, two and three respectively and hence their yields differ from each other (which in turn cause variation in harvesting and packing costs) (see Appendices A7-A9).

(d) Cashewnut activities (CSH1-3)

Three cashewnut activities were included in the model. As for sorghum, each activity is grown on a different land type. Activities CSH1, CSH2 and CSH3 are grown on land type one, two and three respectively and hence differ from each other in yields (which in turn cause variation in harvesting costs).

(e) Ley activities (LEY1, LEY2, LEY3)

In the problem set out, under no circumstances could more than 172 cows and 35 replacement heifers (or 200 cows if replacement heifers are to be purchased) enter the final plan without the ley activities since there are only 500 ha of permanent grassland (pasture) available and each cow and replacement heifer requires 2.5 ha and 2.0 ha of this respectively. The ley activities are introduced as an additional possibility, so that the cattle limit can be raised by using some of the arable land for leys to augment the grazing area.

Three ley activities (LEY1, LEY2 and LEY3) were included in the model. The activities are based on the type of land which may be used for establishing the ley. The activities LEY1, LEY2 and LEY3 can be established on land type one, two and three respectively.

The ley activities in the model have positive values in the monthly cash flow (and hence a negative gross margin) because there is no income from the ley activities as such. The +1 values in the LEY1, LEY2 and LEY3 columns and the arable land rows (LAF1, LAF2, and LAF3 respectively) indicate that one unit of ley requires one hectare of arable land while the -1 values in the permanent grassland row (GRSL) indicate that each unit of ley increases the grass area by one hectare. Ignoring, for the moment, constraints on the minimum areas of various crops, the absolute limit on cattle numbers is no longer 172 cows and 35 replacement heifers (or just 200 cows) but 1206 cows and 242 replacement heifers (or 1,400 cows if replacement heifers are purchased). By putting all the arable land down as ley the total area of grass could be increased in theory to 3,500 ha.

(ii) Livestock activities (POU, PIG, DAIR, REPC)

The model included four livestock activities namely, poultry, piggery, dairy and replacement heifers (raised in the farm) designated POU, PIG, DAIR and REPC respectively.

The coefficients shown for POU, PIG, DAIR and REPC activities have been computed for per unit layer, per unit sow with 12 porkers, per unit cow and per unit replacement heifer respectively.

The rearing of pullets was incorporated in the layer activity and similarly the rearing of sows included raising of porkers. That is the pig activity covered both the breeding sow and the fattening of porkers it produces since there was no adequate data available in which to make realistic separation. Although the variable costs for sows and porkers appear separately in Appendix A15, the separation has been done arbitrarily to indicate the possible cost contribution by each category.

Because of uncertainties due to the nature of livestock production, the choice of livestock activities has in the main been confined to activities representing the systems currently followed on the farm under study. For these activities, the farm records provided an indication of performance in the recent years, which is probably the best basis on which to estimate the level of achievement in the near future.

(iii) Buying activities (BUYS, BUYC)

The model included two livestock buying activities; a replacement gilt buying activity, BUYS, and a replacement heifer buying activity, BUYC. The activity units are one gilt and one replacement heifer respectively.

The replacement heifer buying activity (BUYC) is added as an alternative or supplement to the replacement heifer (REPC) which could be raised on the farm so as to give the model a choice of the most economical way of replacing the cows which are culled. The replacement gilt activity (BUYS) could have been treated the same way, but no alternative to BUYS activity is given because it is the policy of the farm to purchase replacement gilts from outside the farm and keep the same service boars in order to avoid possible inbreeding.

(iv) Selling activities (SLBC, SLHC, SLCC AND SLCS)

The model included four selling activities (SLBC, SLHC, SLCC and SLCS) representing a bull-calf selling activity, a heifer-calf selling activity, a cull cow selling activity and a cull sow selling activity respectively.

All bull calves are sold for veal (or breeding) to interested parties when a few days old at a price of shs. 50 each . It is assumed that the farm incurs no costs on these calves.

About 20% of the heifer calves are kept annually as replacements. The remainder are sold for veal (or breeding) when a few days old at a price of shs. 60 each. An allowance of 5% motality rate for the calves raised for replacement is made and, as such, effectively only 15% of the dairy cows are replaced each year.

Each year, aging or cattle with declining performance are culled and slaughtered for meat in the farm. It is assumed that only 15% of the dairy cattle are culled and that, culls have an average liveweight of 400 kg and a dressing percentage of 50%. The meat is sold at shs. 5/50 per kilogram to farm workers mainly.

Similarly, aging or sows with declining performances are culled and slaughtered on the farm. It is assumed that 33% of the sows are culled and replaced by purchased replacement gilts and that culled sows have an average liveweight of 150 kgs. each and a dressing percentage of 72%. The meat is sold at shs. 7/- per kilogram.

Computation of the revenues obtained from these selling activities are shown in Appendix A18.

(v) Capital transfer activities (CPT1, CPT 2, ..., CPT12)

Included in the model are 12 capital transfer activities (CPT1 - 12) which transfer capital forward between months (January to December) in one production cycle - (see figure 4.2). CPT1 transfers capital from January to

February, CPT2 from February to March and so forth. CPT12 transfers the accumulated capital at the end of the planning cycle to a capital transfer row (ACTR) which then transfers it to a capital inventory activity (CPIN).

The planning process does not begin with any capital in hand except that the farm can obtain a bank overdraft of up to a maximum of shs. 125,000 at any one time. Other revenues are generated from the various production activities of the farm at different stages of the production cycle as shown by the cash flow in the model, Table 4.4. Thus, capital available during the production period each month is estimated within the model.

(vi) <u>Capital borrowing activities (BCP1, BCP2,...,BCP12)</u>

The model included 12 capital borrowing activities, one for each month of the year (BCP1 - 12 representing capital borrowing activities for January, February, ..., in that order, to December respectively). (See figure 4.2)

Each capital borrowing activity of up to shs. 125,000 represents the maximum bank overdraft allowed at any one time and carries a monthly interest of 0.9% (i.e. 10.8% per annum).

(vii) <u>Tractor borrowing activities (JATB, FETB, MATB)</u>

Included in the model are three tractor borrowing activities (JATB FETBand MATB for the months of January, February and March respectively).

These activities allow for borrowing additional tractors from other NAFCO farms, if required. As per Corporation's policy, there is no fee charged by the other NAFCO farms, however, to avoid the model using the borrowed tractors in preference to the farm tractors, a small penalty fee of 7.3 cents per tractor hour (which could represent transportation cost) has been imposed.

The number of tractor hours which can be borrowed in January, February and March are 998, 828 and 915 respectively.

The computation of the tractor hours available for borrowing is shown in Appendix E (v).

(viii) Permanent labour transfer activities (OJPL, FMPL, JSPL)

Three permanent labour transfer activities (OJPL, FMPL and JSPL for the periods October-January, February-May and June-September respectively) are included in the model. The activities OJPL, FMPL and JSPL transfer unutilized permanent labour (LPOJ, LPFM and LPJS respectively) to the casual labour restraints (LCOJ, LCFM and LCJS respectively) when in short supply. Permanent labour can substitute casual labour (when there is need) but not vice versa because permanent labour plays a supervisory role which requires some skill.

(ix) Capital inventory activity (CPIN)

This activity shows the cumulative capital (aggregate gross margin) at the end of the planning period (see section (v) above.

4.3.6 The Basic Data

The basic data for this study were assembled from the records of NAFCO Ruvu Rice Farm by the author during 1977/78 while working on the farm as Acting Manager. Additional information which was required while building the model was obtained from the farm through the mail. Other suitably adjusted information to supplement the input-output data collected on the farm is based on the author's knowledge of the farm operations gained while working at NAFCO Head Office for 2½ years as the scheduled Planning Officer for the farm.

All the yields, prices, revenues and detailed variable costs per unit for each of the various production activities are shown in the computations of the gross margins presented in Appendices A1-A18. Most of the input-output coefficients used in the model have been derived from these appendices.

The data are based on the current methods and techniques of production.

The monthly sales revenue per activity unit for the production activities is shown in Table 4.2 and its derivation is explained in section 4.3.7(b). As mentioned earlier, the monthly revenues are based on a yearly but continuing repetitive production cycle. Sales of products such as eggs, milk and cull cows take place throughout the year, while sales of the other products depend on their harvesting and/or processing periods.

The monthly working capital profile per activity unit for all the production activities is shown in Table 4.3, and its derivation is explained in section 4.3.7(b). The total working capital per activity unit is assumed to be equal to the variable costs needed in the production of one unit of the activity.

The monthly cash flow per activity unit is shown in Table 4.4 and its derivation is explained in section 4.3.7(b).

TABLE 4.2: MONTHLY SALES REVENUE PER ACTIVITY UNIT (Tz shs)

	RICE	RCEH	RCDP	MZE1	2	MZES	SRG 1	2	3	CSH 1	2	3	LEY 1	2	3	POU	PIG	DAIR	REPC	BUYS	BUYC	SLBC	SLHC	SLCC	SLCS
JACPA	900	900	900													24.85		210						85	
FECPA	800	494	800													8.90		210						85	
MACPA	300		494													9.86		245						85	
APCPA																10.33		245						125	
MYCPA																10.67	1500	245						85	
JNCPA																10.33	1800	245						85	
JYCPA	800	600														10.67		175						85	378
AUCPA	900	800	600				600	530	500							9.03		175				25	30	85	
SECPA	900	800	800	1400	1230		1500	1500	1380							8.74		175				25	30	85	
OCCPA	900	900	900	2000	2000	2808										9.03		175						85	
NOCPA	900	900	900			1326				527	517	484				8.74	1500	210						85	
DECPA	800	800	800													9.85	1800	210						125	
TOTAL	7200	6194	6194	3400	3230	4134	2100	2030	1880	528	517	484	-	-	-	131	6600	2520	-	-	-	50	60	1100	756

TABLE 4.3: MONTHLY WORKING CAPITAL PROFILE PER ACTIVITY UNIT (shs)

	RICE	RCEH	RCDP	MZE1	2	MZES	SRG1	2	3	CSH1	2	3	LEY1	2	3	POU	PIG	DAIR	REPC	BUYS	BUYC
JACP	1099	1099	189	73	73	78	113	113	109				10.40	10.75	11.20	5.14	451	104	84		
FECP	701	699	1525	459	459	464	509	509	501				10.40	10.75	11.20	5.18	457	103	82		
MACP	315	313	438	760	760	846	195	195	194				10.40	10.75	11.20	5.25	450	103	82		
APCP	230	230	210	125	125	133	61	61	61				10.40	10.75	11.20	5.20	450	102	82		
MYCP	214	194	230	73	73	174	6	6	6				10.40	10.75	11.20	5.20	450	102	83		
JNCP	90	71	84	20	20	24	248	234	213	5	5	5	10.40	10.75	11.20	5.15	139	102	83		
JYCP	114	90	78	334	318	112	96	92	86	60	60	60	10.40	10.75	11.20	13.46	451	162	98	450	
AUCP	206	204	213	130	128	379	19	19	19	55	55	55	10.40	10.75	11.20	7.63	450	166	101		
SECP	164	224	234	68	68	110				53	52	49	10.40	10.75	11.20	7.44	450	166	101		
OCCP	135	165	190			56				63	62	59	10.40	10.75	11.20	7.54	450	106	86		1500
NOCP	218	219	137							21	21	21	10.40	10.75	11.20	7.68	450	106	84		1000
DECP	578	577	578	70	70	75				21	21	21	10.40	10.75	11.20	7.73	446	104	84	450	
ANNUAL TOTAL	4064	4085	4106	2112	2094	2451	1247	1229	1189	278	276	270	124.80	129	134.40	82.60	5094	1426	1050	900	2500

TABLE 4.4: CASH FLOW PER ACTIVITY UNIT (shs)

	RICE	RCEH	RCDP	MZE1	2	MZES	SRG1	2	3	CSH1	2	3	LEY1	2	3	POU	PIG	DAIR	REPC	BUYS	BUYC	SLBC	SLHC	SLCC	SLCS
JACP	199	199	-711	73	73	78	113	113	109				10.40	10.75	11.20	-19.71	451	-106	84					-85	
FECP	-99	205	725	459	459	464	509	509	501				10.40	10.75	11.20	-3.72	457	-107	82					-85	
MACP	15	313	-56	760	760	846	195	195	194				10.40	10.75	11.20	-4.61	450	-142	82					-85	
APCP	230	230	210	125	125	133	61	61	61				10.40	10.75	11.20	-5.13	450	-143	82					-125	
MYCP	214	194	230	73	73	174	6	6	6				10.40	10.75	11.20	-5.47	-1050	-143	83					-85	
JNCP	90	71	84	20	20	24	248	234	213	5	5	5	10.40	10.75	11.20	-5.18	-1661	-143	83					-85	
JYCP	-686	-510	78	334	318	112	96	92	86	60	60	60	10.40	10.75	11.20	-2.79	451	-13	98	450				-85	-378
AUCP	-694	-596	-387	130	128	379	-581	-511	-481	55	55	55	10.40	10.75	11.20	-1.40	450	-9	101			-25	-30	-85	
SECP	-736	-576	-566	-1332	-1162	110	-1500	-1500	-1380	53	52	49	10.40	10.75	11.20	-1.30	450	-9	101			-25	-30	-85	
OCCP	-765	-735	-710	-2000	-2000	-2752				63	62	59	10.40	10.75	11.20	-1.49	450	-69	86		1500			-85	
NOCP	-682	-681	-763			-1326				-507	-496	-463	10.40	10.75	11.20	-1.06	-1050	-104	84		1000			-85	
DECP	-222	-223	-222	70		75				21	21	21	10.40	10.75	11.20	-2.12	-1354	-106	84	450				-125	-378
GRMA	-3136	-2109	-2088	-1288	-1136	-1683	-853	-801	-691	-250	-241	-214	124.80	129	134.40	-48.40	-1506	-1094	1050	900	2500	-50	-60	-1100	-756

N.B. Positive sign indicates that capital is being used while negative sign indicates that capital is being generated.

The periodic labour availability is shown in Table 4.5 below. Its derivation has been explained in section 4.2.4 (vi) and the computation is shown in Appendex D1.

TABLE 4.5: PERIODIC LABOUR AVAILABILITY

Category	Period	Effective Hours
Casual labour :	October-January	32,640
	February-May	177,888
	June-September	62,560
Permanent labour:	October-January	62,560
	February-May	62,560
	June-September	62,560

The average monthly number of people recorded as seeking temporary work in the farms during the period 1974/75 to 1976/77 (3 years) has been used as an estimate for the available casual labour because of lack of better data which could give a more realistic estimate of the possible available casual labour in the area at any one period.

The periodic labour requirement per production activity unit is shown in Table 4.6 and its computation as derived from Appendices A1-A17 is presented in Appendix D2. The permanent labour and casual labour requirements are subdivided because the former is required mainly for supervisory work which cannot be substituted for by casual labour.

Table 4.7 shows the field-machinery time requirement per activty unit subdivided into requirement per operation. Note that the rice activities require two ploughings and two harrowings each.

Table 4.8 shows the field-machinery time availability and its derivation is shown in Appendix E. The field-machinery time availability is only shown for the months when there is high machinery activity in the farm.

TABLE 4.6: PERIODIC LABOUR REQUIREMENT (HOURS) PER ACTIVITY UNIT

Activity	October - January		February - May		June - September		Total Hours
	Permanent	Casual	Permanent	Casual	Permanent	Casual	
Rice (RICE)	10	23	36	155	14	36	274
Maize (MZE1-2)	8	2	20	72	7	89	198
Seed maize (MZES)	18	6	48	120	15	105	312
Sorghum (SRG1-3)	3	2	28	29	4	80	146
Cashewnut (CSH1-3)	8	32	2	28	4	46	120
Ley (LEY1-3)	-	-	7	5	5	3	20
Poultry (POU)	1	0.2	1	0.5	1	0.3	4
Piggery (PIG)	25	20	15	17	20	27	124
Dairy (DAIR)	16	24	21	19	18	22	120
Replacement heifer (REPC)	15	-	14	-	15	-	44
Rice (with extended harvesting) (RCEH)	12	26	36	155	12	32	273
Rice (with delayed harvesting) (RCDP)	12	27.5	48	167	13	36	303.5

TABLE 4.7: FIELD MACHINERY TIME REQUIREMENT PER ACTIVITY UNIT (Hours)

Activity	Ploughing	Harrowing	Planting	Herbicide Application	Harvesting	Weeding	Other	Total Hours
RICE	5	4	2	1.5	2.5	-	1.2	16.2
RCEH	5	4	2	1.5	2.5	-	1.2	16.2
RCDP	5	4	2	-	2.5	-	1.2	14.7
MZE1	2.5	2	2	1.5	-	-	1.0	9
MZE2	2.5	2	2	1.5	-	-	1.0	9
MZES	2.5	2	2	1.5	-	-	1.0	9
SRG1	2.5	2	2	1.5	-	-	-	8
SRG2	2.5	2	2	1.5	-	-	-	8
SRG3	2.4	1.8	2	1.5	-	-	-	7.7
CSH1	-	-	-	-	-	0.75	-	0.75
CSH2	-	-	-	-	-	0.75	-	0.75
CSH3	-	-	-	-	-	0.75	-	0.75

TABLE 4.8: FIELD MACHINERY TIME AVAILABILITY (HOURS)

	Number	Jan.	Feb.	Mar.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
CRAWLER TRACTORS (D5)	4	1331	1104	915	-	-	1498	1360	1165	1200	1229
TRACTOR (80-100 hp)	3	998	828	686	-	-	1123	1020	874	900	922
TRACTOR (60 - 80 hp)	8	2662	2208	1830	-	-	2995	2720	2330	2400	2458
COMBINE HARVESTER	6	-	-	-	480	1061	1123	1020	-	-	-

4.3.7 Derivation of the Production Coefficients

This section presents an outline of the procedures adopted to derive some of the matrix coefficients from the basic farm data. Because of the large number of coefficients involved it is not possible to cover the derivations of all the input-output coefficients in this account. Only the general procedures followed in the derivation of the following coefficients are explained here: -

(a) Gross margins
(b) Cash flow
(c) Labour availability
(d) Labour requirement
(e) Field-machinery time availability
(f) Field-machinery time requirements

(a) Gross margins (GRMA) derivations

The derivation of the gross margins for the various activities are shown in Appendices A1-A18. The values of the gross margins are not shown explicitly in the model. They are implicitly incorporated in the cash flow (see section 4.3.7 (b) below) and only appear as an accumulated capital inventory activity (CPIN) in the solution.

The general procedure used to calculate the gross margin was to base the gross output on the average yields obtained over the past three years (1974/75-1976/77) (except for rice) and weighted by the current prices to get the gross revenue from which the variable costs calculated at current prices were subtracted. The variable costs have been based on the current methods and techniques of production. It seemed reasonable to base the variable costs of the crop and livestock activities on the existing methods and techniques of production since these have given good results in the past and most of them represent the use of up-to-date techniques.

The gross revenues of the crop and livestock activites were based on average yields in the preceding three years but an exception here was made with regard to rice activities where it seemed that the recent use of herbicides (instead of hand weeding as in the past) was giving yields above those obtained in earlier years and hence rice yield for 1977 is used.

The fixed costs have not been allocated to specific activities as their magnitude will not by definition be related directly with either the particular combination of activities chosen or the levels at which such activities are carried on.

(b) Cash flow derivation

The cash flow coefficients shown in Table 4.4 have been derived by subtracting the per unit monthly variable costs shown in Table 4.3 from the corresponding per unit monthly sales revenue shown in Table 4.2. The sign designated to the coefficient shows whether the activity uses or generates capital. A positive sign shows that the activity uses more capital than it generates and a negative sign shows that the activity generates more capital than it uses during the month in question.

Table 4.3 showing the monthly variable costs profile (or working capital profile) has been derived by allocating the variable costs sown in Appendices A1-A17 proportionately to various months based on the scheduling of the various operations (Appendix B) for each activity. Since it would mean presenting a large number of tables to show how the breakdown of the variable costs was carried out, only three examples are presented here. They are for the three rice activities (RICE, RCEH and RCDP) and these are presented in Appendices C1, C2 and C3 respectively.

The monthly sales revenue per activity unit shown in Table 4.2 has been derived by allocating the gross revenue per activity unit (the computations of which are shown for the various production activities in Appendices A1-A18) to the various months basing on the time of sale of the products assuming a continuing but repetitive production cycle. The proportion of the quantity of each product sold in any particular month was subjectively judged based partly or wholly on the trend of sales of the product during the previous years and partly or wholly on the scheduling of some operations (such as harvesting, milling etc).

Exceptions in the cash flow profile are the capital coefficients of the ley activities which in strict economic terms do not represent a cash flow. The coefficients shown in the model for the ley activities in the capital rows are the amortized values of the ley establishment costs per hectare plus the expected additional annual costs divided equally over the twelve month period.

The amortized values are calculated (see Appendix A13) using the formula shown below: -

$$\text{Amortized value, } A = \frac{\left[P\ i(1 + i)^n\right]}{\left[(1 + i)^n - 1\right]}$$

Where: Annuity A whose Present Value (P) is 1 for a term of n years at a compound rate of interest i per year.

In accordance with the matching concept 1) in accounting, this seems to be the most logical way of treating the ley investment in the model. The problem here is that the model under-estimates the capital requirement during the first year. If lots of ley would come into the equilibrium solution then additional overdraft facilities would be needed. However, this being a capital investment item, additional funds required for it can easily be obtained by arranging a loan from the local banks.

(c) Labour availability derivation

The derivation of the labour availability is explained in section 4.3.4 (vi) and its computation is shown in Appendix D1.

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1) The matching concept states that, "to the extent feasible, costs are reported as expenses in the period in which the associated revenue is reported."[12]

(d) Labour requirement derivation

The computations of the labour requirement per activity unit are shown in Appendix D2. These are also shown as variable costs in Appendices A1-A17. In computing the labour requirement for the cropping activities, it was estimated that one manday was equal to six effective man-hours (or 85% of the working hours), and the number of mandays required per activity unit were based on the previous performance records of the farm.

For the livestock activities the labour requirement was based on the number of people currently employed for a specified number of activity units for a specified length of time. For example, it requires one person working eight hours per day to look after 1000 layer chicks from day old to laying stage (180 days) and one person working seven hours per day to look after 1000 laying birds (one layer house) for 365 days (culling stage). Thus, one layer requires a total of four manhours from day old to culling stage (see Appendix D2 for the computation).

The derivation of the periodic labour requirement per activity unit shown in Table 4.6 is based on the scheduling of the various operations (Appendix B) for each activity and is subdivided into permanent and casual labour depending on how many people are required per operation from each category.

(e) Field-machinery time availability derivation

The computation of the field-machinery time availability is shown in Appendix E. The field-machinery time availability is given by the equation: -

$$T = (D \times P \times M \times H) \text{ hours}$$

Where T is machinery time available
D is the number of work days in the period
P is the proportion of days suitable for field work
M is the number of machineries available (e.g. tractors, combine harvesters, etc)

H is the maximum number of hours each day that the machinery can be expected to be in the field.

(f) Field-machinery time requirement derivation

The field-machinery time requirement per activity unit are shown in Table 4.7. The machinery-time requirement per activity unit per operation and the machinery type used are obtained from the past farm records. The proportion of the total time needed per activity unit and per machinery type during each of the months indicated is based on the type of operation and the proportion of the operation which can be completed during the period. For example for the sorghum activity (SRG1) the field-machinery time requirements per activity unit (1ha) at various periods was derived as shown in Table 4.9 below.

TABLE 4.9: FIELD-MACHINERY TIME REQUIREMENT DERIVATION FOR THE ACTIVITY SRG1 (PER HA)

Operation→ Period and tractor types* ↓	Ploughing (hours)	Harrowing (hours)	Planting (hours)	Herbicide Application (hours)	Total hours per machinery per month
January (80-100 hp)	0.5	-	-	-	0.5
February (80-100 hp)	0.5	0.4	-	-	0.9
March (80-100 hp)	-	-	2.0	-	2.0
January (60-80 hp)	1.5	-	-	-	1.5
February (60-80 hp)	-	1.6	-	-	1.6
March (60-80 hp)	-	-	-	1.5	1.5
Total hours per operation	2.5	2.0	2.0	1.5	8.0

* The time requirement for (80-100 hp) tractor and (60-80 hp) tractor are combined in the model for each period.

CHAPTER FIVE

CHAPTER FIVE

5. DATA ANALYSIS, RESULTS AND DISCUSSION

In the previous chapter a detailed description of the formulation of the LP model for NAFCO Ruvu Rice Farm was presented. In this chapter the method used in analyzing the model and the results of the model will be presented. A detailed interpretation of the results - their effects and implications will be discussed. Also a comparison of the optimum plan with the existing farm organization will be made. However, before dealing with the results and their interpretations, an account of the deficiencies of the model will be given in order to give the reader an indication of what the results might lack.

The chapter will therefore be divided into three main sections. The first will deal with the method of analysis. The second will deal with the deficiencies/limitations of the model as formulated in this study. Then the third section will deal with the interpretation of the optimum solution given by the model and will make comparisons with the existing system. This will include discussions of the effects and/or implications of the results of the model on the actual farming system in existence.

No attempt will be made to draw general conclusions in this chapter. This will be done in the last chapter (chapter seven) which will give a summary of the results as a whole.

5.1 Method of Analysis

The model was analyzed at Massey University Computer Centre using TEMPO Mathematical Programming System (B6700MCP): System/MCP 20 June 79.

"TEMPO is a mathematical programming system which offers the latest advances in computing techniques for linear programming and its extensions. It consists of a basic system and four optimal sub-systems..... The complete system is referred to as TEMPO/ALL (B6700 TEM). Each system constitutes a separate software product of the

Burroughs Corporation with the qualification that none of the four options functions correctly unless it is used with the basic system TEMPO/BASIC."[13]

5.2 Delimitations of the Model

Although as far as possible actual data from the farm were used in formulating the coefficients of the model these did not represent very realistic performances of future periods because they are averages of past performances which do not take into account possible technological improvements.

The LP model does not explicitly consider price, yield or weather risks and uncertainties. However, prices and yields for the more significant activities are tested by sensitivity analysis, and implicitly, the model takes into account weather risk to the extent that the resources or operations in which weather variability is a problem, such as field labour or field-machinery time availability are based on available time estimated by the percentage of days suitable for field work during the period concerned. Weather risks and uncertainties have not been incorporated explicitly in the model because this would complicate the model and jeopardize the whole aim of searching for a good but simple enough model which NAFCO staff can use as a planning tool for the farm and can easily be applied to other NAFCO farms. The method through which risks have been implicitly incorporated into the model (e.g. see section 4.3.7(e)) is more practical and easier to apply to NAFCO farms than using methods such as those which have been suggested by Freund (14), Hildreth (15), Zusman and Amiad (16), Merrill (17), Odero-Ogwel (18), among others. For example, Freund (14) accomplished the introduction of risk into an economic model of a firm and consequently into a linear programming model by describing risky outcomes as probability distributions and then choosing from among alternate possible distributions by the expected utility hypothesis. Zusman and Amiad (16) showed how optimal organization and managerial policies of a farm operating under conditions of low and unstable rainfall can be determined by simulation of the decision process. This was accomplished by evaluating the performance characteristics of various decision rules by simulating the farm over a set of sampled sequences of years with weather events constituting the main stochastic input. Optimal decision rules were defined in terms of the present value and the coefficient of variation of the income flows and were approximated by experimental variation of their parameters. A partial factorial design was first developed in order to determine the main features of the response surface. The optimum solution was approached by the steepest ascent procedure.[16] These procedures and the others mentioned above would be difficult to apply in NAFCO farms due to lack of adequate skills.

The model in this study is a single year model which excludes investment and does allow for within-year adaptive management. Prices and yields used are assumed fixed throughout the year (planning period).

Furthermore, the model does account for the cost of the permanent labour which remains unutilized in the equilibrium solution even though this is paid. But since this is actually a fixed cost it would not affect the gross margins of the activities and hence the solution obtained except for the bank overdraft requirement. Even then, this would be during the first year of the plan only because surplus capital would be available in the subsequent years.

5.3 Results of the Model

In this section the results of the model will be presented, discussed and compared with the actual situation existing. A detailed discussion of the sensitivity analysis results will be given in the next chapter.

5.3.1 The Optimum Solution

The optimum farm plan maximizing gross margins within the limits of the stated restrictions and choice of activities and comparable details of the existing system, are set out in Table 5.1 below: -

TABLE 5.1: THE OPTIMUM SOLUTION (PLAN I)

Activity	Level of Activity	
	Optimum Plan (Plan I)	Actual (1976/77)
RICE (rice)	1054 ha	860 ha
MZE1 (maize)	-	80 ha
CSH2 (cashewnuts)	36 ha	36 ha
SRG1 (sorghum)	-	80 ha
LEY1 (ley)	396 ha	-
LEY2 (ley)	124 ha	-
POU (poultry)	9000 layers	6600 layers
PIG (piggery)	100 sows	50 sows
DAIR (dairy)	352 cows	110 cows
REPC (reared replacement heifers)	70 heifers	19 heifers
BUYS (purchased replacement gilts)	33 gilts	12 gilts
BUYC (purchased replacement heifers)	-	31 heifers
SLBC (bull calves for sale)	141 calves	23 calves
SLHC (heifer " " ")	70 "	8 "
SLCC (cull cows for sale)	53 cows	11 cows
SLCS (cull sows " ")	33 sows	9 sows
"Standard Gross Margin"=	4,208,826 shs	3,304.280 shs.

Additional gain over 1976/77= shs 904,546

The details of the actual figures for 1976/77 are given as a comparison.

The main interest of the proposed plan is on its effect on the farm profit. To be able to measure and compare the results of the actual profits with those of the proposed plan, the figures must be made comparable. A simple comparison of the computed profit from the optimum solution with that actually revealed in the accounts during that period would be misleading owing to differences between prices and yields actually realized and those used as the basis for planning. In order to get a figure which would be comparable, the unit gross margins used in the planning model are applied to the actual activity levels attained during 1976/77 to give an aggregated total which has been referred to as the "standard gross margin". Fixed costs could be deducted from this to give a standard profit but since the fixed costs by definition will not vary, the difference between the standard gross margin of activities during 1976/77 and that of the optimum plan, in itself gives an accurate indication of the anticipated increase in profit. The 'standard gross margin' for the optimum plan is shs 4,208,826 and that of the actual plan during 76/78 is shs 3,304,280. Thus there is an additional gain of shs. 904,546. Before giving any further comparison of the optimum plan with the existing system, a detailed analysis of the optimal plan will be presented.

The results given by the optimal solution are as follows: -

(a) Cropping activities in the basis

The optimum solution (Plan I) shown in Table 5.1 shows that by allocating optimally the resources available to the farm subject to the given restraints only four of the 15 cropping activities in the model would enter the optimum solution. The target crop of the farm, RICE, entered the optimum plan at 1054 ha, which is slightly above the minimum level allowed for in the model. The cashewnut activity (CSH2) entered the solution at 36 ha. In actual fact the CSH2 activity was forced into the solution by the minimum restraint, MINCW, - for reducing the level of the activity by one hectare would increase the aggregate gross margin of the optimum solution by shs. 179.71. Thus had it not been due to the minimum cashewnut constraint, the activity CSH2 would not have entered the optimum solution. The other two activities which entered the solution are the ley activities on land type I and II. LEY1 activity entered the optimum solution at 396 ha and LEY2 activity entered it at 124 ha. These would therefore increase the pastureland by 520 ha hence allowing more cattle to be kept.

These results show that under the optimum plan, the rice crop would still be the major crop. This is in line with the policy of the Corporation that rice production should be the principal activity of Ruvu Rice Farm. Actually if the capital availability in May and the casual labour in February-May could be increased, the aggregate gross margin of the optimum solution would increase by shs 408.18 per every hectare increase (see Table 5.2) up to a maximum of 1061 ha. However, increasing the rice acreage by one hectare without relaxing the constraints would reduce the aggregate gross margin by the same amount. Similarly, reducing the acreage of rice in the optimum plan by one hectare (to a minimum of 1024 ha) would reduce the aggregate gross margin of the plan by shs 933.63 which is quite a substantial amount.

The CSH2 activity has been forced into the plan because 36 ha of the crop have already been established and cashewnut being a perennial crop which takes very little effort to look after when fully established, the farm has no plans to uproot the crop. Since land type II on which the crop is grown has not demand for any other use, the crop can be left unattended. Some crop could still be harvested from it and it would act as a wind-breaker for the farm. The only problem is that the crop could harbour diseases!

As for the RICE activity, the LEY1 activity is also at its optimal level, hence increasing or decreasing its activity would reduce the total gross margin. As Table 5.2 shows, forcing another unit of LEY1 activity in would be costly (i.e. would reduce the total GM by shs 999.81), but forcing LEY2 in would only cost shs -5.58. So any change upwards in the livestock prices or yields may increase the level of this activity in the optimum plan.

TABLE 5.2: THE PROFIT PER UNIT INCREASE OR DECREASE AND THE ACTUAL GROSS MARGIN (GM) FOR THE ACTIVITIES IN THE BASIS* (shs)

Activity	Gm	Per Unit Increase	Per Unit Decrease
RICE	3136	- 408.18	- 933.63
CSH2	241	- 179.71	- INFINITY
LEY1	- 10.40	- 999.81	- 5.62
LEY2	- 10.75	- 5.58	- 7.28
POU	48.40	- INFINITY**	- 58.85
PIG	1506	- INFINITY	- 372.44
DAIR	1094	- 553.22	- 304.77
REPC	-1050	-2766.09	- 159.50
BUYS	- 900	- INFINITY	-1128.61
SLBC	50	-1383	- 761
SLHC	60	- 201.72	-1923.3
SLCC	1100	-3688	-2032
SLCS	756	- INFINITY	-1128.61
BCP1	- 0.009	- 0.016	- 1.38
BCP4	- 0.009	- 0.016	- 0.29
BCP5	- 0.009	0.78	- 0.78
OJPL	0	0	- 12.28
FMPL	0	- 4.68	- 14.06

* Capital transfer activities are not included in the table.

** What the term INFINITY means in this table is that the activity with positive or negative infinity profit coefficient is either at its maximum or minimum level allowed for in the model and thus profit above or below these activity levels respectively would not be valid.

The 'per unit increase' column or the 'per unit decrease' column above indicates the change in the total gross margin per unit increase or decrease respectively in the activity.

(b) Non-basic cropping activities

For the cropping activities and others which did not enter the optimum plan, their shadow prices (or reduced costs) as given by the computer printout in the optimal solution are shown in Table 5.3. The activities are valued relative to the other activities in the optimal plan. Forcing one unit of any of them into the plan would reduce the total gross margin of the plan by the amount shown in the table.

As Table 5.3 shows, forcing one hectare of seed maize (MZES) activity into the solution would cause a larger reduction of the aggregate gross margin of the optimum plan than any other cropping activity. This is probably because of its higher labour requirements than any of the other non-basic activities. Forcing one hectare of this activity into the plan would reduce the aggregate gross margin by shs 2042.

The ley activity, LEY3, would cause the least reduction on the aggregate gross margin (compared to the other cropping activities) if it were forced into the plan. Forcing one hectare of this activity into the plan would reduce the aggregate gross margin by only shs 7.00. This is so even though the activity uses more capital than this and generates no direct revenue. However, the increase would allow more cattle to be reared and there would be no competition for land type III with any other activity.

Except for the LEY3 activity, the reduced costs of all the other cropping activities which did not enter the optimum solution are fairly high. Given that the reduced costs are high, the optimum solution appears very stable. Small changes in prices of the cropping activities will not make the non-basic activities come into the basis.

TABLE 5.3: THE ACTIVITY SHADOW PRICES (REDUCED COSTS) FOR ACTIVITIES NOT IN THE OPTIMAL PLAN

Activity	Shadow Price* (Reduced Cost) (shs)
RCEH	-1498
RCDP	-1239
MZE1	-1213
MZE2	-1359
MZES	-2042
SRG1	- 669
SRG2	- 715
SRG3	- 814
CSH1	- 176
CSH3	- 207
LEY3	- 7
BUYC	- 178
CPT1	- 0.016
CPT4	- 0.016
CPT5	- 0.79
BCP2	- 0.016
BCP3	- 0.016
BCP6-12 @	- 0.009
JATB	- 0.132
FETB	- 0.132
MATB	- 0.132

* These values indicate the amount by which the objective function value (total gross margin) will be decreased if the activity level was increased by one unit. These values are valued relative to the activities within the model.

(c) Livestock activities in the basis

With regard to the livestock activities which were included in the model only the purchase of the replacement heifer (BUYC) activity did not enter the optimum solution. Those in the optimum solution include poultry (POU), piggery (PIG), dairy (DAIR), rearing of replacement heifers (REPC), purchasing of replacement gilts (BUYS), and sale of: bull calves (SLBC), heifer calves (SLHC), cull cows (SLCC) and cull sows (SLCS). The optimum number of each of these production activities are shown in Table 5.1. They include: - 9000 layers, 100 sows, 352 cows, 70 replacement heifers (reared), 33 replacement gilts (purchased) and sale of: 141 bull calves, 70 heifer calves, 53 cull cows and 33 cull sows.

The optimum solution also shows that if it had not been for the constraints, the level of livestock activities would have been much higher. The poultry (POU) activity is constrained by the quantity of the feeds available. The poultry feeds in Tanzania are supplied by the National Milling Corporation but the availability of these feeds is always uncertain. Because the poultry feed constraint (POUF) has a relatively high marginal value product of shs 2.94 (see Table 5.5) - (that is, each additional kilogram of the poultry feed would increase the aggregate gross margin of the optimum plan by shs 2.94), and since the poultry buildings available have a capacity of 600 layers more than the number which entered the optimum plan, efforts should be made in the farm to make its own additional feeds so that at least the maximum possible number of layers can be reared.

The piggery activity (PIG) and the related activities (BUYS and SLCS) are constrained by the maximum sow constraint which is imposed due to limitation of housing facilities and lack of reliable markets for porkers. Because of lack of reliable markets for porkers it would not be feasible to provide more piggery facilities until such time as reliable markets are established. However, the number of sows reared should be maintained at the maximum level because as Table 5.2 shows, decreasing the number of sows by one would reduce the aggregate gross margin by shs 372.44 - which is quite a substantial reduction.

The dairy activity (DAIR) is constrained by the available borrowed capital (BCP5) during the month of May. This in turn constrains all the other dairy related activities (i.e. REPC, SLBC, SLHC and SLCC) whose numbers are dependent on the level of the DAIR activity. As Table 5.2 indicates, forcing one more cow into the solution (up to a maximum of 420 cows) would reduce the aggregate gross margin of the optimum plan by shs 553.22. Also reducing the number of cows below the optimum number by one unit (up to a minimum of 342 cows) would reduce the aggregate gross margin of the plan by shs 304.77. However, if the capital constraint, BCP5 could be released, then increasing the number of cows would also increase the farm profits. Nevertheless, because of the risks involved (especially with animal disease incidences in the area), it is unlikely the management of the farm would accept to rear more dairy cows than the level indicated by the optimum solution. If this would be the case, then BCP5 would not be treated as a serious constraint for the dairy and dairy related activities.

(d) Resource demand

Table 5.4 shows the resource use levels and the slack activities in the optimum plan. (Only the real resources are indicated). The results reveal that most of the resources available to the farm are underutilized but also there are a few which are highly limiting. The resource demand for the optimum plan is as follows: -

(1) Land

With regard to the croppable land, only land type I (LAF1) is fully utilized under the optimum plan. As Table 5.2 indicates, each additional hectare of this type of land made available over and above the existing 1450 ha would add shs 5.62 to the aggregate gross margin. That is the marginal value products of land type I is shs 5.62 which, in other words indicates the amount the farm would be willing to pay in annual rent to get one more hectare of this type of land. The range over which the MVP would be valid is shown in Figure 5.1 below: -

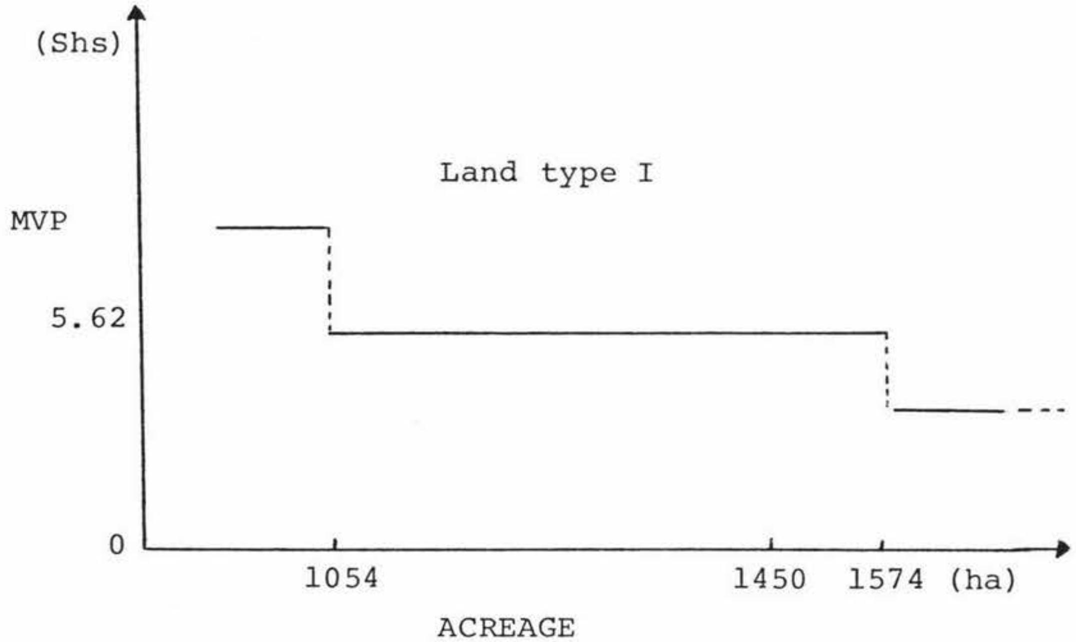

FIGURE 5.1: MARGINAL VALUE PRODUCT (MVP) RANGE FOR LAND TYPE I

The range (520 ha) over which the marginal value product is valid is quite wide. However, considering the magnitude of the change on the aggregate gross margin, it is doubtful whether it would be a worthwhile effort expanding land type I above the currently available land.

For land type II (LAF2) only 160 ha entered the optimum solution, leaving 740 ha unutilized. Using one more hectare of this land (up to a maximum of 559) would cause the aggregate gross margin of the optimum plan to drop by shs 5.58, while using one hectare less (up to a minimum of 36 ha) would cause the aggregate gross margin to drop by shs 7.28. Therefore, only by exploring alternative uses (other than those included in the model) can the slack land type II be usefully utilized.

TABLE 5.4: RESOURCE USE LEVELS AND SLACK ACTIVITIES

Resource	Units	Resource Use Level	Slack Activity[1)]
LAF1	ha	1450	0
LAF2	"	160	740
LAF3	"	0	650
GRSL	"	500	0
POUB	layers	9000	600
POUF	kgs	180000	0
LPOJ	hours	33945	28615
LPFM	"	62560	0
LPJS	"	35891	26669
LCDJ	"	32640	0
LCFM	"	177888	0
LCJS	"	54274	8286
JADS	"	1054	277
FED5	"	1054	50
MAD5	"	211	704
AUD5	"	633	865
SED5	"	843	517
OCD5	"	27	1138
NOD5	"	633	567
DED5	"	843	386
JASLT	"	1689	1973
FESLT	"	1581	1455
MASLT	"	527	1989
AUSLT	"	1054	3064
SESLT	"	1160	2580
OCSLT	"	422	2782
NOSLT	"	1472	1824
DESLT	"	1265	2115
JNCH	"	316	164
JYCH	"	1054	7
AUCH	"	949	174
SECH	"	316	704

1) The slack activity represents the difference between the resource available and the activity level of resource use in the solution.

TABLE 5.5: MARGINAL VALUE PRODUCT (MVP) OF THE EFFECTIVE RESOURCES (shs)

Resource	MVP or dual activity
LAF1	5.62
GRSL	340.75
MINCW	-179.71
MAXS	372.44
JACP	1.82
FECP	1.81
MACP	1.81
APCP	1.81
MYCP	1.79
POUF	2.94
LPFM	14.02
LCFM	14.02

NOTE:

These values (given in the solution print as 'dual activity') indicate the implied value of each of the resources. The unit of each of the resources is valued with respect to the opportunities available within the model; they are not valued at an arbitrary external market value. Therefore, in strict economic terms each of these values is the 'marginal value product' of the resource associated with the best plan. Thus, each represents the amount by which the total gross margin of the optimal plan will be increased or reduced if the supply of the limiting resource is increased or reduced respectively by one unit.

None of the 650 ha of land type III (LAF3) is utilized in the optimum plan. Using any of this land (up to a maximum of 125 ha) would reduce the aggregate gross margin of the plan by shs. 7.22 per hectare. However, in practice some of this land can be used for supplementary grazing during the rainy season, but because this is not always the case it was not included in the model.

All the 500 ha of the pasture grassland (GRSL) would be fully utilized for grazing. As Table 5.5 shows, a high marginal value product is indicated for this land. Thus increasing the grassland area by one hectare would increase the aggregate gross margin of the optimum plan by shs 340.75. This value is relevant up to a maximum of 591 ha of pasture. Decreasing the pasture area by one hectare would also decrease the optimum plan profits by shs 340.75. This value would be relevant up to a minimum of 134 ha of pasture.

396 ha of land type I (LAF1) are used for ley (LEY1). Increasing LEY1 activity by one hectare to provide additional grazing for dairy cattle would reduce farm gross margin by shs. 999.81, since the area sown to rice would be reduced by this area. The shadow prices of the leys are based in part on the assumption that the dairy cows (DAIR activity) and the replacement heifers (REPC activity) graze on leys on the arable land.

(2) Capital

With regard to the capital constraint (as will be seen in Table 5.5), only the January, February, March, April and May capital constraints (JACP, FECP, MACP, APCP and MYCP respectively) seem to be effective restrictions in the optimum plan. Thus it would be worthwhile to be able to borrow more capital in these early months.

From June to December increasing the capital availability does not change the aggregate gross margin of the optimum plan because enough capital to meet the working capital requirement during this period is generated from sales of the farm products. The cumulative profile for the farm is shown in Figure 5.2 below.

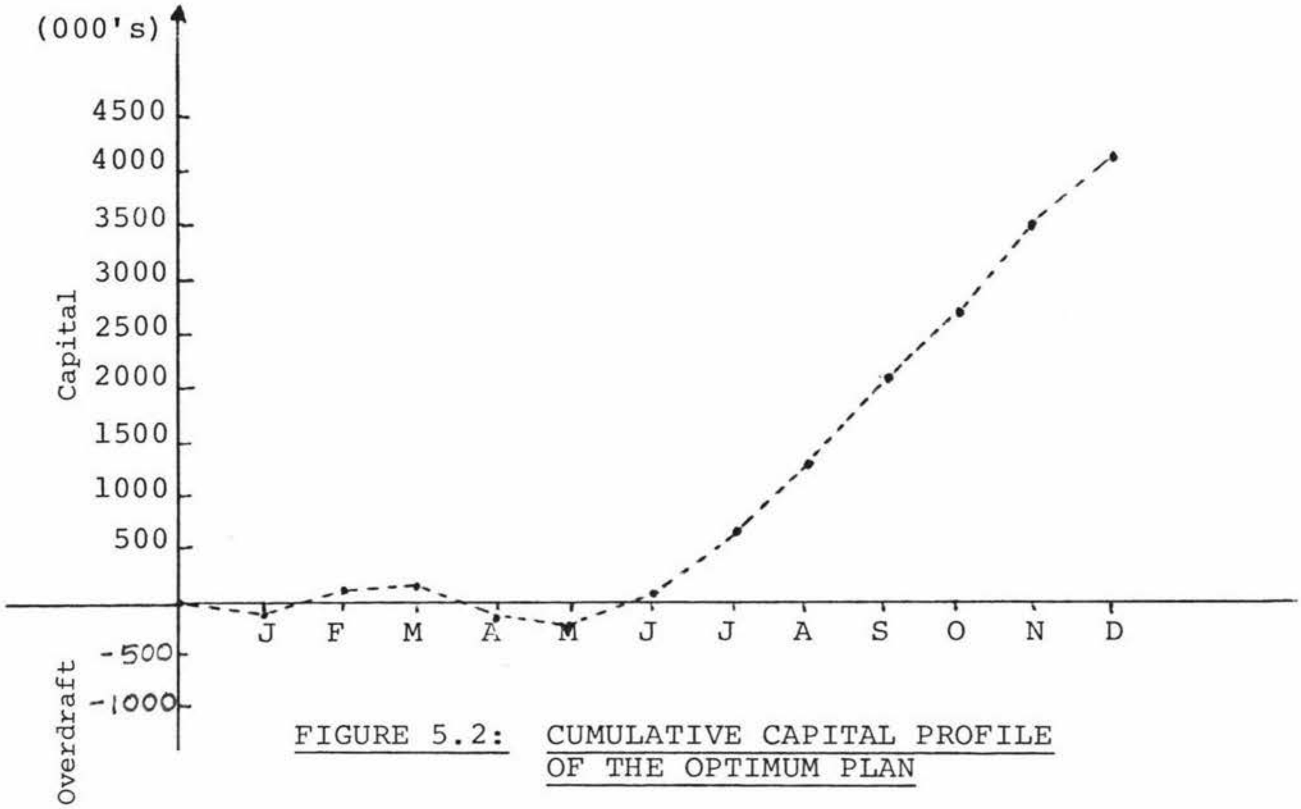

FIGURE 5.2: CUMULATIVE CAPITAL PROFILE OF THE OPTIMUM PLAN

As portrayed in Figure 5.2, the optimum plan would require a bank overdraft of shs. 47,109 during the month of January, shs 96,235 during the month of April and shs 125,000 during the month of May in order to satisfy the working capital requirement during these periods. Capital is more limiting during the month of May and the maximum bank overdraft allowed for (at any one period) is fully used.

Increasing the borrowed capital (BCP5) in May by sh. 1.00 (up to a maximum of shs. 136,631) would increase the aggregate gross margin of the optimum plan by shs 0.78, while decreasing the borrowed capital by sh. 1.00 (up to a minimum of shs. 76,588) would decrease the aggregate gross margin by sh. 0.78. Reduction of the borrowed capital below the required level would be more 'critical' during the subsequent months (see Table 5.2).

3. Labour

As Table 5.4 shows, quite a substantial amount of the permanent labour for the period October-January (LPOJ) and June-September (LPJS), and casual labour for the period June-September (LCJS), remains unutilized in the optimum plan. Also if the permanent labour available during the period February-May (LPFM) had not been transferred to supplement the February-May casual labour (LCFM), which is in short supply, a substantial amount of this would have been left unutilized. This clearly indicates an over employment of permanent labour in this farm. Since this labour has to be paid even when it remains idle or under-utilized, it causes substantial reduction in the net farm profits. This calls for a drastic cut down of the number of the permanent staff currently employed by the farm. Whenever possible the farm should use more casual labour which can be employed as and when required. The reason why a substantial amount of the permanent labour remains unutilized is because most of the farm operations are seasonal and thus leaves much of the permanent labour fairly idle during certain periods of the year.

As Tables 5.4 and 5.5 show, the only two effective labour restrictions in the optimum plan are the February-May permanent labour (LPFM) and the February-May casual labour (LCFM). However, as mentioned before, it is not the permanent labour (LPFM) that is in short supply. It is just casual labour (LCFM) that is in short supply. The permanent labour appears as though it is in short supply because surplus has been transferred to casual labour row in an effort to meet this shortage in the availability of this resource. Even then, the excess February-May permanent labour is not sufficient to satisfy labour demand during the February-May period. Each of the LPFM and LCFM constraints have a marginal value product of shs. 14.02. Thus increasing (up to a maximum of 179,783 hours) or decreasing (up to a minimum of 169,965 hours) either of them by one manhour would increase or decrease respectively the agggegate gross margin of the optimum plan by shs. 14.02. This compares very favourably with the 'hire' rate which is shs 1.56 per hour.

4. Field machinery

The results in Table 5.4 show that for the seasons shown and under the conditions assumed, the field-machinery time is not fully utilized in any of the period defined. However, most of the field machinery available to the farm is fairly old and since machinery breakdown was not taken into account in the calculation of the available field-machinery time (due to lack of data) and also since during some of the periods very little slack field-machinery time is left, it can safely be accepted that the spare capacity will help in periods of breakdown. The numbers of the various machines can therefore be considered not in excess of requirement.

In order to utilize farm machinery more efficiently and to reduce machinery operating costs (which are currently very high) the farm will have to replace the present old models with new models. By doing this the farm will also be able to reduce the number of machines to the optimum level required.

A comparison of the optimum plan with the existing production pattern (1976/77 figures) of the farm will be discussed in the next sub-section. However, it should be noted that the optimum plan obtained using the model formulated in this study does not necessarily represent the highest aggregate gross margin (profit) which could be attained subject to the restrictions operative on this farm. Higher profits could be obtained by including a wider choice of alternatives which have never been tried on this farm before but are known to be fairly profitable. For example, breeding and raising broilers could be included if appropriate data was available. Also the farm could mix its own livestock feed requirement by utilizing rice by-products (mainly rice bran). It would only need to buy mineral mixtures, bone meal, fish meal and other minor ingredients which may be required. In this way the cost of livestock feeds (which accounts for the major part of the variable costs for the livestock activities) could be reduced substantially. Production could also increase because more balanced feeds than available in the market could be made.

5.3.2 Comparison of the Existing System with the Optimum Plan

The calculated increase in the aggregate gross margin obtained with the optimum plan (Plan I) over the 1976/77 plan amounted to shs. 904,546 (or 27.4%). However, part of the increased gross margin can be credited to the expansion of the livestock activities and some gain from increasing the total area cropped by 34 ha. The increased levels of activities contributes shs. 535,222 to the standard gross margin, thus leaving additional profit of shs. 369,324 (or 11.2%) which can mainly be attributed to the reallocation of the resources available to the farm. This represents quite a substantial addition to the profits.

The most marked differences between the existing system and the optimum solution given by the model are the absence of the maize and sorghum activities and also the exclusion of the replacement heifer-buying activity (BUYC) from the plan. Other changes proposed include the establishment of 396 ha of LEY1 activity on land type I (LAF1) and 124 ha of LEY2 activity on land type II (LAF2). Also the acreage of RICE activity is increased from 860 ha to 1054 ha and the activity levels of all of the existing livestock activities are increased except as mentioned above, the BUYC activity which is not included in the optimum plan. The piggery (PIG) activity enters the solution at its maximum level of 100 sows and the cashewnuts (CSH2) activity remains at its existing (minimum) level of 36 ha.

Since the resource availability estimates used in the model are very nearly the same as those actually available during the period 1976/77 and since higher levels of the activities can be produced using the same amounts of resources, this indicates that the resources available have been underutilized. This is especially the case with the permanent labour which even at the increased level of activities is not fully utilized as can be seen in Table 5.4 Under the existing system only 1556 ha of the land (including pastureland) are under useful utilization, while under the optimum plan, about 2110 ha of land would be utilized (this includes pastureland and ley activities). However, even under the optimum plan, over 1400 ha of the croppable land with lower fertility than LAF1 (mainly part of LAF2 activity and all of LAF3 activity) would be left unutilized.

Although the changes proposed in the optimum plan seem far-reaching they do not in fact, call for any very radical shifts in resource use. For example, in the case of land, only 160 ha of land type I which was under maize and sorghum has been turned for other uses. Expansion of the cropping activities has mainly utilized the idle croppable land.

The use of linear programming to allocate the resources available to the farm shows that there can be little doubt that the optimum plan obtained represents a substantial improvement on the existing system.

Furthermore, as mentioned in section 4.3.6, the data used in the model is based on the current methods and techniques of production used on the farm. Nevertheless, even though the existing production system for most of the activities represents up to date production techniques, there is still room for improving them further and thus improve the current yields realized and subsequently increase the farm net profits. Such measures would include improving the levelling of the irrigation fields, optimum use of fertilizers and herbicides, use of improved crop varieties and livestock breeds, etc.

The only notable problem with the optimum plan reached is that it cannot be implemented within one planning season because the ley activities (LEY1 and LEY2) have to be fully established (and this takes more than a year) before the number of cattle can be increased. Therefore, it will take time before the optimum plan can become fully operative if it is accepted for implementation. A gradual change from the existing system to the optimum plan would thus be required.

Furthermore, the optimal plan would be slightly more risky than the current plan with regard to the dairy activity. This is because of frequent outbreaks of livestock diseases in the area due to, and spread by, the ever untreated cattle belonging to the neighbouring local people. Investing too heavily in dairy activity would mean a lot of risk. Also if there was drought it would be difficult to get enough feed for the cattle. However, with good planning, enough feed can always be stored for emergency purposes during the following year and thus reduce the risk involved.

Disregarding the problems mentioned above (which can always be tackled to some degree), the likelihood of the current production moving closer to the optimal plan would be very high. The plan is feasible and practical because it does not involve very drastic changes in the resource use nor does it require resources other than those available or obtainable.

The current plan has been followed rather than the optimum plan (Plan I) for a variety of reasons. First, the most important reason is that the planning methods which have been used (mainly ad-hoc methods and budget analysis) have not been able to allocate the resources as optimally as the linear programming technique used in this study. Secondly, some activities like sorghum and maize have always been included in order to merely use the excess available resources such as land, labour and machinery. Rice crop has been included at a level it was thought convenient and because it is the policy of the Corporation that rice shall be the target activity of the farm. Even then the optimum level of the rice crop has never been attained. In order to achieve the maximum profits possible the farm will have to change its planning strategies, and use a more systematic planning tool like linear programming which has proved useful in this case study.

CHAPTER SIX

CHAPTER SIX

6. SENSITIVITY ANALYSIS RESULTS

Tests were made on the stability of the optimum plan with regard to changes in the various key parameters used in the model. The effects and implications of these changes will be discussed in detail in this chapter.

6.1 Effect of Increasing LCFM or BCP5 CONSTRAINTS

Table 6.1 shows the effect of increasing the available casual labour in the period February-May by 10% and the effect of increasing the maximum capital which can be borrowed in May by 20%.

(i) February-May Casual Labour (LCFM)

As shown in Table 6.1 increasing the available casual labour during the period February-May by 10% would change the initial optimum plan attained quite remarkably. The remarkable changes included in the new optimum plan (Plan II) would be the inclusion of 2 ha of MZE1 activity and 387 ha of CSH1 activity (both of which did not appear in Plan I) and exclusion of LEY1 activity from the plan. The land type I given up by LEY1 activity is taken up in Plan II by the MZE1 and CSH1 activities and the remaining area by the increased level of RICE activity from 1054 ha to 1061 ha.

Growing 2 ha of MZE1 would not be desirable to include in the plan because the acreage is too small. Also growing 387 ha of CSH1 on land type I would certainly not be very acceptable. This is because cashewnut is a perennial crop, and therefore, once planted it would not be easy to change the use of the land if such a necessity arose and cashewnuts are not considered an important food crop in NAFCO. However, a lower acreage which does not use much of the best land would be acceptable.

Other changes which would occur in the optimum plan (Plan I) if LCFM was increased by 10% would include increased levels of the following activities: CSH2 activity from 36 ha to 150 ha, LEY2 activity from 124 ha to 568 ha, DAIR activity from 352 cows to 368 cows and a corresponding increase to all other dairy cattle related activities. Unlike CSH1 activity on land type I, the increase of CSH2 activity on land type II would be quite acceptable because there is not much competition for land type II and this activity would be able to utilize slack labour and machinery during periods of low activity for the other crops. The increase in the number of dairy cows is not great but because of the risks involved (which were mentioned in the previous chapter), the farm would not be very willing to increase the number of cows.

All the changes mentioned above would increase the aggregate gross margin of the optimum solution by shs 158,087 (or 3.8%) which is a significant increase on profits given the fact that no other resource is assumed to increase.

The plan would need to borrow almost the same amount of capital as the optimal solution (Plan I) during the periods January, April and May. Furthermore, except for the BUYC activity, the shadow prices of all the other activities which did not enter the new optimal solution (Plan II) would be much less than those in Plan I. At the same time such a plan would utilize the available resources more fully. As opposed to Plan I, this plan would have relatively less slack permanent labour at any one period. There would be slightly more or less machinery utilization, but still there would be considerable slack machinery-time left unitilized except for the July combine harvester which would be fully used up and limits expansion of the rice activities. If the JYCH constraint could be increased by one hour, the aggregate gross margin of the optimum solution (Plan II) would be increased by shs 1,284 because this would allow one more hectare of the RICE activity to be grown.

TABLE 6.1: EFFECT OF INCREASING LCFM OR BCP5 CONSTRAINTS

Activity	Unit	OPTIMAL SOLN (PLAN I)	LCFM + 10% (PLAN II)	BCP5 + 20% (PLAN III)
RICE	ha	1054	1061	1061
RCEH	"			
RCDP	"			
MZE1	"		2	
MZE2	"			
MZES	"			
SRG1	"			11
SRG2	"			
SRG3	"			
CSH1	"		387	
CSH2	"	36	150	36
CSH3	"			
LEY1	"	396		378
LEY2	"	124	568	71
LEY3	"			
POU	layers	9000	9000	9000
PIG	sows	100	100	100
DAIR	cows	352	368	327
REPC	heifers	70	74	65
BUYS	gilts	33	33	33
BUYC	heifers			
SLBC	bull calves	141	147	131
SLHC	heifer calves	70	74	65
SLCC	cull cows	53	55	49
SLCS	cull cows	33	33	33
CPIN	T. shs	4208826	4366913	4221232
BCP1	"	47109	47569	51385
BCP4	"	96235	96293	116916
BCP5	"	125000	125000	150000

The effect of increasing February-May casual labour shows positive changes in the initial optimum plan, and since these changes are quite remarkable it means this constraint is an important factor which should be evaluated carefully to ascertain its availability and if it can be increased to this level then Plan II (suitably adjusted) should be implemented instead of Plan I.

(ii) Borrowed Capital in May (BCP5)

The optimum solution (Plan I) indicates that borrowed capital is most constraining during the month of May since during this period the maximum bank overdraft allowed for is fully used up. To find the effect on the optimum solution if the maximum capital which can be borrowed could be increased, the amount has been increased by 20% to a maximum of shs 150,000.

Table 6.1 (Plan III) indicates such an increase would not cause a very significant change in the optimum solution (Plan I). The only new activity which would enter the new optimum solution would be the sorghum (SRG1) activity which would enter the solution at 11 ha (but this would not be desirable to undertake). The RICE activity would increase slightly from 1054 ha to 1061 ha while both the ley activities (LEY1 and LEY2) would drop in acreage slightly and significantly respectively. With exception of the poultry (POU) and piggery (PIG) activities which would remain at their maximum levels, the other livestock activities would drop slightly. These changes would increase the aggregate gross margin of the optimum solution (Plan I) by shs 12,406 (or 0.3%) which is not a significant increase.

6.2 Effect of Varying Yield, Price and Milling Percentage of the RICE activity

Since RICE is the most significant activity in the optimum solution (Plan I) it is expected that variation in any of its three most important parameters (yield, price and milling percentage) might affect the stability pf the plan significantly. An increase or reduction of any of these parameters would affect the total profitability of the farm. Therefore, these parameters have been varied to see how the optimum plan would be affected if any of them would drop or increase above the level used in the planning model.

(i) Yield Variation

Table 6.2 shows the effect on the optimum plan (Plan I) if the RICE activity yield varies by -5%, -10%, -15%, +5%, +10% and +15%. (In computing the effect of reducing the yield by -15% the MINR restraint in the model was removed to avoid an infeasible solution due to insufficient capital generated given the overdraft constraint).

In this sub-section the effect of each of these variations on the optimum plan will be discussed separately and general conclusions given at the end.

(a) 5% yield reduction

As seen in Table 6.2, reducing the yield of the RICE activity by a mere 5% would change the optimum solution (Plan I) significantly, but no new activities would enter the optimum plan except the purchase of replacement heifers, BUYC. The level of RICE activity would drop slightly from 1054 ha to 1021 ha - a decrease of about 3%. The level of LEY1 activity would increase from 396 ha to 429 ha and that of LEY2 activity from 124 ha to 293 ha. This would allow the number of cows to be increased from 352 to 463 and in addition be able to rear 32 replacement heifers. Because of resource constraints, sixty more replacement heifers required would have to be purchased. The sale of bull calves, heifer calves and cull cows would increase correspondingly with the increase in the number of cows. The cashewnut (CSH2) activity would remain at its minimum level while those of poultry (POU) and piggery (PIG) activities would remain at their maximum levels. The capital borrowed during the months of January and April would also have to be increased. These changes would decrease the aggregate gross margin of the optimum solution (Plan I) by shs 461,682 (or -10.9%) which is a substantial decrease in profits. Decreasing the yield of the RICE activity by 5% without changing the plan would decrease the aggregate gross margin by shs 632,400 (or -15%) which is 4.1% less

TABLE 6.2: RICE: EFFECT OF YIELD VARIATION ON THE OPTIMAL SOLUTION (Activity levels)

YIELD (Kgs/ha)		3400	3600	3800	4000	4200	4400	4600
% YIELD CHANGE		-15%	-10%	- 5%	0%	+ 5%	+10%	+15%
RICE	ha	531*	1000	1021	1054	1061	1061	1061
RCEH	ha							
RCDP	ha	378						
MZE1	ha							
MZE2	ha							
MZES	ha							
SRG1	ha					64	163	222
SRG2	ha							
SRG3	ha							
CSH1	ha	525	93					
CSH2	ha	36	36	36	36	36	36	36
CSH3	ha							
LEY1	ha	16	357	429	396	325	125	
LEY2	ha	614	443	293	124	11		
LEY3	ha							
POU	layers	9000	9000	9000	9000	9000	9000	9000
PIG	sows	100	52	100	100	100	100	100
DAIR	cows	390	520	463	352	288	215	172
REPC	heifers	78		32	70	58	43	34
BUYS	gilts	33	17	33	33	33	33	33
BUYC	heifers		104	60				
SLBC	bull calves	156	208	185	141	115	86	69
SLHC	heifer calves	78	208	153	70	58	43	34
SLCC	cull cows	58	78	69	53	43	32	26
SLCS	cull sows	33	17	33	33	33	33	33
CPIN	(shs)	2940021	3272671	3747144	4208826	4605708	5035783	5437569
BCP1	(shs)		81814	72202	47109	12466		
BCP2	(shs)	7368	67					
BCP3	(shs)							
BCP4	(shs)	125000	86630	121441	96235	87607	79167	40369
BCP5	(shs)	125000	125000	125000	125000	125000	125000	90896
BCP6	(shs)		11163				20846	5657

(* The ≥ 1,000 ha restraint has been relaxed here) than the new optimum plan.

(b) <u>10% yield reduction</u>

Decreasing the RICE activity-yield by 10% would cause even more significant changes in the optimum solution. The most remarkable changes would be the CSH1 activity which would enter the solution and the decrease of piggery (PIG) activity from its maximum level of 100 sows to 52 sows. At that level of yield the optimum plan also shows that it would be more profitable to purchase replacement heifers rather than rearing them. The LEY1 activity would decrease slightly and that of LEY2 activity would increase considerably from 124 ha to 443 ha allowing more cows to be kept. Additional capital would have to be borrowed during the months, of January, February, April, May and June (of which May is the most capital constraining period). The RICE activity itself would enter the solution at its minimum level of 1000 ha. All these changes would reduce the aggregate gross margin of the optimum solution (Plan I) by shs 936,155 (or -22%) which is again a very substantial reduction of the profits.

(c) <u>15% yield reduction</u>

A further decrease of the RICE activity-yield would change the optimum solution (Plan I) even more. Reducing the yield by 15% to 3,400 kgs per hectare and removing the minimum rice constraint (MINR) from the model (to avoid an infeasible solution) would reduce the RICE activity from 1054 ha to 531 ha and 378 ha of delayed-planted rice (RCDP activity) would enter the solution. The level of LEY1 activity would be reduced from 396 ha to 16 ha. The land type I (525 ha) released by the reduction in the acreage of rice and LEY1 activities would be taken up by cashewnuts (CSH1 activity). Also LEY2 activity would be increased from 124 ha to 614 ha allowing the DAIR activity to be expanded from 352 cows to 390 cows and the REPC activity from 70 to 78 heifers. This new optimum solution would reduce the aggregate gross margin of Plan I by shs. 1,268,805 (or -30%) which again is a very substantial reduction in farm profits.

From experience, the drops in yield as predicted in the three cases explained above are quite possible. Since the results above indicate that the optimum plan (Plan I) is fairly sensitive to reduction in the yield of the RICE activity below the estimated 4,000 kgs per hectare, then it is imperative that before implementing such a plan it should be ascertained that the assumptions made in the planning (which can affect yield) can be achieved.

(d) 5% yield increase

Contrary to the above, should the yield of the RICE activity increase (which is also quite possible) above the estimate used in the planning, the optimum solution would not change very remarkably. However, the aggregate gross margin would improve considerably (see Table 6.2). Increasing the yield by 5% would reduce LEY1 activity from 396 ha to 325 ha and the land released is taken up by SRG1 activity which enters the new optimum solution and by the increase in the level of RICE activity from 1054 ha to 1061 ha. Also the LEY2 activity would be reduced from 124 ha to 11 ha. The reduction of both the ley activities is a consequence of the reduction in the DAIR activity and all the other activities associated with it. The poultry (POU) and piggery (PIG) activities would remain at their maximum level and the cashewnuts (CSH2 activity) would remain at its minimum level of 36 ha. The aggregate gross margin of the optimum solution (Plan I) would increase by shs. 396,882 (or 9.4%) which is quite a significant increase on the farm profits given the fact that only slight changes occur in the optimum plan.

(e) 10% and 15% yield increase

Increasing the yield of the RICE activity by 10% or 15% would cause a similar trend of changes in the optimum solution (Plan I). As the yield rises higher and higher more of SRG1 activity enteres the optimum solution and less and less of the DAIR and REPC activities enter the basis which in turn lead to a reduction in the level of the ley activities. The level of RICE activity cannot be increased above 1061 ha because it is constrained at this level by the July-combine harvester (JYCH).

Increasing the yield (at least up to 15%) would not affect the levels of POU and PIG activities in the optimum solution. They both remain at their maximum levels which reflects high profitability compared to the other activities. On the contrary, the CSH2 activity remains at minimum level at whatever level of the RICE activity which is an indication of how unprofitable this activity is in comparison to the other activities in the basis.

Furthermore, the results also show that even at an increase of 15% in the yield of the RICE activity, the farm would still need to borrow additional capital during the months of April, May and June. And although at 10% and 15% yield increase the optimum plan would not change remarkably, the aggregate gross margin would increase by shs 826,957 (or 19.6%) and shs 1,228,743 (or 29.2%) respectively. Both of which are substantial increases to the farm profits.

The large increases on the aggregate gross margin emphasize the need for the farm to improve the rice yields in order to increase profits. An investigation carried on the farm has shown that there are two obvious measures which the farm could take to increase the rice yields. The measures required would be to improve the levelling of the farm and to reduce the size of the field blocks and plots in the area with rice irrigation system in order to be able to control irrigation and drainage much better. At present it is not possible to irrigate the crop evenly because of poor levelling of the irrigated fields and it is impossible to drain-off water from the field in time for harvesting unless this operation is commenced before the appropriate time. The uneven irrigation of the crop causes reduction in yield. Delayed drainage postpones harvesting (because combine harvesters cannot get into the field) and this causes overdrying of the crop in the field which, in turn, leads to shattering of the crop before and during harvesting. This also makes the rice brittle and thus lowers the milling percentage and ultimately the revenue. In addition, more labour has to be employed for the water drainage operation, thus increasing the variable costs which lowers the farm profits.

The loss matrix indicating the aggregate gross margin of the farm at poor (-10%), normal, and good (+10%) yield levels of rice at minimum, optimum and maximum levels of the RICE activity is shown in Table 6.3. This shows what would happen to the farm profits if the yield of rice decreased below or increased above the normal yield (4000 kg/ha) at 3 different rice activity levels which entered the optimum plans shown in Table 6.2.

TABLE 6.3: LOSS MATRIX AT VARIOUS YIELD AND ACTIVITY LEVELS OF RICE (shs)

Action	Poor Yield (3600 kg/ha)	Normal yield (4000 kg/ha)	Good yield (4400 kg/ha)
1. 1000 ha	3,272,671	3,992,671	4,712,671
2. 1054 ha (Plan I)	3,245,289	4,208,826	4,967,926
3. 1061 ha	3,241,739	4,205,969	5,035,783

The loss matrix above shows that it is best to opt for the optimum solution (Plan I) when normal yields are expected. If poor yields are expected the plan with 1000 ha of rice will give the best aggregate gross margin. If good yields are expected, then the plan with 1061 ha of rice will give the best aggregate gross margin.

If capital was more freely available the maximum RICE solution would be the best to opt for because this will give the best aggregate gross margin in bad and normal years. More capital would have to be borrowed in a poor year. However, it should not be forgotten that the model is a single year model and therefore the second year may have surplus capital available which will overcome the borrowing problem.

(ii) Price variation

The effect (on the optimum solution) of varying the price of the RICE activity by the same percentage as that of the yield would be similar as that shown for the yield variation in Table 6.2 and therefore the interpretation would be similar as well. However, the price is not expected to fluctuate much during one planning period, and if anything, an upward trend of the price would be expected.

(iii) Milling percentage variation

Milling percentage of the rice crop is an important factor which determines the amount of revenue obtained from the crop. The milling percentage can vary widely depending on the rice variety, moisture content of the crop at harvesting time, weather condition at harvest (wet or dry) and storage conditions, among other factors. Because there are so many factors which can affect the milling percentage, the chances for this to vary from that used in the planning are fairly high. Therefore, this parameter has been tested in the model to see how its variations would affect the optimum solution (Plan I).

Table 6.4 shows how the optimum plan would change if the milling percentage of rice (60%) used in the model were to drop by 5%, 10% and 15% and also if it were to rise by 5% and 10%. Cases like these have been recorded on this farm a number of times and therefore they are not unusual. The effect of each on the optimum plan will be discussed separately.

(a) 5% milling percentage reduction
Reducing the milling percentage by 5% would change the optimum plan (Plan I) quite remarkably. The RICE activity would drop to its minimum level allowed for in the model and LEY1 activity would drop from 396 ha to 363 ha. The land type I released by both of these activities would be taken up by the CSH1 activity which enters the new optimum solution. The LEY2 activity would increase from 124 ha to 405 ha allowing the DAIR activity to be increased from 352 to 507 cows. The

TABLE 6.4: RICE: EFFECT OF MILLING % VARIATION ON THE OPTIMAL SOLUTION

MILLING PERCENTAGE		45%	50%	55%	60%	65%	70%
% CHANGE		-15%	-10%	-5%	0%	+5%	+10%
RICE	ha			1000	1054	1061	1061
RCEH	ha	305	305				
RCDP	ha	592	592				
MZE1	ha						
MZE2	ha						
MZES	ha						
SRG1	ha					136	222
SRG2	ha						
SRG3	ha						
CSH1	ha	553	553	87			
CSH2	ha	45	45	36	36	36	36
CSH3	ha						
LEY1	ha			363	396	183	
LEY2	ha	486	486	405	124		
LEY3	ha						
POU	layers	9000	9000	9000	9000	9000	9000
PIG	sows	100	100	86	100	100	100
DAIR	cows	340	340	507	352	236	172
REPC	heifers	68	68		70	47	34
BUYS	gilts	33	33	29	33	33	33
BUYC	heifers			101			
SLBC	bull calves	136	136	203	141	94	69
SLHC	heifer calves	68	68	203	70	47	34
SLCC	cull cows	51	51	76	53	35	29
SLCS	cull sows	33	33	29	33	33	33
CPIN	shs	2911350	2911350	3434794	4208826	4899586	5523152
BCP1	shs			83539	47109		
BCP2	shs			5751			
BCP3	shs						
BCP4	shs	125000	125000	120781	96235	81514	4295
BCP5	shs	125000	125000	125000	125000	125000	54497
BCP6	shs					11819	

rearing of replacement heifers would drop out from the optimum solution completely and instead the plan would include the purchase of 101 replacement heifers to avoid REPC activity competing for land (for pasture) and labour with the more profitable activities in the basis. The activity PIG, which has been shown to be fairly stable when various parameters are decreased or increased, would also drop from 100 sows to 86 sows. The only activities which would not change would be the poultry (POU) and cashewnuts (CSH2) activities. Additional capital would have to be borrowed during the months of January, February and April to enable implementation of such a plan. In all, the aggregate gross margin of the optimum solution (Plan I) would be reduced by shs 774,032 (or -18.4%) which represents a very significant change to the profits of the farm.

(b) <u>10% milling percentage reduction</u>

At 50% milling percentage (10% reduction) or below, no RICE activity would enter the optimum solution. However, 305 ha of the extended harvested rice (RCEH activity) and 592 ha of delayed-planted rice (RCDP activity) would enter the new optimum solution.[1)] This still makes the rice crop the most important activity in the plan. Another important crop which would enter the plan would be the CSH1 activity. This would enter the solution at 553 ha - which as mentioned before would not be desirable on land type I. The other cashewnut activity (CSH2) would also increase slightly above the minimum level to 45 ha. Furthermore, no LEY1 activity would enter the new optimum plan because all the land type I would be taken up by RCEH, RCDP and CSH1 activities. However, LEY2 would be increased considerably from 124 ha to 486 ha. However the DAIR activity would have to be reduced slightly from 352 cows to 340 cows because of the LEY1 activity which is dropped out of the plan.

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1) The change in the milling percentage for rice is not applied to the RCEH and RCDP activities because this was taken into account when these were computed. Also the minimum rice constraint (MINR) is removed from the model to avoid an infeasible solution.

Under such a plan it would also be more economical to rear replacement heifers than purchasing them. The POU and PIG activities would remain at their maximum levels of 9000 layers and 100 sows respectively. Compared to the optimum solution (Plan I), the aggregate gross margin of this new optimum plan (at 50% milling percentage) would be lower by shs 1,297,476 (or -30.8%) - which is a very substantial reduction on the profits.

The effect of reducing the milling percentage by 15% would be the same as that of reducing it by 10% because in both the cases the RICE activity would not enter the solution.

The effects of lowering the milling percentage of the RICE activity, as discussed above, show that slight reductions would cause remarkable changes in the optimum solution, thus making the optimum solution (Plan I) very sensitive to variations in the milling percentage. The changes are even more pronounced than those caused by equivalent changes in the yield.

(c) <u>5% milling percentage increase</u>

If the milling percentage would increase by 5% (i.e. to 65%) the optimum solution (Plan I) would also change quite significantly. The RICE activity would increase to 1061 ha, the level at which it is constrained by the July-combine harvester (JYCH), otherwise more would have entered the new optimum plan. Sorghum (SRG1) which did not enter the optimum solution (Plan I) would enter the plan at 136 ha. LEY1 activity would be reduced drastically to 183 ha while the LEY2 activity would be omitted completely from the plan. The DAIR activity is reduced from 352 cows to 236 cows. The CSH2, POU and PIG activities would not change. These changes would cause the aggregate gross margin of the optimum solution to rise by shs 690,760 (or 16.4%).

This plan seems to be a more practical one for implementation than Plan I because it includes fewer dairy cows (a more desirable number) and thus requires less investment in ley establishment. Also inclusion of the sorghum crop (SRG1) is important because this can be used for making livestock feed mixtures in case of shortage of other livestock feeds. The plan also attaches importance to the target crop of the farm, rice, by including the maximum possible acreage of the crop as permitted by the resource availability.

(d) <u>10% milling percentage increase</u>

Increasing the milling percentage by 10% (i.e. to 70%) would also change the optimum solution quite significantly. The RICE activity would increase to 1061 ha, the level at which it is constrained by the July-combine harvester (JYCH constraint). Also 222 ha of sorghum (SRG1 activity) would enter the solution. Thus only 1283 ha of land type I would be utilized leaving 167 ha unutilized as well as all of land type II and III (except the 36 ha of land type II which is under cashewnuts). No ley activity would enter the optimum solution and therefore the DAIR and REPC activities would be limited to the numbers which can be supported by the available pasture land (the GRSL constraint). Thus only 172 cows and 34 replacement heifers (reared) would enter the solution. The cashewnut (CSH2), poultry (POU) and piggery (PIG) activities would remain the same at 36 ha, 9000 layers and 100 sows respectively. These changes would increase the aggregate gross margin of the optimum solution (Plan I) by shs 1,314,326 (or 31.2%). The magnitude of these changes show how important it is to control those factors which affect the milling percentage of the rice crop. The yield of paddy rice could be very high but if the milling percentage is low, then the revenue is also reduced dramatically. Therefore, the optimum solution (Plan I) can only be valid if the milling percentage of the rice crop is maintained around 60%. To ensure that high milling percentage is maintained, the following measures, should always be taken: -

1. Suitable rice varieties known to have high milling percentage should be grown.
2. The crop should be harvested as soon as it is dry enough for harvesting.
3. The crop should not be harvested when it is wet.

4. The paddy rice should be thoroughly dried immediately after harvesting and stored under dry conditions.
5. The timing of planting should be such that the harvesting of the crop should fall in the dry season.

If we imagine that the farm was planned along the lines of Plan I and that the year turned out to be a bad one (weatherwise), would we have been better off with a more conservative plan with regard to the variation in milling percentage? This is shown in the loss matrix (Table 6.5) below in which there are 3 actions and 3 weather conditions and indicates what the aggregate gross margin would be in each case.

TABLE 6.5: LOSS MATRIX AT VARIOUS MILLING PERCENTAGE LEVELS OF RICE ACTIVITY shs

Actions	Poor weather (-10% milling %)	Normal weather (At 60% milling %)	Good weather (+10% milling %)
1. Plan (-10% milling %)	2,911,350	2,911,350	2,911,350
2. Plan I	2,899,143	4,208,826	5,473,994
3. Plan (+10% milling %)	2,898,599	4,205,969	5,523,152

Table 6.5 shows that the farm would not be better off with a more conservative plan and thus emphasizes the need to have the conditions which affect the milling percentage under control.

In conclusion, as the discussion above (on the effect of varying yield, price and milling percentage of rice on the optimum solution) has shown, slight changes in any of these parameters would change the optimum solution (Plan I) completely and hence invalidate the plan. However, any upward changes of these parameters without changing Plan I, would still increase the aggregate gross margin although not by the same magnitude. Therefore during planning, the estimated value of these parameters to be used should be as realistic as possible, otherwise the plan reached may not be optimum when it comes to actual implementation (see further comments at the end of this chapter).

6.3 Effect of Forcing RCEH, RCDP and MZE1 Activities Separately into the Optimum Solution

Circumstances do arise (mainly due to weather problems or machinery breakdown) such that harvesting of rice (RICE activity) is extended over a much longer period than normal or planting of the crop is delayed. In such circumstances the scheduling of operations, the requirement of some resources and the yields realized are affected and for these reasons each of these cases is treated as a different activity. Also circumstances do arise in NAFCO where the Government may require the Corporation to grow a certain crop or crops for reasons such as those mentioned in Section 2.4.3 even though it might not be a viable undertaking for the Corporation. Maize being a staple food in most areas in Tanzania would be a possible crop the Corporation may be required to grow on any of its farms. Because of these circumstances, the extended harvested rice (RCEH), the delayed planted rice (RCDP) and maize (MZE1) have been forced separately into the solution (plan) to see how the results of the optimum solution would be affected. The results of forcing any of these activities into the plan are shown in Table 6.6. The effects are as follows: -

(i) Effect of Forcing 400 ha of RCEH into the Plan

As Table 6.6 shows, with or without the MINR constraint in the model, forcing 400 ha of RCEH activity into the solution would reduce the RICE activity down to 620 ha only. Another remarkable change which would occur is that the piggery (PIG) activity and the associated activities (BUYS and SLCS) would be dropped out of the optimum solution completely. The cashewnut (CSH1) activity would enter the optimum solution at 6 ha, while CSH2 and POU activities would remain the same at 36 ha and 9000 layers respectively. The dairy (DAIR) activity would increase considerably to 526 cows which in turn would require the ley activities (LEY1 and

TABLE 6.6: EFFECT OF FORCING RCEH, RCDP & MZE1 SEPARATELY INTO THE OPTIMAL SOLUTION

ACTIVITY FORCED-IN		"NONE" (Optimal Solution)	RCEH (≥ 400ha)	RCDP (≥ 400 ha)	MZE1 (≥ 100 ha)
RICE	ha	1054	620	658	1000
RCEH	ha		400		
RCDP	ha			400	
MZE1	ha				100
MZE2	ha				
MZES	ha				
SRG1	ha				
SRG2	ha				
SRG3	ha				
CSH1	ha		6		
CSH2	ha	36	36	36	36
CSH3	ha				
LEY1	ha	396	424	136	350
LEY2	ha	124	391		222
LEY3	ha				
POU	layers	9000	9000	9000	9000
PIG	sows	100		100	51
DAIR	cows	352	526	219	429
REPC	heifers	70	-	44	
BUYS	gilts	33		33	17
BUYC	heifers		105		86
SLBC	bull calves	141	210	88	172
SLHC	heifer calves	70	210	44	172
SLCC	cull cows	53	79	33	64
SLCS	cull sows	33		33	17
CPIN	shs	4208826	3551294	3706675	4053869
BCP1	shs	47109			7106
BCP2	shs				
BCP3	shs				
BCP4	shs	96235	36852	74869	66904
BCP5	shs	125000	125000	125000	125000
BCP6	shs		90648		25805

LEY2) to increase to 424 ha and 391 ha respectively. All the other activities associated with the DAIR activity (i.e. BUYC, SLBC, SLHC and SLCC) would increase correspondingly. Under such a plan it would be more economical to buy all the 105 replacement heifers required than rearing them on the farm. These changes would reduce the aggregate gross margin of the optimum solution by shs 657,532 (or -15.6%), which is quite a significant change in the profit of the farm.

Furthermore, as with the optimum plan, this new plan would leave about 42% of the permanent labour during the periods October-January and June-September unutilized. Also at any one time over 50% of the available machinery-time would sit idle.

These results show that extending the rice harvesting period well into September would have quite a detrimental effect on the profits of the farm.

(ii) Effect of Forcing 400 ha of RCDP into the Plan

Forcing 400 ha of delayed-planted rice (RCDP) into the optimum solution would change the optimum solution quite differently compared to the effect of forcing 400 ha of RCEH into the solution. The difference is mainly due to the fact that less working capital would be required for the RCDP activity than for RCEH activity during the periods January, February and March because the planting operation would be delayed and hence less operational costs would be required during these periods.

The effect of forcing a minimum of 400 ha of the RCDP activity into the solution would be as shown in Table 6.6. These results show that RICE activity would be reduced from 1054 ha to 658 ha. LEY1 activity would be reduced from 396 ha to 136 ha while LEY2 activity would be omitted completely from this plan which is a reflection of the drastic reduction of the DAIR activity from 352 cows to 219 cows. The CSH2, POU and PIG activities would not change.

Under such a plan only about 50% of the permanent labour during the periods October-January and June-September would be utilized. Similarly all the field machinery available would be underutilized.

The optimum plan obtained after forcing 400 ha of RCDP into the plan would have an aggregate gross margin which would be 11.9% less than that of Plan I. Thus, delaying planting the rice crop would have less disastrous effects on the optimum plan than extending harvesting of the crop. Nevertheless, they would both change the optimum solution remarkably and there would be a serious under-utilization of the resources available to the farm unless these (especially permanent labour and field machinery) were reduced and used elsewhere. For example the extra machinery could be hired out or lent to other NAFCO farms which may require them.

(iii) Effect of Forcing 100 ha of MZE1 into the Plan

By forcing 100 ha of MZE1 activity into the plan, the optimum solution (Plan I) would be changed significantly as can be seen in Table 6.6. The RICE activity would be reduced to 1000 ha where it is constrained by the minimum activity, MINR. They LEY1 activity would decrease slightly while LEY2 activity would increase from 124 ha to 222 ha. The DAIR activity would increase from 352 cows to 429 cows and no replacement heifers would be reared since under such a plan it would be more economical to purchase all the 86 replacement heifers required. As has been shown to be the case with all the other parameters tested before, the CSH2 and POU activities would not change. With the POU activity it is because this activity provides little competition with the others for the farm resources and infact it generates continuous capital throughout the year.

Such a plan would use more land than Plan I but would still leave over 45% of the permanent labour during October-January and June-September underutilized as well as about the same amount of slack field-machinery time. The aggregate gross margin of the optimum solution (Plan I) would however, only be reduced slightly by shs 154,957 (or -3.7%).

6.4 Concluding Remarks

The sensitivity analysis results discussed above indicate that the optimum solution (Plan I) given by the model is quite sensitive to changes in most of the crucial assumptions made with regard to the parameters used in the planning. Slight changes in any of them, or forcing any of the activities which did not enter the plan into the solution, would alter the optimum solution (Plan I) considerably. The significance of these results is that they have shown that much can be gained by the study of a variety of plans arrived at by varying the initial assumptions. For example, although the plan obtained by forcing 100 ha of maize (MZE1) activity into the solution differs radically from the original optimum plan, the profits differ only slightly and hence the new optimum plan might have advantages which would more than compensate for the small loss.

Overall it appears to be very much a trade-off between cropping and dairying. When rice becomes more profitable then dairy decreases. The limit of the rice acreage is 1061 ha (because of the July-combine harvester limitation) but continued yield or price increases in the RICE activity will bring in more capital which enables other crops to be grown (see Table 6.1 Plan III and Table 6.2. When yield increases 5%, 10% and 15%).

If RICE activity decreases in profitability, the acreage decreases and thus labour gets released and this seems to lead to an increase in Cashewnuts (see Table 6.1 Plan II and Table 6.2 when yield is decreased by -10% and -15%). Also the dairy (DAIR activity) increases, which automatically changes related livestock activities.

As shown by the sensitivity analysis, poultry (POU) and piggery (PIG) are very much independent and stable activities.

This trade-off between rice and dairy is important. It shows how important it is to get yields, prices and other variables right. If prices or yields are too favourable for dairying (by mistake), this may lead to too great a conversion of agricultural land to leys (and this takes time).

Further the model has shown the importance of capital and labour constraints. If neither of these were present, the RICE activity would be at 1061 ha which would give the best aggregate gross margin in bad and normal years.

It should however, be noted that the optimum solution does not result from any one change as tested here, but is the sum effect of a number of changes which occur together, either simultaneously or within a short range of time, and therefore on deciding whether to implement the optimum plan, all these factors should be taken into account together.

CHAPTER SEVEN

CHAPTER SEVEN

7. SUMMARY AND CONCLUSIONS

7.1 General

The need to accelerate the development of the agricultural industry in Tanzania (which is the backbone of the economy) has prompted the government to establish national Corporations to undertake this task. Under corporate structure large scale mechanized farms (which peasant farmers have failed to establish and operate) can be established and run more efficiently. However, proper planning in such corporations is imperative in order to achieve this objective.

This study has dealt with one such Corporation in Tanzania called National Agricultural and Food Corporation (NAFCO) established to deal mainly with production of food crops in the country. The aim of the study has been to show how such a corporation can be operated efficiently so that maximum food production is achieved from scarce resources.

The approach was to first examine the problems facing the Corporation. In the discussion on the problems of NAFCO it was revealed that most of the NAFCO farms have been making losses throughout their whole life time. An indepth examination of these problems revealed that lack of appropriate planning has been one cause of the unprofitability of the subsidiaries (farms). The use of some form of systematic planning tool, one simple enough for NAFCO staff to apply, but better than the current planning methods (i.e. budget analysis and gross margin analysis) could improve profits. In this study linear programming has been evaluated as a planning tool for a large single farm of NAFCO.

The application of linear programming to corporate farm planning is demonstrated by using NAFCO Ruvu Rice Farm which is a typical representative NAFCO farm. The study concentrated on the level of resource management/planning aspects of food production at subsidiary level only. The aim was to develop a suitable linear programming model for the farm, use this model to determine the optimal farm plan(s) and associated information and evaluate whether the technique would form a suitable planning tool for NAFCO farms. The model developed is only an example and it is expected that it could easily be applied to most other NAFCO farms with minor modifications or substitutions of activities.

Attention has been mainly confined to finding the optimum combination of activities which are already being produced, and using available resources and current techniques of production in order to get a better perspective of the usefulness of the planning tool in resource planning by comparison with the existing production pattern. Higher profits could have been obtained by including a wider choice of alternatives and also by using better and improved methods of production.

The suggested ways of improving profits would be more applicable under corporate farm structure than under peasant farming structure because the former would have the necessary skills and resources. Also, the necessary data for planning is more readily available or obtainable.

7.2 Recommended Farm Plan

The plan computed for Ruvu Rice Farm using linear programming indicates that profits could be substantially improved with a new combination of activities giving a better use of the available resources. The increase in profits in relation to the current income (the aggregate gross margin) calculated on a standard basis is put at shs 904,546 (or 27.4%). Part of this increase can be credited to the increased levels of some of the activities. About 11.2% of the increase can wholly be attributed to reallocation of the resources. In all probability the plan obtained would be a feasible plan to implement. However, it is also unlikely that NAFCO management would implement the plan exactly as it is. For one, it is unlikely the establishment of 396 ha of ley on land type I would be accepted fully because this land is highly suitable for rice growing. In this case, even if the farm was not using it for rice or any other crops, apart from ley, some of the farm workers and/or the neighbouring Ujamaa Village might ask for the land for growing their own rice. These people are likely to be given priority over ley establishment which arguably, one would say can be established on land type II. For another, the increase in the number of dairy cows would have to be achieved gradually since their increase would have to follow the establishment of the ley activities (which take time). Apart from these two activities, the rest of the activities in the optimum plan (see Table 6.1) could be implemented according to plan but almost invariably there would be a need to make short-term adjustments in the light of prevailing conditions.

As shown by the sensitivity analysis results in chapter 6, the optimum plan is fairly sensitive to changes in any of the main parameters used in the model and since the prediction of the anticipated results is bound to be hazardous even if the exact plan is implemented the realized profits would not be exactly the same because the main components of the gross margins (yields, prices and costs) are likely to vary. Nevertheless the optimum solution obtained in this study represents a useful bench-mark plan against which to judge other farm plans since the optimum place represents a substantial improvement on the existing system.

The comparison of the optimum plan (Plan I) with the optimum solutions arrived at after changing certain parameters in the model (i.e. the sensitivity analysis results) show that there are certain common features. The most obvious is that the poultry (POU) and piggery (PIG) activities are very much independent and stable activities since they appear in all plans. The poultry activity remains constant at 9000 layers in all plans and, except in very few cases, the piggery activity remains at its maximum allowed level of 100 sows.

The rice activities (RICE and/or RCEH and/or RCDP) appear in all plans but at varying levels. Overall it appears to be very much a trade-off between cropping and dairying. When rice becomes more profitable than dairy then dairy decreases (so do ley activities) and vice versa. Better yields or prices for rice means more capital and this enables other crops to be grown. On the other hand if rice yields or prices fall, the acreage decreases and thus labour is released which in turn leads to an increase in cashewnuts. Because of the trade-off between rice and dairy it is imperative that yields, prices and other variables used in planning are correct.

None of the cropping activities to be grown on land type III (LAF3) appear in any of the solutions at any of the levels of yields and prices tested. However, even though not included in the model, this land can be used as a supplementary grazing area for the dairy cattle.

Inclusion of the ley activities in the plan is dependent on the proviso that the dairy and the replacement heifer activities enter the solution at levels above 172 cows and 34 heifers respectively (or 200 cows only where the replacement heifers are to be purchased). The numbers at which these activities entered the optimum plan (i.e. 352 cows and 70 heifers) would be the maximum acceptable levels because of the risks involved - mainly due to animal disease incidences or scarcity of animal feeds (in the event of drought).

The cashewnut activity (CSH2) appears in all (except one) of the optimum solutions computed at its minimum level of 36 ha. The marginal value product of this activity in most cases indicates that its position would have been much lower or none at all had it not been for the minimum constraint (MINCW) imposed in the model. In the cases where cashewnut on land type I entered the optimum plans at high levels it was argued that this would not be acceptable because cashewnut being a perennial crop would 'fix' the use of the land and thus reduce the flexibility of changing the farm plan(s) in future if need arises.

The total available capital in each period, especially during the months of January, April and May, is limiting in all the optimum plans computed and therefore it would be worthwhile to be able to borrow more capital during these months. May is the most capital-limiting period and it is during this period when more bank overdraft than currently available is required.

The optimum plan (Plan I) also indicates the permanent labour employed by the farm to be in excess of optimal requirement. Therefore, reducing the number of the permanent labour on the farm would raise the profit potential except during the February-May period when the excess permanent labour is used to supplement the casual labour requirement. Even then it is expected that in the very near future, adequate casual labour (which is cheaper than permanent labour) will be available during this period because of the growth of a new rural township nearby. Therefore, the farm should find means and ways of reducing the excess permanent labour which contributes a great deal to the reduction of the farm profits.

The restrictions on the total casual labour available used in this study resulted in the October-January and February -May seasonal restrictions being fully taken up. This may not always be the case because the labour requirement is not evenly distributed during any one period and therefore the limitation of casual labour might not always be as critical as the solution indicates. Further subdivision of the seasonal restrictions would entirely be empirical but it would be very difficult to subdivide further the labour requirement for the various activities in the model, more logically, using the data available. The major problem here is to define the period during which a particular operation or part of it may be performed and secondly to determine the number of days within that period when weather conditions may be suitable and hence permit the operation to be undertaken.

7.3 Evaluation of the Planning Tool

The use of linear programming has enabled the farm under study to be analysed in a more comprehensive and practical way than would have been the case if the current planning methods were applied. The method enabled a greater range of alternative adjustments and their consequences to be analysed by changing the assumptions in respect to resource requirement and availability and/or policy decisions. The various plans computed (in the sensitivity analysis) gave an indication of what could be expected, or done if changes in the assumptions made during planning were envisaged. That is, the solution showed how great the advantages of the activities which entered the plan were over those which did not. Also the sensitivity analysis results showed how increasing or decreasing one or more resources would affect the optimum mix of activities and the value (aggregate gross margin) of the plan. Therefore the use of linear programming in this study has shown that it can be used within the context of a fairly complex farm situation to indicate means of considerably increasing profits through the better use of the available resources.[8] This increase was achieved without any improvement in technical performance.

Linear programming was more capable of analysing resources like labour more realistically than other ad hoc farm planning methods in use. It eliminated the weak concept of working with total labour per annum and instead treated labour separately in four periods - thus distinguishing labour available during different seasons.

Although a lot of arithmetic was required in making the analysis, a highly skilled technician was not required to do the computations because a computer was used. This also provided accurate solutions and additional information of value like shadow prices, limiting processes, etc which enabled appropriate decisions to be made with regard to the stability of the optimum plan and means to improve the profits even further.

Some of the conclusions reached, such as the need to reduce the number of permanent employees or increasing acreage of rice, etc could have been reached with simpler methods such as budgeting. However, using such methods alone, it is unlikely that the relative advantages of rearing or purchasing replacement heifers would have become apparent. Nor the extent to which the dairy activity (and so the ley activities) could profitably be extended. Part of the merit of linear programming is, of course, that an exact optimum plan is reached maximising gross margins (profits). With a method like budgeting it may be relatively easy to improve on the existing system but the resulting plan can still fall a long way short of the optimum.[7]

No more data was required than was available for the current planning methods in use except that the LP problem required a more detailed specification of the restraints (land, capital, labour and machinery-time) and more detailed input data. The availability of adequate and reliable data in corporate farms makes linear programming technique a more appropriate planning tool than under peasant farm structure. With corporate farms it is easy to obtain specific data relevant to individual farms because detailed records for each farm are normally kept. In most NAFCO farms it is evident that more data are available for planning than can be handled in practice by the existing methods in use.

The major disadvantage with LP is that it assumed constant input-output ratios, which is not true in actual farming conditions. Also the programming process proceeded as though the price and input-output expectations formulated were equally reliable for all products and therefore treated all activities as though they were risk free. The optimum plan did not therefore take the risk preference of management into account.

Also it was difficult to specify in detail certain restraints like capital, labour and machinery requirements because of the difficulty of predicting what the actual situation will be like several months ahead.

Furthermore, even though LP technique gives an exact plan, the fact remains that no exact plan can remain optimum for more than a short time. Therefore the management of the farm must continually cope with changing prices and introduction of new production techniques. Nevertheless, as Simpson (1960) puts it, "... the skillful use of linear programming should provide a guide to the direction in which a farm system ought to be developed if it is to return a high level of profits."[8]

Another problem which NAFCO may face in using this planning tool is lack of computing facilities which are few in the country. However, this should not prevent the Corporation from employing the technique because the advantages could well outweight whatever problems may be experienced in getting access to computer facilities.

7.4 Conclusion

The conclusion given here only applies to what this study has achieved with regard to its aims. Other conclusions have already been drawn when the relevant sections were discussed in the previous sections.

The aims of the study were first, to develop a linear programming model for a representative farm of NAFCO. Secondly, to use this model to determine optimum farm plans and associated information. Thirdly to evaluate the technique as to its suitability as an aid in corporate farm planning. The development of the model in chapter four and the discussion of the results in the last three chapters have shown that these aims have been achieved.

The linear programming model developed in this study has demonstrated that the farm profits of NAFCO Ruvu Rice Farm could be increased substantially by allocating the farm resources more optimally. Repeating the optimisations of the model by changing the various assumptions proved to be quite useful in providing additional information on which to base management decisions. These results provided a better understanding of the effects and implications on what would happen if the anticipated yields prices and certain policy decisions were to change. The optimum plan computed should with minor changes, be both acceptable and realizable in practice.

Under corporate farm structure, specific data relevant to individual farms is more readily available than under peasant farm situations; and this makes linear programming technique a more appropriate planning tool in the former than in the latter structure. An important limitation to the application of linear programming (i.e. lack of data) is eliminated. Also because of the large scale nature of the Corporate farms, the availability of a wide choice of activities and resources as well as availability of the necessary skills and defined objectives; linear programming would form a suitable planning tool for NAFCO farms.

If more data was available a more detailed model could have been developed. Even then, it is expected that by making minor alterations and additions to the model developed in this study and feeding in the appropriate input-output coefficients for a particular farm of NAFCO, the model could easily be applied to the majority of NAFCO farms for planning and hence improve their profits.

In developing countries, where there is lack of computer packages for analyzing very complex models and lack of necessary skills, the formulation of linear programming should be limited to simple models as developed in this study.

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APPENDICES

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APPENDICES

GROSS MARGINS FOR VARIOUS PRODUCTION ACTIVITIES: NAFCO RUVU RICE FARM

APPENDIX A.1: RICE ACTIVITY (Gm/ha)

REVENUE:		
4,000 kg x 60% milling % x shs 3/00 per kg = shs		7,200
LESS: VARIABLE COSTS		
Seed 150 kg x shs 2/40 = shs	360	
Machinery costs: -		
Crawler tractor (D5) 201; 2.5hrs @ 80/- x 2	400	
Tractor 80-100hp, 101; 0.6hrs @ 40/- x 2	48	
" 60- 80hp, 751; 7.5hrs @ 30/-	225	
Other machinery costs	225	
Combine harvester 101; 2.5 hrs @ 40/-	100	
Fertilizers - TSP 125kgs @ sh 1/40 in 3yrs	58	
- Urea 240kgs @ sh 1/70	408	
Herbicides - Preforan 30;121 @ sh 48/-	576	
- Stam F.34, 61 @ shs 36/-	216	
Supplementary handweeding 10md @ 10/45	104	
Insecticide - DDT 25%, 41 @ 13/-	52	
Labour - Drivers & helpers (field machinery etc 40 hrs @ 6/-	240	
Others field operations (fertilisers, herbicides & insecticide application, irrigation, etc) 20 md @ sh 12/-	240	
Electricity (irrigation pumps) est	80	
Field transport (harvested crop)	40	
Drying and winnowing 5md x 10/45	52	
Milling - labour 4md x 10/45	42	
packing material 24 bags @ 7/-	168	
electricity (milling plant)	30	
Miscellaneous expenses	400	4,064
Gross margin/ha = shs		3,136

APPENDIX A.2: RCEH (Extended Harvesting) - Gm/ha (28% of crop harvested in September).

(NB 40% of the crop still in the field by September is lost = 11% of total crop, and milling % of that crop drops to about 53% i.e. total average = 58%).

REVENUE:

3,560 kgs x 58% milling % x shs 3/00 per kg = shs		6,194
LESS: VARIABLE COSTS		
Seed 150 kgs x 2/40 = shs	360	
Machinery costs:		
Crawler tractor (D5) 20l; 2.5hrs @ 80/- x 2	400	
Tractor 80-100hp, 10l; 0.6 hrs @ 40/- x 2	48	
" 60- 80hp, 7.5l; 7.5 hrs @ 30/-	225	
Other machinery costs	225	
Combine harvester 10l; 2.5 hrs @ 40/-	100	
Fertilizers - TSP 125kgs @ shs 1/40 average 3yr	58	
- Urea 240kg @ shs 1/70	408	
Herbicides - Preforan 30;12l @ shs 48/-	576	
- Stam F.34, 6l @ shs 36/-	216	
Supplementary handweeding 10md @ 10/45	104	
Insecticide - DDT 25%, 4l @ 13/-	52	
Labour - Drivers & helpers (field machinery) 45 hrs @ 6/-	270	
Other field operations (fertilizers, herbicides & insecticide application, irrigation etc) 20md @ shs 12/-	240	
Electricity (irrigation pumps) est.	80	
Field transport	45	
Drying & winnowing 4.5 md x 10/45	47	
Milling - Labour 3.5 md x 10/45	37	
Packing material 21 bags x 7/-	147	
Electricity (milling plant)	27	
Miscellaneous expenses	420	4,085
Gross margin/ha = shs		2,109

APPENDIX A.3: RCDP (Delayed Planting) (Gm/ha)

(N.B. Loss of crop as for extended harvested rice)

REVENUE:

3,560 kg x 58% milling % x shs 3/00 per kg = shs		6,194
LESS: VARIABLE COSTS		
Seed 150 kgs x 2/40	360	
Machinery costs:		
Crawler tractor (D5) 201; 2.5hrs @ 80/- x 2	400	
Tractor 80-100hp; 101, 0.6hrs @ sh 40/- x 2	48	
" 60- 80hp; 7.51, 6.5hrs @ sh 30/-	195	
Other machinery costs	225	
Combine harvester 101, 2.5hrs @ sh 40/-	100	
Fertilizers - TSP 125kgs @ shs 1/40 over 3yrs	58	
- Urea 240 kg @ shs 1/70	408	
Herbicides - Preforan 30;121 @ shs 48/-	576	
- Stam F.34, 61 @ shs 36/-	216	
Supplementary handweeding, 10md @ 10/45	104	
Insecticide - DDT 25%, 41 @ shs 13/-	52	
Labour - Drivers & helpers (field machinery) 43.5 hrs @ shs 6/-	261	
Other field operations (fertilizers, herbicides & insecticide applications & irrigation) 2.5 md @ shs 12/-	300	
Electricity (irrigation pumps) est	80	
Field transport	45	
Drying & winnowing 4.5 md x 10/45	47	
Milling - Labour 3.5 md x 10/45	37	
Packing material 21 bags @ 7/-	147	
Electricity	27	
Miscellaneous expenses	420	4,106
Gross margin/ha = shs		2,088

APPENDIX A.4: MAIZE (MZE1) (Gm/ha)

REVENUE:

4,000 kg @ shs 0/85 = shs			3,400
LESS: VARIABLE COSTS			
Seed 25 kg @ sh 2/80		70	
Machinery costs - tractors 9hrs @ shs 30/-		270	
Fertilizers - TSP 150 kg @ shs 1/40		210	
- SA 375 kg @ shs 1/00		375	
Herbicide - gesaprim 5 l @ 50/-		250	
Insecticide - DDT 5%, 12.5 l @ 5/70		72	
Thinning 2md @ 10/45		21	
Manual weeding (supplementary) 5 md @ 10/45		52	
Harvesting (manual) 10 md x 10/45		105	
Field transport		30	
Grading & shelling 6 md x 10/45		63	
Packing material 40 bags @ shs 6/10		244	
Other labour:	(Fertilizer, herbicide and insecticide applications, etc) 10 md @ shs 12/-	120	
Miscellaneous expenses		230	2,112
Gross margin/ha = shs			1,288

APPENDIX A.5: MAIZE (MZE2) (Gm/ha)

REVENUE:

3,800 kg @ shs 0/85 = shs		3,230

LESS: VARIABLE COSTS

SEED 25 kg @ shs 2/80	70	
Machinery costs: tractors 9 hrs @ shs 30/-	270	
Fertilizers - TSP 150 kgs @ 1/40	210	
- SA 375 kgs @ 1/00	375	
Herbicide - gesaprim 5 l @ 50/-	250	
Insecticide - DDT 5%, 12.5 l @ 5/70	72	
Thinning 2 md x 10/45	21	
Manual weeding (supplementary) 5 md x 10/45	52	
Harvesting (manual) 9.5 md x 10/45	99	
Field transport	30	
Grading & shelling 6 md x 10/45	63	
Packing material 38 bags @ 6/10	232	
Other labour: (Fertiliser, herbicide and insecticide application, etc) 10 md @ 12/-	120	
Miscellaneous expenses	230	2,094
Gross margin/ha = shs		1,136

APPENDIX A6: SEED MAIZE (MZES) Gm/ha

REVENUE:			
Grd. A 60%: 2,340 kg @ shs 1/20		2,808	
Grd. B 40%: 1,560 kg @ shs 0/85		1,326	4,134
LESS: VARIABLE COSTS			
Seed 25 kg @ 2/80	70		
Machinery costs : Tractors 9 hrs @ 30/-	270		
Fertilizers - TSP 200 kg @ 1/40	280		
- SA 375 kg @ 1/00	375		
Herbicide - gesaprim 5 l @ sh 50/-	250		
Insecticide DDT 5%, 12.5 l @ 5/70	72		
Thinning 3 md x 10/45	32		
Manual weeding (supplementary) 5 md x 2 @ 10/45	105		
Pollination (labour) 5 md x 10/45	52		
Harvesting (manual) 10 md x 10/45	105		
Field transport	30		
Drying 5 md x 10/45	52		
Grading & shelling 9 md x 10/45	94		
Packing material 40 bags @ 6/10	244		
Other labour: (Fertilizers, herbicide & insecticide application) 10 md @ 12/-	120		
Miscellaneous expenses	300		2,451
Gross margin = shs			1,683

APPENDIX A7: SORGHUM (SRG1) (Gm/ha)

REVENUE:

2100 kg/ha @ 1/00	= shs		2,100

LESS: VARIABLE COSTS

Seed 40 Kg @ 3/80	152	
Ploughing (2.5 hrs @ 48/-)	120	
Harrowing (2 hrs @ 40/-)	80	
Planting & herbicide application (3.5 hrs @ 30/-)	105	
Field machinery labour 14 hrs @ 6/-	84	
Herbicide - gesaprim 4.5 l @ 50/-	225	
- application 2 md @ 10/45	21	
Thinning 2 md @ 10/45	21	
Manual weeding (suppl) 4 md @ 10/45	42	
Harvesting (manual) 10 md @ 10/45	105	
Field transport	24	
Threshing & winnowing 4 md @ 10/45	42	
Packing material 28 bags @ 6/10	171	
Miscellaneous expenses	55	1,247
Gross margin/ha = shs		853

APPENDEX A8: SORGHUM: (SRG2) (Gm/ha)

REVENUE:

2030 kg @ 1/00	= shs		2,030

LESS: VARIABLE COSTS

Seed 40 kg @ 3/80	152	
Ploughing (2.5 hrs @ 40/-)	120	
Harrowing (2 hrs @ 40/-)	80	
Planting & herbicide application (3.5 hrs @ 30/-)	105	
Field machinery labour 14 hrs @ 6/-	84	
Herbicide: gesaprim 4.5 l @ 50/-	225	
" application 2 md @ 10/45	21	
Thinning 2 md @ 10/45	21	
Weeding (manual) suppl. 4 md @ 10/45	42	
Harvesting (manual) 9.5 md @ 10/45	99	
Field transport	24	
Threshing & winnowing 4 md @ 10/45	42	
Packing material 26 bags @ 6/10	159	
Miscellaneous expenses	55	1,229
Gross margin/ha = shs		801

APPENDIX A9: SORGHUM (SRG3) (Gm/ha)

REVENUE:

1,880 kg/ha @ 1/00 = shs			1,880

LESS: VARIABLE COSTS

Seed 40 kg @ 3/80	152	
Ploughing (2.4 hrs @ 48/-)	115	
Harrowing (1.8 hrs @ 40/-)	72	
Planting & herbicide application (3.5 hrs @ 30/-)	105	
Field machinery labour 14 hrs @ 6/-	84	
Herbicide - gesaprim 4.5 l @ 50/-	225	
- application 2 md @ 10/45	21	
Thinning 2 md @ 10/45	21	
Manual weeding (suppl) 4 md @ 10/45	42	
Harvesting (manual) 8.5 md @ 10/45	89	
Field transport	20	
Threshing & winnowing 4 md x 10/45	42	
Packing material 24 bags @ 6/10	146	
Miscellaneous expenses	55	1,189
Gross margin = shs		691

APPENDIX A10: CASHEWNUT: (CSH1) (Gm/ha)

REVENUE			
480 kg @ 1/10	= shs		528
LESS: VARIABLE COSTS			
Pruning 3 md x 10/45		32	
Weeding: 2 weedings x 5 md x 10/45		105	
Harvesting 480 kg @ -/20		96	
Grading & packing 1 md x 10/45		10	
Miscellaneous expenses		35	278
Gross margin/ha = shs			250

APPENDIX A11: CASHEWNUT: (CSH2) (Gm/ha)

REVENUE			
470 kg @ 1/10	= shs		517
LESS: VARIABLE COSTS			
Pruning 3 md x 10/45		32	
Weeding: 2 weedings x 5 md x 10/45		105	
Harvesting 470 kg @ -/20		94	
Grading & packing 1 md x 10/45		10	
Miscellaneous expenses		35	276
Gross margin/ha = shs			241

APPENDIX A12: CASHEWNUT: (CSH3) (Gm/ha)

REVENUE			
440 kg @ 1/10	= shs		484
LESS: VARIABLE COSTS			
Pruning 3 md x 10/45		32	
Weeding: 2 weedings x 5 md x 10/45		105	
Harvesting 440 kg @ -/20		88	
Grading & packing 1 md x 10/45		10	
Miscellaneous expenses		35	270
Gross margin = shs			214

APPENDIX A13: LEY ESTABLISHMENT COSTS (per ha)

Seed (cynodon) 20 kg @ shs 8/-		160
Ploughing (2.5 hrs @ 48/-)		120
Harrowing (2 hrs @ 40/-)		80
Seed sowing 1 md x 10/45		10
Fertilizers: TSP 50 kg @ 1/40		70
SA 200 kg @ 1/00		200
Miscellaneous expenses		60
	shs	700

Amortized value over a period of 50 years at a compound rate of interest of 10% per year is:

$$= 700 \frac{[0.1(1 + 0.1)^{50}]}{[(1 + 0.1)^{50} - 1]} = 700 \times 0.1009 = 70.60 \text{ sh/yr}$$

For LEY 1 on land LAF1 average additional annual costs = 54.00 shs/yr.

$\therefore$ Annual costs = 70.60 + 54.20 = shs 124.80
i.e. shs 10.40 per month.

For LEY 2 on land LAF2 average additional annual costs = 58.00 shs/yr.

$\therefore$ Annual costs = 70.60 + 58.40 = shs 129.00
i.e. shs 10.75 per month

For LEY 3 on land LAF2 average additional annual costs = 63.00 shs/yr.

$\therefore$ Annual costs = 70.60 + 63.80 = shs 134.40
i.e. shs 11.20 per month

The formula used was:

$$\text{Amortized value } A = \frac{P[i(1 + i)^n]}{[(1 + i)^n - 1]}$$

Where: Annuity (A) whose Present Value (P) is 1 for a term of n years at a compound rate of interest i per year.

APPENDIX A14: POULTRY (Gm/ha)

REVENUE:

Eggs 1 x 365 days x 60% laying x -/53	116	
Cull bird (after 12 months laying) @ 17/- x 88%	15	131

LESS: VARIABLE COSTS

Purchase of chick (d.o.c.) @ 5/80	5.80	
Costs up to laying stage (6 months):		
- Feeds 0.048 kg x 180 days x 1/20	10.40	
- Vety drugs, vaccines & other medicaments	2.17	
- Labour	1.28	
- Other expenses	0.86	
Costs during laying (12 months):		
- Feeds 0.10 kg x 365 days x 1/10 + min. 0.365 kg x 12/-	44.53	
- Vaccines, drugs & other medicaments	6.24	
- Labour 1 person/1000 birds @ 380/- p.m.	4.56	
- Other expenses	6.76	82.60
Gross margin/bird = shs		48.40

APPENDIX A15: PIGGERY (Gm/saw)

Each sow farrows twice per year with an average survival of 6 porkers per litter. Porkers are sold at an average of 50 kgs dressed weight each at 5 months old.

REVENUE:

2 litters @ 6 porkers x 50 kgs @ shs 11/- = shs 6,600

LESS: VARIABLE COSTS

(1) Each porker for 5 months		
Feeds: 2kg x 150 days x 0/80	240	
Vety drugs & vaccines	30	
Labour $\frac{\text{(5 men x 380/- pm x 5 mths)}}{\text{600 porkers}}$ x 2 batches	32	
Sundry expenses	24	
12 porkers x	326	
=	3,912	
(2) Each sow for 12 months		
Purchase of gilt (33 1/3% of cost)	300	
Feeds: 2.5 kg x 365 days x 0/75	684	
Vety drugs & vaccines	40	
Labour $\frac{\text{(2 men x 380/-pm x 12 mths)}}{\text{100 sows}}$ + 20% overtime	110	
Sundry expenses	48	5,094
Gross margin/sow = shs		1,506

PURCHASE OF A REPLACEMENT GILT

The price for purchasing a replacement gilt elsewhere in the country is on average shs 900/-.

i.e. Average liveweight 90 kg @ shs 10/- = shs 900/-

APPENDIX A16: DAIRY COWS (Gm/ha)

REVENUE:		
Milk: 280 days x 6l/cow/day x shs 1/50 @ = shs		2,520
LESS: VARIABLE COSTS		
Feeds - concentrates 4 kgs x 280 days x -/65	728	
- Rice straw 20kg for 90 days x 0/10	180	
- Mineral supplements	72	
Vety drugs, vaccines & spraying	50	
Hygiene & related misc. costs	40	
Labour $\frac{\text{(5 men x 380/-pm x 12mths)}}{\text{100 cows}}$ + 25% overtime	285	
Milk fed to replacement calf 180 l x 1/50 x 15%	41	
Sundry expenses	30	1,426
Gross margin/cow = shs		1,094

APPENDIX A17: REPLACEMENT HEIFER (Gm/heifer)

Raised for two years

REVENUE: None shs		-
LESS: VARIABLE COSTS		
Labour $\frac{\text{(2 men x 380/-pm x 24 mths)}}{\text{100 heifers}}$ + 25% overtime	228	
Feeds: Milk (calf stage) 180 l @ 1/50	270	
Mineral supplements	120	
Rice straw (supp) 15 kg x 180 days x 0/10 (in dry season)	270	
Vety drugs, vaccines & spraying	84	
Hygiene & related misc. expenses	30	
Sundry expenses	48	1,050
Gross margin = shs		- 1,050

PURCHASE OF A REPLACEMENT HEIFER

The average price for purchasing a two year old replacement heifer elsewhere in the country is shs 2,500/-

APPENDIX A18: 1. SELL OF BULL-CALVES

Bull-calves are sold when they are a few days old at a price of shs. 50/- each.

2. SELL OF HEIFER CALVES

About 20% of the heifer calves are kept back annually as replacements, the remainder are sold when a few days old at a price of shs. 60/- each.

3. SELL PRICE OF CULL COW

Average liveweight 400 kg each
50% dressing percentage
Price shs. 5/50 per kg
∴ 400 kg x 50% x 5/50 = shs 1,100/-

4. SELL PRICE OF CULL SOW

Average liveweight 150 kgs each
72% dressing percentage
Price shs. 7/- per kg
∴ 150 kg x 72% x 7/- = shs 756/-

APPENDIX B: SCHEDULING OF VARIOUS OPERATIONS

APPENDIX B.1: RICE

Job	Time
First ploughing	August- September
Second ploughing	November-December
Harrowing	January
Levelling	Mid January-February
Planting	Mid January-February
Herbicide application	February-March
Irrigation	March-April
Fertilizer applications (twice)	March & April
Insecticide application	March
Hand weeding	March-May
Bird control	April-May
Drainage	May-June
Harvesting	Mid June-August/Sept (1st wk)
Field transport	June-August/Sept (1st wk)
Drying & winnowing	June-August/Sept
Milling & packing	July-March

N.B. (1) Extended harvesting goes on until end of September.

(2) Delayed planting starts in mid February to end of March.

APPENDIX B.2: MAIZE

Job	Time
Ploughing	Mid December - January
Harrowing	January - February
Planting	March
Thinning	March
Herbicide application	March
Insecticide application	March - April
Fertilizer application (twice)	April & May
Manual weeding (twice for seed maize)	April (and May for seed maize)
Pollination	May
Harvesting (manual)	July - August
Field transport	July - August
Grading & shelling	August - September (Sept. - October for seed maize)
Packing	August - September (Sept. - October for seed maize)

APPENDIX B.3: SORGHUM

Job	Time
Ploughing	January/February
Harrowing	February
Planting	March
Thinning	March
Herbicide application	March
Fertilizer application (twice)	March & April
Manual weeding	April
Harvesting (manual)	June - July
Field transport	June - July
Threshing, winnowing & packing	June - August

APPENDIX B.4: CASHEWNUT

Job	Time
Pruning	November - December
Weeding	July - August
Harvesting	September - October
Grading & packing	October

APPENDIX B.5: PIGGERY

Job	Time
First Servicing (mating)	February
First farrowing	June
Second servicing (mating)	August
Second farrowing	December
Sell-out (first litter)	November/December
Sell-out (second litter)	May/June

APPENDIX C1: RICE: MONTHLY VARIABLE COSTS (WORKING CAPITAL) BREAKDOWN (TZ Shs)

Period	Seeds	Combine Harvester	Tractors	Fertilizer	Herbicide	Weeding	Insecticide	Machine Labour	Electricity (Irrigation)	Transport	Drying	Milling Labour	Packing Material	Milling Electricity	Miscellaneous	Total
Jan			170		792			100				4		3	30	1099
Feb			164	408			52	40				4		3	30	701
Mar			45	58		40		100	40			2			30	315
Apr						40		100	40						50	230
May						24		40					100		50	214
June		30								10	15	5			30	90
July		40								20	15	5		4	30	114
Aug		30	105							10	22	5		4	30	206
Sept			125									5		4	30	164
Oct			29									4	68	4	30	135
Nov			130					50				4		4	30	218
Dec	360		130					50				4		4	30	578
	360	100	898	466	792	104	52	480	80	40	52	42	168	30	400	4064

APPENDIX C2: RCEH: MONTHLY VARIABLE COSTS (WORKING CAPITAL) BREAKDOWN (Tz shs)

Period	Seeds	Combine Harvester	Tractors	Fertilizer	Herbicide	Weeding	Insecticide	Machine Labour	Electricity (Irrigation)	Transport	Drying	Milling Labour	Packing Material	Milling Electricity	Miscellaneous	Total
Jan			170		792			100				4		3	30	1099
Feb			164	408			52	40				3		2	30	699
Mar			45	58		40		100	40						30	313
Apr						40		100	40						50	230
May						24		50					80		40	194
June		12								6	10	3			40	71
July		28								13	12	4		3	30	90
Aug		32	105							14	15	4		4	30	204
Sept		28	125							12	10	5		4	40	224
Oct			29					20				5	67	4	40	165
Nov			130					50				5		4	30	219
Dec	360		130					50				3		3	30	577
	360	100	898	466	792	104	42	510	80	45	47	37	147	27	420	4085

APPENDIX C3: RCDP: MONTHLY VARIABLE COSTS (WORKING CAPITAL) BREAKDOWN (Tz shs)

Period	Seed	Combine Harvester	Tractors	Fertiliser	Herbicide	Weeding	Insecticide	Machine & Other Labour	Electricity (Irrigation)	Transport	Drying	Milling Labour	Pacing Material	Milling Electricity	Miscellaneous	Total
Jan			110					40				5		4	30	189
Feb			198	408	792			90				4		3	30	1525
Mar			112	58			52	151	10			3		2	50	438
Apr						40		100	40						30	210
May						40		40	30				80		40	230
June						24		20							40	84
July		24								11	10	3			30	78
Aug		48	76							22	20	4		3	40	213
Sept		28	129							12	17	4		4	40	234
Oct			64				20					5	67	4	30	190
Nov			48				50					5		4	30	137
Dec	360		131				50					4		3	30	578
	360	100	898	466	792	104	52	561	80	45	47	37	147	27	420	4106

APPENDIX D1: LABOUR AVAILABILITY COMPUTATION

(a) Monthly casual labour availability

Period Code	Month	Available Labour (people)	Average per period	Total Hours	Effective Hours (85%)
LCOJ	October	49	60	38,400	32,640
	November	43			
	December	50			
	January	98			
LCFM	February	163	327	209,280	177,888
	March	355			
	April	400			
	May	390			
LCJS	June	212	115	73,600	62,560
	July	154			
	August	54			
	September	40			

(b) Permanent labour availability

Number of permanent employees = 115 people
Number of working hours/week/person = 40 hours
Number of working weeks/year = 48 weeks
Effective hours = 85%

Therefore, available hours = 115 x 40 x 48 x 85%
= 187,680 hours/year

For each of the 3 periods = 62,560 hours

APPENDIX D.2: COMPUTATION OF LABOUR REQUIREMENT PER ACTIVITY UNIT

Rice (RICE):	39	mandays x 6 hrs + 40 hrs	= 274 hrs/ha
Maize (MZE 1-2):	33	" x 6 hrs	= 198 hrs/ha
Seed maize (MZES):	52	" x 6 hrs	= 312 hrs/ha
Sorghum (MZE 1-3):	22	" x 6 hrs + 14 hrs	= 146 hrs/ha
Cashewnut (CSH 1-3):	20	" x 6 hrs	= 120 hrs/ha
Ley (LEY 1-3):	3¼	" x 6 hrs = 19.5 hrs	say 20 hrs/ha

Poultry (POU): $\frac{\text{1 person x 8hrs/day x 180 days}}{\text{1000 pullets}}$

$+ \frac{\text{1 person x 7hrs/day x 365 days}}{\text{1000 layers}}$

= 1.44 hrs + 2.56 hrs = 4 hrs/bird

Piggery (PIG): $\frac{\text{5 people x 1720hrs/yr + 2 people x 1920 hrs/yr}}{\text{100 sows}}$

= 124 hrs/sow

Dairy Cows (DAIR): $\frac{\text{5 people x 1920 hrs/yr}}{\text{100 cows}}$

+ 25% overtime = 120 hrs/cow

Replacement heifers (REPC): $\frac{\text{2 people x 6hrs/day x 365 days}}{\text{100 heifers}}$

= 43.8 say 44 hrs/heifer

Rice (with extended harvesting) (RCEH): 38 mandays x 6hrs + 45hrs = 273 hours/ha

Rice (with delayed planting) (RCDP): 43 mandays x 6 hrs + 45.5 hrs = 303.5 hrs/ha

APPENDIX E: COMPUTATION OF FIELD-MACHINERY TIME AVAILABILITY

The field-machinery time availability is the product of: -

(a) the number of work days in the period
(b) the percentage of days suitable for field work
(c) the number of machines (e.g. tractors, combine harvesters, etc) and
(d) the maximum number of hours each day that the machinery can be expected to be in the field.

(i) CRAWLER TRACTORS (D5)

January	: 26 days	x 80%	x 4	x 16 hrs	=	1331.2	hours
February	: 23 days	x 75%	x 4	x 16 hrs	=	1104	"
March	: 26 days	x 55%	x 4	x 16 hrs	=	915.2	"
August	: 26 days	x 90%	x 4	x 16 hrs	=	1497.6	"
September	: 25 days	x 85%	x 4	x 16 hrs	=	1360	"
October	: 26 days	x 70%	x 4	x 16 hrs	=	1164.8	"
November	: 25 days	x 75%	x 4	x 16 hrs	=	1200	"
December	: 24 days	x 80%	x 4	x 16 hrs	=	1228.8	"

(ii) TRACTOR (80-100hp)

January	: 26 days	x 80%	x 3	x 16 hrs	=	998.4	hours
February	: 23 days	x 75%	x 3	x 16 hrs	=	828	"
March	: 26 days	x 55%	x 3	x 16 hrs	=	686.4	"
August	: 26 days	x 90%	x 3	x 16 hrs	=	1123.2	"
September	: 25 days	x 85%	x 3	x 16 hrs	=	1020	"
October	: 26 days	x 70%	x 3	x 16 hrs	=	873.6	"
November	: 25 days	x 75%	x 3	x 16 hrs	=	900	"
December	: 24 days	x 80%	x 3	x 16 hrs	=	921.6	"

(iii) TRACTOR (60-80hp)

January	: 26 days	x 80%	x 8	x 16 hrs	=	2662.4	hours
February	: 23 days	x 75%	x 8	x 16 hrs	=	2208	"
March	: 26 days	x 55%	x 8	x 16 hrs	=	1830.4	"
August	: 26 days	x 90%	x 8	x 16 hrs	=	2995.2	"
September	: 25 days	x 85%	x 8	x 16 hrs	=	2720	"
October	: 26 days	x 70%	x 8	x 16 hrs	=	2329.6	"
November	: 25 days	x 75%	x 8	x 16 hrs	=	2400	"
December	: 24 days	x 80%	x 8	x 16 hrs	=	2457.6	"

(iv) COMBINE HARVESTER (FOR RICE)

June	: 25 days	x 40%	x 6	x 8 hrs	=	480	hours
July	: 26 days	x 85%	x 6	x 8 hrs	=	1060.8	"
August	: 26 days	x 90%	x 6	x 8 hrs	=	1123.2	"
September	: 25 days	x 85%	x 6	x 8 hrs	=	1020	"

(v) BORROWED TRACTORS (60-100hp)

January	: 26 days	x 80%	x 3	tractors	x 16hrs	=	998.4	hr
February	: 23 days	x 75%	x 3	"	x 16hrs	=	828	"
March	: 26 days	x 55%	x 4	"	x 16hrs	=	915.2	"