A LINEAR PROGRAMMING ANALYSIS
OF AN IRAQI STATE FARM

by

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ABSTRACT

In this study linear programming is used to develop gross margin maximising farm plans for an examplar state farm in Iraq. The activities of the farm included a variety of cash crops, fodder crops, poultry and livestock activities. Sensitivity analyses were also used to serve as a guide to the stability of the various plans. The effects of crop-rotations, buying in concentrate feedingstuffs, government constraints on outputs, and alternative price systems were examined. The data used were from a 1979-1983 survey of resource inventories, and represented conditions at average performance. Under the present Iraqi Agricultural policy, the results of this study indicate the importance of using crop rotation systems and of bought-in concentrate feedingstuffs. They also indicate that among all the alternatives considered, the dairy activity combined with certain fodder crops, poultry and malting barley as a cash crop is the most profitable combination. In a fully relaxed model, within Iraqi prices, poultry will dominate all the farm activities, while in a fully relaxed model with world prices, the solution is consistent with the existing farm plan. This study indicates the effectiveness of the linear programming technique in addressing the problem of farm planning. It also shows how influential the system of relative prices is upon the optimal solution. It is suggested the Iraqi authorities should establish an effective set of agricultural prices which stimulate agricultural production and satisfy a competitive equilibrium in the agricultural sector.

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CHAPTER 1

INTRODUCTION

1.1. The Problem

In spite of the Land Reform Act of 1970, Iraqi agricultural production has lagged behind population growth, causing the country to become a net importer of agricultural products. As a consequence, a major feature of this decade is concern with how to relax the constraints that have retarded growth in agricultural production. Low net farm income is frequently cited as an indication of problems existing in the agricultural sector of the Iraqi economy.

As in many developing countries, Iraqi agricultural resources are not efficiently allocated and the country's production is below its potential maximum. Therefore special efforts are required to overcome this constraint and the planning of the economy has been given high priority. Regarding planning for the agricultural sector, a greater effort should be made to determine the regional resource potential with view to generating practical recommendations on the optimum use of land and water resources; the improvement of farming systems and planning methods for the individual agricultural units; the development of an effective system of supporting institutions and services; and better utilization of human, mechanical, and capital resources in the agricultural sector.

Iraq is trying to reverse the existing situation. The principle objective of the Government is to improve the agricultural technology and farming practices in order to establish a fully-modernised agriculture on the country's land, reach self-sufficiency in food and achieve diversification of the economic base, particularly by expanding agriculture.

Natural resources are relatively favourable in Iraq, and agricultural development enjoys, at present, a high priority in the Government's development plan. There is no shortage of funds to handicap development efforts. However, a major constraint for an expanded development programme in Iraq is a shortage of trained manpower, including skilled farmers and technical personnel.

To assist agricultural development the Government of Iraq has decided to establish forms of agricultural production (cooperatives, collective farms, state farms), which allow the application of efficient management and modern technology. The Government has also the intention of giving increased emphasis to the establishment of state farms. State farms will be created for promoting development in the livestock sector, in rainfed agriculture and in the development of new lands. Because of their organisation and their objectives, as we shall see in Chapter 2, the state farms would have larger choices of technologies and input mixes to achieve their goals.

However, the increased use of fertiliser, better seeds and animal species, and the introduction of other improved technologies may not turn out to be economical and effective in increasing agricultural productivity by themselves. The question of better management of economic combinations of resources and products is an important area for investigation.

In this respect, emphasis should be given to micro-level planning for the individual agricultural production units, such as cooperatives, collective, state and private farms (a wider planning framework that deserves particular attention is the regional specialisation of Iraqi agriculture). It would be desirable to direct emphasis not only to the production of individual commodities, but also to the entire production structure, to the inter-relationships between various forms of agricultural production, and to better integration of livestock and crop production.

All Iraqi farms are faced with the above mentioned problems. But the problem of farm planning is of particular importance on the state farms, which are characterised by the combination of many activities, including cash and fodder crops, and some livestock. Since several activities are carried out on state farms, it is difficult for the farm manager to select the proper combination of activities that maximises farm income under given resource constraints. Farm managers need information concerning the relative returns from the various activities and combinations of activities. They also need to know the combination of activities which is best suited to the given set of resource conditions. Given this information, managers can make the necessary adjustments to improve the farm income.

There cannot be one single solution for all farms. The profitability of a particular resource depends upon the quality and quantity of other resources with which it is combined. The best plan for one farm may not be best for others because of the possible differences in land, labour, capital, and managerial abilities. Even the best plan for a particular farm is subject to change over time if the quantities and/or relative prices of the factors should change. An optimum farm plan for a particular farm, therefore, is the one which fits the resource constraints imposed by that individual farm and its operator for a particular time. In fact, added pressure has been exerted on the individual farm decision-maker in Iraq, since the supply of many products, and their prices, are under government control.

This study concentrates on the micro-economic problem of efficient resource use on an individual state farm (macro-economic problems are recognised but are not within the scope of this study). In order to focus on the main problems confronting those concerned with the allocation of available resources for an optimal pattern of crop and livestock production in a state farm in Iraq, the Al-Nahrawan State Farm was selected as a case study for this thesis, as discussed in Chapter 2. Initially prices, government farm programmes and other parameters, which the individual farm cannot directly affect, are treated as given. Subsequently the effect of changes in prices and resource constraints are investigated.

Statement of the Problem

Iraqi state farms possess sufficient resources, but do not employ them efficiently. The low returns they achieve is partially due to inefficient use of resources on individual farms.

Statement of the Hypothesis

An efficient plan based on linear programming, utilising the existing level of technical efficiency and input-output relationships, could increase resource use efficiency and returns to resources on individual state farms in Iraq.

1.2. Objectives

The farm case study approach may serve as an effective technique in guiding individual farm management decisions, particularly if the technique and information used can be adapted to the individual farm resource situations. In addition, some input-output data which are compiled for use in programming a farm case study may serve as a data source for individual farm linear programming on a wider basis in Iraq.

This research was initiated to explore alternative opportunities for increasing net returns on an individual state farm in Iraq. Planners might use this information as a guide to select the most profitable combination of activities to suit the farm resource constraints. It would also be possible to use the technique to guide resource allocation for other state farms.

The specific objectives of this study are:

1. To present a linear programming model in which the livestock activities and crop rotations can be selected simultaneously.

2. To formulate initial and alternative optimum farm plans for the Al-Nahrawan State Farm.

3. To estimate the resources used and unused, and to find the net returns for these optimum farm plans.

4. To determine the effects of introducing crop rotation constraints into the original planning model.

5. To examine the effects of buying concentrate feedstuffs rather than producing all of the livestock feed requirements.

6. To examine the effects of changes in prices or resource constraints on the optimal solutions. This will be done for two particular cases:

   (a) when farm outputs are not constrained.

   (b) when alternative prices are used.

7. To determine the ranges of the activity net revenue (or variable cost) for which the optimal solutions remain stable.

8. To compare the optimal solutions with the present farm plan, and between themselves.

9. To examine the factor demand curves for the most critical resources and services.

1.3. Method of study

From among many Iraqi state farms the Al-Nahrawan State Farm was selected as a case study for this research, for reasons discussed in Chapter 2. The major activities of this farm are dairy cattle, cash and fodder crops, and sheep and poultry.

To develop the planning model for the farm, several visits and meetings were made with each productive unit. The activity production processes were identified and the resource requirements for each process determined. Appropriate input and output prices were then determined, and the cost-return budgets developed for the production processes. However, in developing the enterprise budgets for the planning model, some data were insufficiently specified for a detailed programming analysis. For example, sufficient data were not generally available in the farm records for labour input data by activity and time periods. Thus, the farm records had to be supplemented with information gathered from the relevant administrations and agricultural institutes during my field work visits. Additional information was also obtained from several publications, in particular from research studies (specific sources are provided in the references). Often, the "standard" or "average" performance data presented are directly applicable to a particular situation; in other cases considerable adjustment had to be made.

Because of the availability of data, the establishment of the activity costs and returns were based on 1981 prices, while input and output quantities were based on the average for the period 1979-1983. The crop activity budgets were developed on a per hectare basis, and the livestock on a per unit basis. The net returns budgeted for each activity were returns over variable costs.

The resource constraints were set up and the farm plans were developed and then presented in such a way that they could be easily discussed. A detailed analysis and comparison of every plan was avoided. The main effects of different assumptions are picked out and discussed briefly.

The optimal plans under various resource situations were determined by using the simplex method of linear programming. Optimal solutions for variable resource and variable price programming methods were obtained by using the computer programmes presented in Appendix 2.

1.4. Outline of the Thesis

Following this introduction, a general description of Iraqi agriculture and farming structure in Iraq is provided in Chapter 2. In Chapter 3 the available resources of the Al-Nahrawan state farm are described and in Chapter 4 the existing structure of production, the required resources of the farm activities, and the farm costs and revenues are provided. In Chapter 5 optimisation and mathematical programming is reviewed and in Chapter 6 post-optimality and demand curve analysis is discussed. Chapter 7 gives a survey of selected literature on the use of linear programming for individual farm situations. Chapter 8 is devoted to the formulation of the basic planning model and the building of the input-output matrix of the Al-Nahrawan State Farm. The initial planning results and the effects of adding crop rotation constraints are presented and discussed in Chapter 9. Chapter 10 concentrates on the effect of changes in prices or resource constraints on the optimal solutions. The effects of using alternative world prices on the optimal solutions are investigated in Chapter 11. In Chapter 12 implicit demand curves for the farm's scarce factors of production are derived and discussed. The limitations of the models and data used are summarised in Chapter 13, while finally, in Chapter 14, the most important implications are drawn.

CHAPTER 2

IRAQI AGRICULTURE AND STATE FARMS

2.1. Introduction

This chapter is divided into the following sections: general comments on the major features of the Iraqi agriculture system; farming structure, and the institutional structure of state farming in Iraq; a brief historical review of the setting up of state farms and their aims in Iraqi agriculture; general characteristics of the management and administrative system of state farming in Iraq; and general concluding remarks on the implications of the further development of the planning system.

2.2. General Comments on the Major Features of Iraqi Agriculture

2.2.1. Introduction

The Iraqi approach to agricultural production organisation has been identified through official documents, and especially the Agrarian Reform Laws of 1958 and 1970. The economic achievements in the field of land reform are briefly reviewed to allow a better understanding of past experience in the socialisation of agriculture in Iraq and the reasons behind the new orientations in this field. As these orientations are not only of an economic nature, political and social aspects have been touched upon within the framework of that socialisation of agriculture, as defined by the government of Iraq.

The 1932 Law of Settlement of Land Rights gave the tribal leaders (Sheikhs) the status of legal owners of the land previously belonging to the tribes. The sheikhs, who were relatively few, therefore took control over large holdings and tribesmen were confined to work as tenant share-croppers under the direction of the sheikhs or their representatives. Moreover, city merchants rented land from the sheikhs and employed farmers as labourers or share-croppers. This system was based on short-term and immediate profits and impeded any substantial improvement of land potential through long-term yielding investments. The land owner was interested in returns for minimum effort. The share-cropper had no incentive to invest, and even if he intended to, his limited income would not allow him to do so. The Agrarian Reform Law of 1958 aimed to abolish the feudal system of land-holdings and organise better the agricultural production with a view to improving the standard of living of the rural population. Land ownership was limited to 250 hectares of irrigated land and to 500 hectares of rainfed land. Land owned in excess of this was expropriated and compensation paid. The law also decreed the setting up of cooperatives, with compulsory membership for new owners. By 1970 agrarian reform had abolished the feudal system, but had failed to achieve the projected increase in agricultural output. Lack of qualified people in sufficient number, and lack of appropriate resources impeded the implementation of the programme of agrarian reform. Furthermore, and especially at the beginning, the lack of data (on distribution of ownership, economic factors, assessment of the difficulties to be encountered, etc.) led to its inadequate execution and to ill-prepared projects. Up to 1970, it was argued that the only solution for Iraqi agriculture was a radical reorganisation of the institutional structure. This led to the belief in change towards socialised agriculture, with the breaking up of the institutional power structure by a new agrarian reform law. The Agrarian Reform Law of 1970 gave a new impetus to the Agrarian Reform Programme and set a new direction for the organisation of agricultural production in Iraq. The ceiling on land ownership was reduced, and fixed according to such parameters as: zones (rainfed, irrigated), land potential, method of irrigation, crops grown, location in relation to markets, etc.. Compensation for land requisitioned was abolished and land owners no longer had the right to choose the land they wished to retain. Collective distribution was to replace distribution of land to individual farmers in order to plan better the agricultural production, the conservation and development of resources and to take advantage of the perceived benefits of large-scale farming [FAO, 1975; pp.1-4].

There was rapid development in the socialisation of the agricultural sector. The number of state and collective farms increased, and the cooperative movement expanded rapidly.

2.2.2. Natural Resources

The Republic of Iraq has a total area of 43.492 million hectares, of which 43.397 million hectares are land area [FAOb, 1984; p.53]. Iraq is situated in south-west Asia and lies between latitudes 29^{o} 5′ and 37^{o} 22′ North, and between longitudes, 38^{o} 45′ and 48^{o} 45′ East. Geographically the country can be divided into four major areas:

(i) The Alluvial Plain. This comprises 1/5 of the area of Iraq and lies between the Tigris and the Euphrates rivers in the north, the Iranian frontier in the east, and the desert plateau in the west.

(ii) The Desert Plateau. This is situated in the west of Iraq and encompasses 3/5 of the country's area.

(iii) The Mountainous Region. This is situated in the north and north-east of Iraq and includes 1/5 of the area of Iraq.

(iv) The Terrain Region. This is a transitional region between lowlands in the south and the high mountains in the north. It forms 75 percent of the Mountainous Region [C.S.O., 1980; pp.9-10].

The Iraqi climate is continental and subtropical, with a rainfall system similar to that of the Mediterranean area. Rainfall occurs almost totally in winter, autumn and spring. Average rainfall values range from 50 mm in the far south-western parts to 1000 mm in the far north-eastern territories [C.S.O., 1983; p.12]. Water and land resources are relatively favourable in Iraq. The Tigris and Euphrates rivers are the principle sources of water. Potentially arable land is estimated at 12 million hectares or 27.5 percent of the total area of the country. In 1980 the cultivated area under winter crops amounted to 4.925 million hectares, while 2.825 million hectares were planted with summer crops. At present, land and water use intensity is relatively low. The strategy of the Government is to introduce new systems of cultivation intensively to utilise available land and water resources [FAOa, 1983; p.3].

2.2.3. Population and the Demand for Food

In spite of the rapid growth of population which has been characteristic for Iraq during the last two decades, Iraq is still sparsely populated in relation to its natural resources. The population of the country reached 14.6 million in 1983 [FAOb, 1984; p.69]. Between 1957 and 1983 the population of Iraq more than doubled (in 1957 Iraqi population was only 6.3 million [C.S.O., 1980; p.32]). This population increase created a substantially greater demand for food. The total population was estimated to reach 15.1 million in 1984 [FAOb, 1984; p.69] and the figure is projected to reach 17.6 million in 1990 [FAOa, 1983; p.4]. Therefore, in the future, due to further increases of population and personal incomes, substantial further increases in the demand for food can be expected. Attempts to meet growing consumer demands and decrease imports of food can be considered as the major policy objectives in agricultural planning.

2.2.4. The Role of Agriculture in the Iraqi National Economy

Iraq, as many other oil producing countries, is seriously concerned with diversifying its economy. Although the Iraqi agriculture system is diverse and many changes have occured since 1970, still one of the Government's principal objectives is to establish a fully-modernised agricultural system. However, the share of agriculture in the overall national product has continuously decreased over the past years as a result of the more rapid growth of the non-agricultural sectors of the economy. During the period 1960-1980, agricultural production increased by about 30 percent against a tenfold increase of the GDP during the seventies, mainly as a result of the rapid rise in income from the oil sector [FAOa, 1983; p.3]. In 1982, the share of agriculture in the total national income was about 9.9 percent [C.S.O., 1983; p.121]. In the past few years about 10 percent of national investment funds have been allocated to agriculture [C.S.O., 1983; p.129], whereas about 1.370 million (or 38.4 percent) of the active population (3.572 million in 1983) has continued to be engaged in agriculture, forestry and fishing [FAOb, 1984; p.69].

In an international comparison, Iraqi agriculture has been developed remarkably quickly during recent years. The output of the agricultural sector increased by 125.8 percent between 1975 and 1980 (at constant 1975 prices) [C.S.O., 1983; p.128].

The balance of agricultural trade is negative, reflecting the fact that agriculture has not been able to cope with growing consumer demands. In 1982 Iraq spent I.D.335 million on imported agricultural goods (I.D.209.8 for foodstuffs and I.D.125.2 for agricultural raw materials) [C.S.O., 1983; pp.166-167], while in 1979 the country spent I.D.198.9 million on imported foodstuffs, live stock and meat, dairy products, fruits and the like. The largest import items were cereals, and livestock and poultry products, at I.D.43.412 million and I.D.30.560 million respectively. The import of foodstuffs for animals is also notable, at I.D.1.677 million in the same period [C.S.O., 1980; pp.171-174].

The exports of agricultural goods increased by I.D.7.1 million between 1975 and 1980 [C.S.O., 1983; p.123]. Among the agricultural export products, dates should be mentioned first; these have been traditionally a major agricultural source of export revenue. Vegetables to neighbouring countries have also taken a growing place in exports (fruit and vegetables exports were I.D.14.911 million in 1979) [C.S.O., 1980; p.171].

2.2.5. Investment in Agriculture and the Level of Agricultural Production

Corresponding with the past growth in overall agricultural production, the capital stock of the agricultural sector has also been considerably increased. In 1982, the numbers of tractors and pumps in use reached 29,956 (249.6 tractors per 1000 hectares of arable land) and 37,736, respectively [C.S.O., 1983; p.86], while the number of harvesters and threshers was estimated to be about 5,490 [FAOb, 1983; p.288]. Gross domestic fixed capital formation in the agricultural sector increased by 28.2 percent (at constant 1975 prices) between 1975 and 1980 [C.S.O., 1983; p.128]. Reclaimed land was increased by 83,575 hectares during the same period (from 11,325 hectares in 1975 to 94,900 hectares in 1980) [C.S.O., 1983; p.125]. The total cultivated crop area increased by about 416,325 hectares in 1980 and 676.637 hectares in 1983 (241,2850 hectares in 1975) [C.S.O., 1983; p.115]. However, the yields of the major crops are still very low, both in absolute value and in international comparison (e.g. about 706 kg./hectare for wheat and about 1,217 kg./hectare for barley, compared with 2,143 kg./hectare and 2,116 kg./hectare respectively, for international levels in 1983) [FAOb, 1984; pp.110-114]. In 1980 the percentage shares of various crops in total cultivated crop area were as shown in Table 2.1.

Table 2.1. The Percentage Shares of Various Crops in Total Cultivated Crop Area in 1980 and 1983 (hectares).

Crop	1980(1) Area	%	1983(2) Area	%
1. Cereals	2,424,650	85.7	2,759,025	89.3
2. Vegetables	207,000	7.3	227,850	7.4
3. Fodder crops	56,525	2.0	na	-
4. Industrial crops	32,925	1.2	31,662	1.0
5. Legumes	55,050	1.9	34,125	1.1
6. Tubers and bulbs	24,050	0.9	14,350	0.5
7. Oil seed	28,975	1.0	22.475	0.7
Total	**2,829,175**	**100.0**	**3,089,487***	**100.0**

Note: na = not available. * Excluding fodder crop area.

Source:

(1) Ministry of Planning, Development of Iraqi Economy for the Period 1975-1980, part 2, Committee of Economic Planning, Republic of Iraq, Baghdad, 1983; p.115.

(2) C.S.O., (Central Statistical Organisation), Annual Abstract of Statistics, Ministry of Planning, Baghdad, 1983, pp.63-69.

With regard to livestock, in 1982 there were estimated to be 3.1 million head of cattle, 11.9 million head of sheep and 20 million chickens [FAOb, 1983; pp.217-223].

The growth in crop and animal production is shown in Table 2.2. This table shows that both total plant and livestock production increased between 1975 and 1980. Between 1980 and 1983, there were considerable fluctuations in the growth of Iraqi agricultural production, particularly in the volume of crop production.

Table 2.2. Percentage Growth of Iraqi Crop and Livestock Production (1975 to 1980 and 1980 to 1983).

	1975 (000 tonnes)	1980[1] (000 tonnes)	%change	1983[2] (000 tonnes)	%change
Total crop production	7,717.3	9,739.6	+ 26.2	..	..
Cereals	1,371.9	1,888.4	+ 37.6	1,816.5	-3.8
Forage crops	3,429.6	4,368.5	+ 27.4	na	..
Tubers and bulbs	133.4	230.9	+ 73.1	178.8	-22.6
Industrial crops	200.7	248.6	+ 23.9	121.2	-51.3
Vegetables	1,454.6	1,738.7	+ 19.5	2,233.0	+28.4
Fruit	377.8	609.1	+ 61.2	na	..
Dates	697.2	596.9	- 14.4	345.3	-42.2
Livestock production					
Red meat	97.3	115.3	+ 18.5	95.7	-17.0
White meat	37.9	103.7	+173.6	152.1	+46.7
Milk	296.1	310.6	+ 4.9	342.9	+10.4
Wool and hair	9.0	11.9	+ 32.2	18.2	+52.9
Eggs	618.7	972.9	+ 57.2	844.2	-13.2

Source:
(1) Ministry of Planning, Development of Iraqi Economy for the Period 1975-1980, part 2, Committee of Economic Planning, Republic of Iraq, Baghdad, 1983, (pp.116-117 for crop production and p.121 for livestock production).
(2) C.S.O., (Central Statistical Organisation), Annual Abstract of Statistics, Ministry of Planning, Baghdad, 1983; pp.63-65 for crop production and p.78 for livestock production.

Note:
Red meat = Beef, Veal, Mutton, Lamb and Goat meat.
White meat = Chicken and Fish.
na = not available
.. = unknown

The relatively favourable financial position of Iraq has facilitated high investment in agriculture in the past. Several new agricultural complexes, irrigation systems, and cattle and poultry breeding farms have been established. New crops have been planned in order to enable the development of the livestock sector. Consequently, it has been postulated that marginal land in the rainfed area would be used as range land and would be mainly devoted to the production of feed requirements for the development of the livestock sector. Agricultural development in Iraq is financed primarily from resources accumulated in other sectors of the economy rather than from capital earned by agricultural producers. The central allocation of investment funds is an important feature of Iraqi investment policy. In 1982, I.D.768 million was allocated for investment in agriculture, representing 10 percent of the total planned investment [C.S.O., 1983; p.129].

Iraq will probably continue to invest heavily in agriculture and rural development in the future as the government seeks to achieve self-sufficiency in food. If this is the case, increasing emphasis will be placed on livestock and other high-value products; for the production operations concerned, large-scale units are generally regarded to be the most appropriate areas for investment.

2.3. Farming Structure and the Institutional Structure of State Farming in Iraq

2.3.1. Farming Structure

The agricultural system of Iraq is a "mixed system" of private and socialised farms. At present there are four general types of farms in Iraq. The socialised sector of agriculture is represented by three types of farm systems; the first are state-owned farms, which constitute only a small proportion of the present production of the Iraqi agriculture sector, and cover 1.6 percent of the arable area. The second type of farm, involving only about 1.5 percent of the arable land, is the collective farm. These are 76 collective farms, spread over an area of 184,250 hectares with a total of 8,818 members. The great bulk of the socialised sector, involving 47.2 percent of the arable land, operates through cooperative farms. These form the third type of farm system, and there are 1,994 local and specialised cooperatives spread over an area of 5.664 million hectares, and these have 374,000 members. The fourth type of Iraqi farms, representing 50.3 percent of the arable land, belong to private farmers [MAAR, 1980; p.5].

Recently, a legal framework for establishing joint state and private agricultural enterprises was created to encourage private investment in agriculture [Law No.35, 1983]. However, the Iraqi government's intention is to eliminate peasant exploitation by following a "land to the tiller" policy. Government policy also stresses the primacy of increased production over the achievement of a specific form of agricultural enterprise. This involves a certain degree of centralised control to achieve a more complete satisfaction of the needs of society. Thus the individual private farmer can work individually but subject to the demands of the state. Also, new technology is coming to the countryside in a socialised form and all farms can take advantage of it, whatever their size and economic capacity. Consequently, the private farmer can be considered as an integral part of a developed socialist system.

Parallel with the Iraqi objectives in the field of agricultural development, large-scale, integrated agricultural settlements were created. These were intended to satisfy the Iraqi population's demand for food; to provide the required raw material for the national agricultural industrialisation; to ensure a considerable surplus of certain agricultural products for export; and to be centres for development of techniques and exemplars of modern methods. Therefore these agricultural settlements are likely to be the most efficient production organisations for increasing production and introducing better management techniques and modern technologies [FAO, 1975; p.9]. To this end, the most important assumptions are stated as follows:

(i) Large-scale firms are run on capitalist lines and maximise profits. Therefore, they would employ labour up to the point that the (positive) wage rate equalled the marginal product.

(ii) Large-scale firms are expected to raise sufficient capital to buy the essential inputs (which are usually very high), and to introduce new technology as soon as they can. In the case of Iraq, the direct supervision of the state provides the needed technical and financial resources.

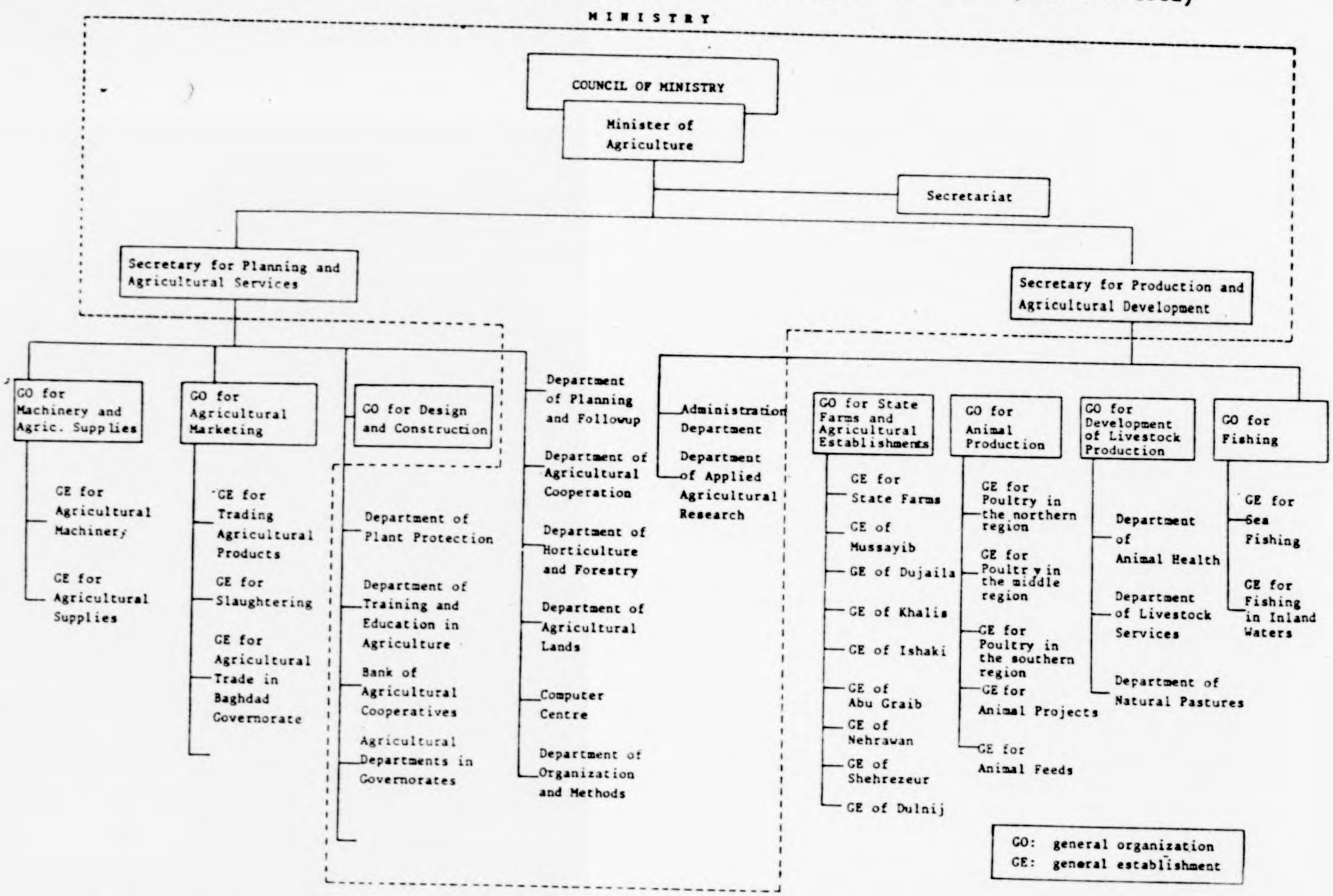
(iii) Since the units of production are assumed to be large scale, they have to be highly or fully mechanised. They are therefore expected to produce greatly increased quantities at greatly reduced costs.

2.3.2. The Institutional Structure of State Farming

As we have seen above, Iraqi state farms are fully integrated elements of a nationwide system. Figure 2.1 is an organisation chart of the national agricultural sector. Four major components exist in descending order: the Ministry of Agriculture and Agrarian Reform; General Organisation; General Establishments; and Production Units. The Ministry of Agriculture and Agrarian Reform and its functional departments represent the highest decision-making authority, the other divisions falling under its authority. There is distinct centralisation of decision-making in which the Ministry of Planning and the Ministry of Finance participate at the top of the hierarchy. Central targets are communicated and implemented, mainly through direct administrative means. Centralised decisions include: targets of production; targets for area allocation and yields; investment allocation; central financing; distribution of inputs; compulsory delivery to central marketing organisations; the setting of wages and salaries; and the fixing of producer prices.

The general organisation has both administrative and business functions, while the general establishments are the basic organisations of agricultural production and services. The latter operate as large-scale companies having several production or operation units/branches, which may be located in a given area or all over the country. The production and service units, such as crop production farms, animal stations, processing units, storage houses, etc., are the primary organisational elements of production and services, and have only limited authority and limited economic independence.

Figure 2.1. Organisation of the Ministry of Agriculture and Agrarian Reform (December 1982)



Source: FAOa, Organisation and Management of State Farming in Iraq, United Nations-Economic Commission for Western Asia, Joint ACWA/FAO Agricultural Division, Baghdad, 1983, p.7, (unpublished study).

The present organisation of the agricultural sector was established in 1979. The complicated institutional structure of state farming (Figure 2.1) comprises two general organisations, namely:

i. The General Organisation for State Farms and Agricultural Establishments (GOSE)

This comprises both state farms specialised in crop production and state farms with a mixed production structure (involving both crops and animals). Under GOSE, state farms are organised either within the General Establishment for State Farms (GES), or as one of a number of regional agricultural establishments (regional land and agricultural development projects).

ii. The General Organisation for Animal Production (GOAP)

Under this, farms specialise mainly in animal husbandry. They are organised into:

a. The General Establishment for Animal Project (GEAP) This manages only animal farms for cattle or sheep and, in addition, some land where green fodder, silage and hay are produced for the animal stock; and

b. The General Establishment for Poultry This manages only poultry farms. There are presently three general establishments for poultry, one each in the northern, central and southern regions.

As a result, it can be seen that there are four major levels in the system of organisational structure and at least three sublevels within each organisation (more details about the latter will be investigated in the next chapter).

2.4. Historical Review of the Setting up of State Farms and their Aims in Iraqi Agriculture

2.4.1. Historical Review

The historical account of the setting up of state farms is briefly reviewed in order to enable a better understanding of the past experience in the development of these state owned organisations, and (later on) the role they have achieved in Iraqi agriculture.

Government farms, as they were then called, existed in Iraq even before the implementation of the Agrarian Reform Law of 1970, the first government farm being established near Baghdad in 1921 [FAOa, 1983; p.5], and the second one near Al-Sulaimaniya in 1933 [AOAD, 1983; p.4]. Up to 1958 only five such farms were operational, with an area of 41,750 hectares. These farms were recognised to be of an experimental nature, and specialised mainly in the production of cotton and some selected seeds [AHMAD, 1980; p.62]. Five more government farms were organised after 1959 as a result of the implementation of the first Agrarian Reform Law. This was done with the help of the Soviet Union, which had practical experience in this domain, under the 1959 agreement for economic and technical cooperation. This included the establishment of specialised farms to produce main crops such as cotton, sugarbeet, rice, medical plants, and cereal crops [HABIB, 1976; pp.407-410]. The development of state farms received great attention under the Second Agrarian Reform Law of 1970. As a result, a large expansion in numbers and aims of specialised and mixed state farms has taken place, in order for them to occupy a decisive and leading position in the productive operation of the agricultural sector. In the seventies the number of state farms and the area covered by them rapidly increased. As a result, by 1980 the number of state farms reached 29, with an area of 213,500 hectares, contributing no more than 2 percent of the gross output [FAO, 1983; p.5]. During the same period, independent and integrated farming units were created for specialised and mixed animal husbandry. The state owned animal husbandry and the state owned mixed farms, which have been established recently, represent the second major element of Iraqi state farming in addition to crop farming (see next section).

2.4.2. The Aims Behind the System of State Farms in Iraq

The large-scale establishment of agricultural settlements, which in my interpretation includes all types of agricultural production (crops, animals, seeds, etc.) performed by state owned organisations, are an important element of the country's agricultural economy. They were established to fulfill several aims (details can be found in HAC [1978], AL-KHAFFAF, KATHEM and KAMEL [1979], FARAJ [1979], MAAR [1980; 1981], and AOAD [1983]):

- To ensure the required level of supply of certain agricultural products (strategic commodities) and especially of raw materials for agro-industries.

- To provide the cooperative and private sector with the improved seeds and breeding stock required for the rapid growth of agricultural production.

- To serve as exemplars of modern methods (as models) and experimental stations for the surrounding farms, especially collectives and cooperatives.

- To give leadership in agricultural technology, by introducing new crops and new technologies and by large scale testing of the results of applied research at institutions and research stations.

- As they demonstrate the advantages of large-scale production, they would have to be the most efficient agricultural production organisations in the country, in order to obtain the greatest possible increase in supplies by raising the productivity of agriculture, within the national plan [AL-DAHIRI, 1976; p.4].

- They would have to maintain social efficiency by playing an effective part in establishing the equilibrium in the consumption market and between crop and livestock production. Therefore they have to increase the importance of the market and support the agricultural integration policy [Al-Khattab, 1979; p.45].

- Since state farming was seen as the ideal form of organisation of agricultural production, and exemplars of socialist cooperation, they would have to be the basic forms of socialised agriculture in the country, at least in the first phase of the socialisation of agriculture (the base of the state in its activity in the agricultural sector) [HABIB, 1976; p.416].

In addition to the previous tasks, state farming has cultural, social and political effects. On the political side, state farms occupy an important position in developing the national economy; they can play an effective part in supporting the national regime and assist socialist transformation. Also state farms can be used as an effective instrument against foreign monopolies for some seed and industrial crop production.

On the cultural side, state farms perform educational and guidance roles, as they are frontier models and centers of diffusion for the surrounding district. In addition they play a great role in socialist reconstruction in agriculture and deepening the cooperative structure in the rural areas [ATIYAH, 1981; p.17].

On the social side, state farms play an active part in raising the workers health, cultural and material standards, thus playing a part in reducing the welfare gap between urban and rural areas. Also, state farms provide large-scale employment, especially in the districts which have an unemployment problem. Moreover, state farms lead to conditions allowing improvement in the peasants' outlook, guiding them towards a scientific and socialist view of the world. Also, the relationships between the educated agricultural staff and the agricultural workers helps to remove the workers from their inert isolation and individuality.

2.5. General Characteristics of the Management and Administrative System of State Farming in Iraq

Based on field work investigations, in May and June 1984, at selected state farms and most of the organisational units discussed in previous sections (including visits, meetings and the study of documents and formulae used), I concluded that the basic principles of management and organisation are rather similar at the various components of the state farming system. However at the local level there are certain differences in the quality of the work at the individual farms, particularly the quality of management. The major characteristics of the management and administrative system of state farming in Iraq may be briefly illustrated here.

i. Decision-making in state farming is centralised and while it is based on economic principles, political, strategic and social considerations play an at least equal role. The execution of plan targets and the organisation of production operations are under the authority of the individual farms.

ii. The system of state farming in Iraq comprises four major levels and at least three sublevels within each organisation, with the parallel existence of GOSE and GES. The necessity for all of these existing levels in the organisational structure system is undoubtedly questionable in any system of economic management.

iii. Iraqi state farms operate with limited financial independence. The farms are expected to finance direct cash expenditures from returns on the sale of products and certain outside services. All income remaining goes to the government budget. In the event that there are losses, they are covered by government resources. Therefore, the overall financial consequences of farming are never calculated. The depreciation of fixed assets is not considered, and the real financial balance of a given year is not compiled. The income or loss reported does not reflect the annual financial results. The new investments, the replacement of old machinery and buildings, the development of the irrigation facilities and the expenditures of the land reclamation programmes, are fully financed by the government (they form part of the free-of-charge investment programme).

iv. The accounting system of state farms follows the same principles as the financing. This system satisfies the needs of the central financial organisations; it does not take into account the needs of production management and decision making. Actual production operations are not recorded according to products and production units; operations having no direct cash results remain completely out of the system. The output and cost data pertaining to the most recent production period are collected by the Planning and Follow-up Department to assist planning for the next year.

v. Skilled and manual field workers are paid according to the days spent actually working. Basic daily wages are determined by the government, although there are concrete attempts to replace this practice with payments based on actual output.

vi. Since the availability of qualified personnel at all levels of management and administration is the major factor determining the success of the state farms, especially when the role of managers is complex, strong professional ability is required. However, the shortage of qualified personnel at the production process levels of management appears to be a key obstacle to the efforts of improving the efficiency of the state farming system.

vii. Most of the highly skilled managers work at the top of system, relatively far from the farming units. There is a shortage of qualified personnel at the lower levels of management, especially of the production managers needed to improve the efficiency of the system. The administration covers only manual work and it is organised in a traditional way. In management and administration only desk calculators are used; accounting machines and computers are not used. The farms are equipped with the necessary means of communication such as telephone, telex and radio.

viii. State farms in Iraq are very well equipped with modern machinery and buildings. The level of mechanisation and capital investment seems relatively high compared with the economic potential and the skills and traditions of the work force.

ix. The methods used in organising field operations do not seem to fit completely the available technology. The efficient use of machinery and equipment requires the detailed scheduling and organisation of each major operation. These organisational plans should cover all the equipment and manpower of a given operation, and determine the required capacities and desirable uses.

x. Lastly, but not least, the planning and budgeting system of state farming in Iraq was investigated in more detail, regarding its connection with the core of this study.

Planning starts at the farm level on the basis of central guidelines; farm proposals are discussed at General Establishment and

General Organisation levels with feedback to the farms. Finally, the Ministry of Agriculture and Agrarian Reform reviews and approves plans, in consultation with the Ministry of Planning. The discussions taking place at this stage offer the possibility of a consensus being reached.

Medium-term (five year) and annual plans are developed at every level of the state farming structure. Both medium-term and annual farm plans have a similar content, comprising:

a. Production targets: crop and animal species; area allocation and number of animals; yields and outputs; and direct physical input requirements at farm level.

b. Investment needs are calculated on the basis of production targets and available physical resources, without feasibility and efficiency studies.

c. Budget (annual plan only): calculations of direct cash expenditures and returns at the farm level. These plans do not cover all important areas of farming.

2.6. Conclusions

There is a great deal of dissatisfaction and some disappointment among officials and scientists concerning the performance of some of the state farms, especially those operating in crop production. However, previous studies suggested different interconnected recommendations, following from the common assumption that Iraqi state farms should be managed according to economic principles to reach a higher level of efficiency than at present. The lack of skilled managerial staff is mentioned as the major hindrance to achieving production and economic targets. Five other areas were listed by AL-DAHIRI [1976] and FARAJ [1979] as major problems for the state farming system. These were shortage of well trained labour; poor operation and maintenance of farm machinery; inadequate use of the irrigation systems; the low level of social services available for farm employees; and the lack of a well-designed planning system.

We have seen that state farming in Iraq seeks to achieve various targets, which having close links with the whole agricultural sector and the national economy. It therefore has the difficult task of achieving several requirements at the same time (objective evaluation requires well-defined objectives and clear priorities) and cannot be evaluated apart from the rest of the economy and the economic management principles applied in the country. In addition, economic efficiency and profitability can hardly be reached through a system that operates only partly on the basis of economic principles, where personal incentives do not encourage better economic results. Also the system of free investment and large subsidies do not generally contribute to economically more efficient solutions and do not foster efforts to improve economic performance. Moreover, the transformation of traditional agriculture into an efficient sector of the economy could be a much more difficult task than introducing new industrial methods and technologies.

The establishment of state farming is a long-term process. Its successful realisation requires the coordination of many development activities and the sustained and strong commitment of the government.

In view of the previous assessment, the achievements of the state farming system in Iraq must be acknowledged. The necessity and importance of this sector in Iraqi agriculture should not be questioned solely on the basis of some present disappointment in some economic results. Of course, considerable further improvements can be effected in the state farming sector, mainly along the lines of the removal of bottlenecks and other shortcomings mentioned in this section.

Without question, the most pressing tasks to improve the efficiency of the existing state farming organisations include:

(i) the strengthening of the economic principles in the management of state farms, which necessitates a definition of objectives and the setting of targets for state farming, and the determination of policy instruments to achieve central targets

(ii) the decentralisation of decision-making in some form, especially in plan targets

(iii) the introduction of more efficient personal incentives, especially a performance-based wage system for manual and technical workers with relation to actual measured output in every operation

(iv) the further simplification of the management structure of state farming

(v) the better integration of crop and livestock production enterprises with the introduction of better rotation systems

(vi) the establishment of food processing facilities to create true agro-industrial complexes covering the entire chain of food production within the organisation

(vii) the further development of the planning and financial systems, in order to facilitate the setting of appropriate economic objectives and the monitoring of their implementation (further details in Chapter 14).

The core of this thesis is a study of the Al-Nahrawan State Farm, which is organised within the General Establishment of Al-Nahrawan; this has been studied in detail for several reasons:

1. Its economic importance, which can be shown by:

i. its location (near Baghdad, the biggest consumption center in the country);

ii. its products, which are mainly milk (either for direct consumption or for dairying) and also meat, wheat and malting barley;

iii. its economic tasks for the surrounding collective, cooperative, and private farms.

2. It is considered as the most developed diffusion center in the country in providing support to social, cultural and political affairs, not only for the surrounding peasants and the whole district, but also at the level of Iraqi agriculture in some aspects

(e.g. it has the only training cooperative centre in the country).

3. It is considered as a pilot farm and a main centre to undertake certain agriculture research, and to apply new technologies in large-scale integrated production and marketing.

4. It has relatively certain available data necessary for this research.

The farm is described in more detail in the following chapters.

CHAPTER 3

THE AVAILABLE RESOURCES OF THE AL-NAHRAWAN STATE FARM.

3.1. Introduction

This chapter comprises four sections. The first deals with the organisation and the present management system of the General Agricultural Establishment of the Al-Nahrawan; the second gives a brief historical review of the development of the Al-Nahrawan State Farm, and also focuses on its organisational structure; the third section concentrates on the physiographical conditions of the Al-Nahrawan area; the last section reviews and assesses the available productive resources of the Al-Nahrawan State Farm.

3.2. General Agricultural Establishment of the Al-Nahrawan (GAEN)

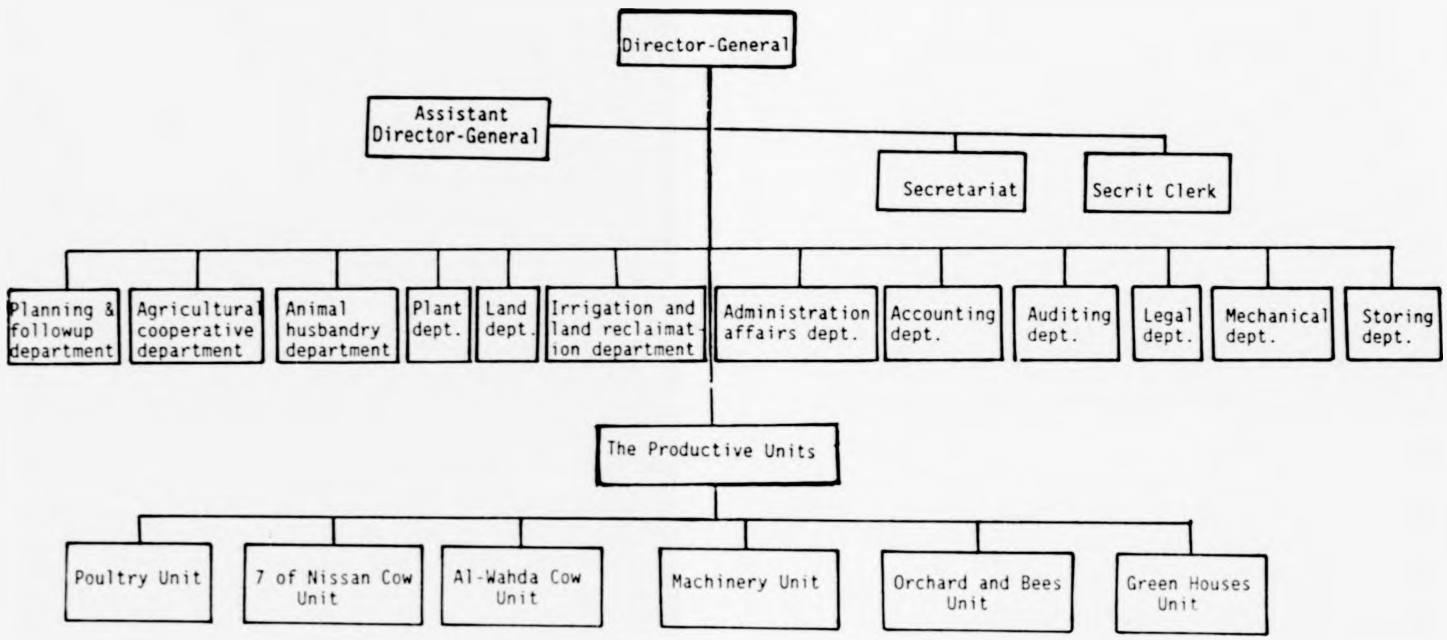
The General Agricultural Establishment of the Al-Nahrawan is a regional land and agricultural development project. It was established in the second half of 1978, and received considerable attention from the government. The major objectives of the establishment is to set plan targets for productions and yields, and to serve in agricultural and rural development. The General Agricultural Establishment of Al-Nahrawan provides vegetables, grain, fruit, honey, wood, animal and poultry products for the surrounding area, especially for the city of Baghdad. In addition, houses, a training center, schools, health centre, roads, water and electrical power systems were constructed under the centrally financed development programme. The investment in development of agricultural production facilities is one of the establishment's tasks. Land and water for agricultural investment are also provided by the project.

The total area of the GAEN is 123,750 hectares, of which 75.35 per cent (93,250 hectares) are irrigated land. The total area of land available for cultivation is 103,500 hectares. Family holdings account for 13,000 hectares (10.5 per cent of the total area). An area of 110,750 hectares (89.5 per cent) is organised under the socialist sector, of which 5.46 per cent (6,048.5 hectares) is for the state farm, 29.68 per cent (32,875 hectares) for the cooperative farms, 19.41 per cent (21,500 hectares) for the Ministries and administrative officials, and 45.45 per cent (50,325 hectares) under the direct control of the General Agricultural Establishment of Al-Nahrawan [GAEN, 1984; MAAR, 1981].

The organisational structure of the GAEN is shown in Figure 3.1. The Director-General is the chief executive, with centralised decision-making power. Because of its huge activities and tasks, GAEN has a large number of organisational units; some of these relate to the state farm and others to the cooperatives. However green houses, orchards and the machinery units are run by the GAEN directly, while the planning, cooperative, animal husbandry, crop production, land, irrigation and land reclamation, administration affairs, accounting and storing departments all have tasks and responsibilities for the whole establishment area, including small farm holdings, cooperative, state farm, establishment management itself, and the establishment infrastructure.

From a managerial and organisational point of view, GAEN may be considered a large, diversified agricultural production firm, having functions such as representing the government to the small farm

Figure 3.1. Organisational Structure of the General Agricultural Establishment of Al-Nahrawan



Source: Farm records, 1984.

holders. It is also entrusted with important social, political and cultural functions by virtue of its managing complete projects, including infrastructure development and extension services. The functions of such a large organisation may cause lower efficiency and be at the root of substantial losses. But of course, under careful management and sound planning, it may bring equally substantial benefits to each component of the system. Economically, the cooperation between large-scale and small-scale production seems to offer advantages for both parties and may fulfill important political and social roles as well.

Within the GAEN during 1984-1985, state farming management was reorganised into one state farm, the Al-Nahrawan State Farm. This reorganisation was because of the interrelationships between the diversified responsibilities, coupled with a shortage of specialist and administrative staff. At present four major productive units and an administration unit have already been allowed to function separately by the state farm.

3.3. The Al-Nahrawan State Farm

Two state farms, the Al-Wahda and the 7 of Nissan farms, were the basic units of the Al-Nahrawan state farm. Therefore a brief review must be made of the historical development of these farms and then the present organisational structure of the Al-Nahrawan state farm will be examined.

The **Al-Wahda State Farm** was established in the middle region of Iraq in 1965. It was located to the south-east of Baghdad, about 40 kilometers from the city centre, by the main road between Baghdad and Al-Kut city. It lay on the left bank of the Diala river. The total area of the farm was 2,375 hectares, of which 2,043 hectares were available for cultivation. The farm produced grain and field crops. In 1972 animal husbandry started to take a place in the farm plans, therefore a building with a capacity of 250 dairy cattle was constructed. Poultry raising also began in 1972, with the construction of a 480m^2 poultry field. In 1976 bee keeping started, with a total of 290 hives. 180 green houses (for vegetable production) were established in 1977, each with an area of 180m^2. In 1978 there was 513 head of dairy cattle, with the total capacity of the extended buildings being 600 head. Eight poultry fields, with a capacity of 24,000 birds, were established in order to produce eggs commercially [Farm records, 1979-1984; MAAR, 1981; pp.96-100].

The **7 of Nissan State Farm** was established on 7 April 1970, as an exemplar state farm. It was located in the same area as the Al-Wahda state farm, about 16 kilometers from the new bridge of Diala. The total area of the farm was 3,673.5 hectares, of which 2,606.5 hectares were cultivated land. It specialised in grain and field crop production. Since 1975, animal husbandry has begun to have greater importance, therefore green and seed fodder crops have become the major crops in the farm. Sheep breeding began in 1973 with a stock of 1,248 head. Poultry raising started in 1974 with 4 buildings of 140,000 birds total capacity. In 1975 80 Friesian cows were bought and buildings for 1,200 dairy cattle were constructed. In 1977 an orchard was established and an area of 5,000 hectares dedicated to fruit production. However, in 1978 the number of sheep fell to 10,491 head and the dairy herd was reduced to 1,093 head, while the total capacity of the buildings was 2,400 head. Eight poultry fields, with a total capacity of 280,000 birds, were used for poultry-meat production [MAAR, 1981; pp.90-95; Farm records, 1970-1978].

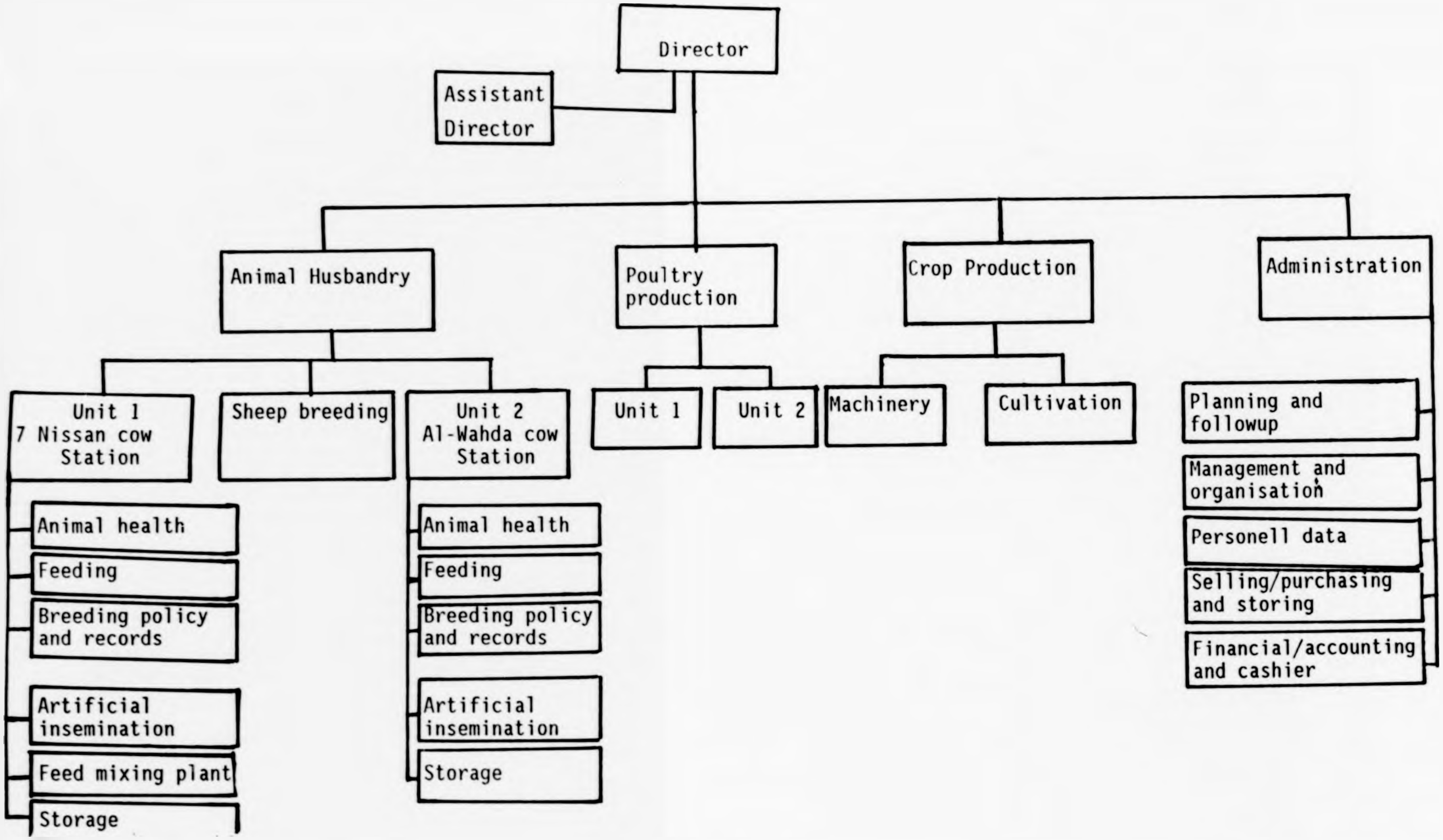
In 1978 both farms came under the management of the socialist sector of the GAEA, when they were oriented to specialise in animal and poultry production. In 1983 the farms were merged and organised into the state farm of Al-Nahrawan, in order to apply a new system of specialisation, utilising productive units and skills from the previous Al-wahda and the 7 of Nissan state farms [Farm records, 1978-1984].

3.4. The Organisational Structure of the Al-Nahrawan State Farm

The internal organisational structure of the Al-Nahrawan state farm is shown in Figure 3.2. As we can observe, the organisation of the farm follows the main branches of the activities. The farm operates within the framework of an annual plan. The single decision-maker of the farm is the director. All the main organisational units are managed directly by him. According to decision-making practice, the execution of plan targets and the organisation of production are under the authority of the farm. The management and administrative organisation of the Al-Nahrawan state farm follows this plan and the principles and structure that exist at the General Establishment of the Al-Nahrawan.

As shown in Figure 3.2, there are four major organisational units immediately supervised by the director. These are animal husbandry,

Figure 3.2. Organisational Structure of the Al-Nahrawan State Farm



Source: Farm records, 1984.

poultry breeding, crop production (including the machinery station), and administration.

The animal husbandry unit is the main organisational unit of the farm. It comprises, mainly, the 7 of Nissan cow unit and the Al-Wahda cow unit; each unit keeps Friesian dairy cattle. The main product of each unit is fresh milk, which is delivered to the milk-processing industry. Heifers are raised for breeding; at present they all remain at the farm for replacement and increasing the cattle stock. The bulls are fattened on the farm and sold to the slaughtering industry. Within the animal husbandry units, highly skilled specialists are in charge of the breeding policy, the health of the animals, feeding and artificial insemination. Breeding records are kept and the feed-mixing plant, which stores and weighs foodstuffs, also operates within this unit. The technology of milk production is up to date and all the equipment necessary for efficient production is in place. The milk yield is 2,850 kgs per cow, which is an acceptable level for the present conditions.

The crop production unit is in charge of the farm crop land. All field operations, including irrigation and machinery servicing, are organised by this unit. Fodder, such as alfalfa, maize, barley, etc., is produced for the farm's own needs.

The poultry unit is managed by an independent production unit which is in charge of breeding poultry for the commercial production of table eggs. The unit has no land for producing feed, which is supplied from outside the farm. The unit is equipped with relatively modern, efficient technology. Animal diseases and rat control seem to be the major problems for the unit's operation. The unit's decision-making authority is limited to the execution of the annual plan, which is focused around production targets, though of course the farm's proposals are considered in the planning procedure. The financial independence of the unit stays also within the framework of the execution of the annual plan.

The farm has a sheep production unit, using desert land with additional feeding from crop land grazing. It operates directly under the director of the animal husbandry unit. Since the government's decision (at the end of 1981) to direct all the state farms in Iraq not to raise sheep, this unit is disappearing from the farm's activities.

The maintenance and operation of machinery falls under the machinery sub-unit, which is a semi-independent unit and in charge of the execution of central objectives and targets. It has an independent system for accounting and financing in order to control its operations. Consequently, the productive units pay their machinery costs according to a standard cost per hour. However, the use of machinery is based on an annual plan, decisions being made by the director at regular meetings of unit heads.

Because of the nature of its production, only relatively few of the Al-Nahrawan state farm staff are used for administration, planning and follow-up, management, personnel, selling, purchasing and financing.

There is no real accounting work at the farm; only cash expenditures and returns are recorded by the cashier. Most of the administrative work is done at the general establishment level. The basic indicators of economic efficiency, such as feed conversion rates, unit costs and average annual grain yields are rarely calculated.

3.5. Geographical Situation of the Al-Nahrawan State Farm

The Al-Nahrawan State Farm is located 40km to the south-east of Baghdad area in Al-Madaeen Kaza. It lies at latitude 33^0 North and longitude 44^0 East, at an altitude of about 34.5m above sea-level [C.S.O., 1976; p.42]. The topography of the General Establishment of Al-Nahrawan is generally level to gently undulating. It lies on part of the alluvial plain and falls steadily from the north to the south; its altitude varies from 31m in the south to 38m in the north [Al-SAIDI, 1982; p.37].

Climate in the midle region of Iraq is continental and subtropical, arid to semi-arid. It is hot and dry in summer, cool in winter. There are great temperature variations between day and night, summer and winter; the maximum temperature reaches 45-50C. In winter warm weather prevails, the temperature remains above the frost level except for a few nights [C.S.O, 1983; p.12]. Temperature ranges are between 41C, from June to September, and 16C in winter. The average temperature ranges between 21 - 35C during the summer and it falls to 6C in winter time. Annual mean temperature is about 22C. The difference between the maximum and the minimum temperatures during the year is about 29C [C.S.O., 1983; p.38].

The annual mean relative humidity is about 43 percent, while the lowest relative humidity is about 23 percent in June and July; the highest is 72 percent in January [C.S.O, 1983; p.38].

Annual mean rainfall is 147 millimetres, of which 124.6 millimetres fall between December and April [C.S.O., 1983; p.41].

The whole area is under the influence of the north-western wind, which prevails in Iraq during all seasons of the year. It is cool and dry in winter whereas in summer the wind moderates the weather [C.S.O., 1983; p.12]. The annual mean wind speed is 3.54 km/hour, and its range is between 3.65 km/hour in April and 5.37 km/hour in August [Al-SAIDI, 1982, p.40].

According to the 1983 data, the mean daily incoming radiation is 499 mw/cm^2, and the mean daily sunshine duration is 9.1 hours [C.S.O., 1983; p.44]. The normal mean sea level pressure is 1010.1 m.b. [C.S.O., 1983; p.42].

3.6. The Available Productive Resources of the Al-Nahrawan State Farm

According to the existing financing system of Iraqi State farms, some of the direct physical inputs to production are not limited by any budget; these include fertiliser, seeds, pesticides, concentrated feed, medicines, etc.. Now these inputs are related to the real executed level of the farm activities, so they will not be considered as scarce resources in studying the available productive capacity of the farm's resources. Disregarding financial resources as a constraint therefore, the available resources of the farm will be classified, and then studied, under the five following sub-sections: (i) cultivable land (ii) water available for irrigation (iii) labour (iv) buildings and the fixed equipments assets, by types and capacities (v) machinery and equipment.

(i) <u>Cultivable Land</u>

Some land of the Al-Nahrawan State Farm has already been allocated to the 7 of Nissan and the Wahda cow stations. The total area of the 7 of Nissan cow station is 3,673.5 hectares. The land available for cultivation amounts to 2,606.5 hectares, or 71 percent of the total area. Of this, 500 hectares are under orchards, bees and green-houses. Therefore 2,106.5 hectares are available for crop production, of which only 1,000 hectares (47.5 percent) have already been restored and brought into use. Accordingly, the cultivated area under summer crop production cannot exceed the irrigated land area as scheduled in the annual plans of the farm, while that which is under the winter crop could be equivalent to the whole area of the crop land available.

The Al-Wahda cow station forms the rest of the total area of the Al-Nahrawan state farm. Its area is 1,850 hectares, of which 1,737.5 hectares are cultivated land and available for winter crop production. The total area available for summer crop production is 687.5 hectares, as determined by the irrigation system and the area of the restored land.

The soil of the Al-Nahrawan farm is alluvial, and had been deposited by the Tigris river and influenced by the alluvion (alluvium) of the Diala river [CAAS, 1978; p.37]. Gypsum ($CaSO4.2H_2O$) is present in concentrations between 2-3 percent in the vast majority of the farm's soil. The land has been classified, by the General Establishment of Land and Land Reclamation [GESLR, 1979; pp.5-9], into three arable classes and two classes of non-arable land, of which appropriate use is possible under very favourable economic conditions (data on the area of each class are not available).

1. Class 1 - Arable: The soil limitations are related to the very low content of organic matter, the moderately low phosphorus content, the very high lime content, the relatively unstable structure and the limited depth of the Mesopotamian Alluvium. This class of land exists at the front of the farm by the edge of Diala river. It has the highest potential for agricultural use.

2. Class 2 - Arable: Soils deeper than 1.5 metres, with moderatly good structure and fairly uniform texture, and not limited by drainage and topography, are mapped as class 2 land. Where drainage and/or topography are limiting, the land class cannot be higher than class 3. The soil in this land class has no salinity-alkalinity problem, i.e. the PH is less than 9.0 and total salts do not exceed 0.5 percent. The class 2 lands are undulating, with smooth slopes (generally 0.5 - 3 percent). Drainage conditions, both surface and internal, are not limiting

and irrigation can proceed without special pre-treatment. All the class 2 lands are at present used for feed crops.

3. Class 3: Arable. Arable land of low capability: This land is inferior to class 2 for irrigation development. Where topography is limiting, reclamation methods will include grading of uneven surfaces, irrigation by contour check or contour furrow on steeper slopes, terracing, stabilisation of gullies, etc.. Where the soils are shallow there is a restriction on the range of crops which can be grown, but the crops included in the recommended cropping pattern are not affected by this restriction. Where soil salinity-alkalinity is the limiting factor, reclamation is by leaching and the application of soil amendments. Where drainage is limiting, reclamation is by closer spacing of drains. Most of the class 3 land, like the class 2 land, is used for feed crops.

4. Non-Arable land: These lands do not meet the minimum requirements of class 3 lands. They are, therefore, not suitable for irrigated use. Some of them are at present used for rainfed cereal crops. Other areas, where the soils are too shallow even for rainfed cultivation, are used for grazing.

(ii) **Water Resources for Irrigation**

Because of the low level of the mean annual rainfall in the region of the farm, its irrigation system depends mainly on the quantities of water available in the Tigris river and its branches. The farm is watered from the Diala river (a branch of the Tigris river), by a pumping station equipped with four electrical pumps, with a total output of $6m^3$ per second. The available quantity of water flowing through the irrigation canals averages $4.5m^3$ per second. The canals lose an average of 48 percent of the irrigation water because of their bad construction and the absence of an effective system of maintenance.

According to the operational system of the pumping station, three pumps have to be working 24 hours a day between May and October, and 18 hours a day between November and April. Therefore, the average daily quantity of water available for irrigation flowing through the irrigation canals is assumed to be $388,800m^3$ during the period between May and October, and $291,600m^3$ during the period between November and April. As shown in Table 3.1, the monthly quantity of water available for the farm ranges between $4,852,224m^3$ as a maximum and $3,079,296m^3$ as a minimum.

Table 3.1. The Available Quantities of Water for Irrigation

Month	Worked days	Daily output	Monthly output	Available quantities*	Holidays
January	22	291600	6415200	3335904	4 Fridays and 3 days holiday
February	23	"	6706800	3487536	4 Fridays and 1 day holiday
March	26	"	7581600	3942432	4 Fridays and 1 day holiday.
April	26	"	7581600	3942432	4 Fridays.
May	25	388800	9720000	5054400	5 Fridays and 1 day holiday.
June	26	"	10108800	5256576	4 Fridays.
July	25	"	9720000	5054400	4 Fridays and 2 days holidays.
August	23	"	8942400	4650048	5 Fridays and 3 days holidays.
September	26	"	10108800	5256576	4 Fridays only.
October	22	"	8553600	4447872	5 Fridays and 4 days holidays.
November	24	291600	6998400	3639168	4 Fridays and 2 days holidays.
December	27	"	7873200	4094064	4 Fridays.

*The available quantities of water for irrigation are 52% of those shown in Column 4.

Source: This table is computed from 1983 farm records.

(iii) Labour

The farm employs 230 people, of whom 27 are managerial, technical and administrative staff and 203 are workers. Of the workers, 115 are skilled and 88 are nonskilled.

The annual labour hours available for the farm is 482,328 man hours. This figure was assessed by calculating the total number of annual hours supplied by the workers using (a) 8 hours as a standard day (b) 296 days are considered as working days for the year.

Table 3.2. The Labour Available at the Al-Nahrawan State Farm.

	7 Nissan	Al-Wahda	Egg Station	Maintenance	Total
Official Staff	10	5	2	10	27
Skilled Workers	62	42	11	-	115
Non-Skilled workers	61	27	-	-	88
Total	**133**	**74**	**13**	**10**	**230**

Source: Farm records for 1983.

(iv) Buildings and Fixed Equipment Assets

For the purposes of this study, building and other establishment assets at the Al-Nahrawan state farm can be represented as follows:

(1) The 7 of Nissan Cow Station comprises 24 cow houses, of which 16 houses each have a capacity of 75 milking cows; the other 8 houses each have a capacity of 150 dry cows. There exist also 7 rooms, of which 3 are for milk-feeding calves, 3 are for non milk-feeding calves, and one room is for isolating sick cows. Also in this unit there are 17 sheep houses with a total capacity of 8,500 head, and 2 bathing troughs. In addition, there is a center for artificial insemination; a feed mixing plant with an output of 2 tonnes every 8 hours; a veterinary center; a milking center; a weighing bridge; 5 garages; 3 stores; an administrative building; 2 houses, and a guard room (see Table 3.3).

(2) The Al-Wahda cow station comprises 8 cow houses, of which 4 houses each have a total capacity of 75 milking cows, 3 houses each with a total capacity of 100 non-milking cows, and one house managed for breeding calves up to 6 months old. This unit also has an independent building for administration and veterinary tasks; an automatic milking center; a weighing bridge; 3 stores and one garage.

(3) The poultry unit comprises 16 houses for laying hens with a total capacity of 48,000 laying birds, 2 stores, of which one is a cool store; 16 automatic feeding troughs, 400 egg-laying troughs, 75 drinking places, 2 electrical power engines, 74 air coolers, 8 fans, 132 air drawers, one refrigerator and 2 lorries.

Table 3.3. **Buildings and Fixed Equipment Assets**

Items	7 of Nissan station			Al-Wahda station		
	Number	Space m^3	Capacity	Number	Space m^3	Capacity
Cow houses	24	64,200	2,400	8	8,850	
(of which)						
Milking-cow houses	16	-	1,200	4	5,000	300
Dry-cow houses	8	-	1,200	3	3,150	300
Milk-feeding calve/rooms	3	-	300	1	700	100
Others calve rooms	3	-	300			
Isolative room	1	-	100			
Sheep houses	17	32,448	8,500			
Artificial insemination center	1	550				
Feed mixing plant	1	180	2Ton./day			
Veterinary center	1	175				
Bathing Trough	2	240				
Automatic milking unit	1		10 Cows	1		8Cows
Weighing Balance bridge	1			1		
Stores	3	1,409		3	1,200	
Cool stores	1					
Garages	5	335		1	30	
Administration building	1	105		1	75	
Guard room	1	10				
Accommodation houses	2	556				
Poultry station						
Poultry houses	16	12,480	48,000			
Stores	1					
Cool stores	1					
Feeding trough	16					
Egg-laying trough	400					
Drinking places	75					
Electrical power engines	2					
Air-cooler	74					
Fans	8					
Airdrawers	132					
Refrigerators	2					

Source: Farm records, 1983.

(v) **Machinery and Equipment**

The farm is well equipped with modern machinery. As shown in Table 3.4, the farm has 30 medium size tractors, 3 large size tractors, 4 green feed harvesters, 4 grain combines, 5 bale compressors, 11 ploughs, 7 seed drills, 10 harrowing discs, 23 trailers, 3 ditchers, 3 fertiliser distributors, 2 feed stirring machines, etc.; these machines are used on the farm cropland and for animal services.

Table 3.4. Number, Model and Size of Machines and Equipment Available for the Al-Nahrawan State Farm

Machines and Equipments	Number	Model and Size of Machine to be Used
Medium size tractor	30	Fiat 850 and Fiat 1000
Large size tractor	3	Fiat 1300
Forage harvester	4	Mower (self-propelled)
Combine	4	Self-propelled
Bale compressor	5	Connected with Fiat 1000
Plough	11	" " Fiat 1000 or 850
Seed drills	7	" " " " " "
Harrowing discs	10	" " " " " "
Trailer	23	" " " " " "
Disc ditcher	3	" " " "
Levelling machine	1	" " " "
Straightening machine	1	" " " 1300
Fertiliser distributor	3	" " " 1000
Feed Machine Stirring	2	" " " "
Irrigation ditcher	1	" " " 1300
Hoe	1	
Sprayer	1	

Source: Farm records, 1983.

Machinery hours available for the farm have been computed by taking into account that each tractor works ten hours per day, a forage harvester works 5 hours per day, and a grain combine works 8 hours per day during the period between 1 May and 31 July. Seasonal medium size tractor hours available for the farm have been computed. The available machinery hours amount to 21,300 tractor hours for the first season, 23,100 tractor hours for the second, 22,200 tractor hours for the third and 21,900 tractor hours for the fourth season. The annual available machinery hours for the large size tractors amount to 7,080 tractor hours; for the green feed harvesters availability is 5,900 harvester hours, and for the grain harvesters about 2,336 combine hours (see Table 3.5).

Table 3.5. Machinery Hours Available for the Al-Nahrawan State Farm

Period from to	No. of working days	Machine hours available	Notes
Medium size Tractor			
1Jan.-13March	71	21300	12 Fridays & 5 days holidays
1Apr.-30June	77	23100	13 " " 1 day holiday
1July-30Septem.	74	22200	13 " " 5 days holidays
1Octob.-31Decem.	73	21900	13 " " 6 " "
Large-size trac.	295	8850	21 " "17 " "
Forage harvester	295	5900	21 " "17 " "
Grain harvesting (1 May-31July)	73	2336	13 Fridays and 6 days "

Based on Table 3.4.

CHAPTER 4

THE EXISTING PRODUCTIVE ACTIVITIES OF THE AL-NAHRAWAN STATE FARM

4.1. Introduction

This chapter is in three sections; the first outlines the existing structure of production; the second deals with the required resources of the various activities; the last section deals with cost and revenue analysis.

4.2. The Existing Structure of Production

At present there are three major productive activities at the Al-Nahrawan State Farm, namely dairy cattle, crop production and commercial egg production. The small herd of sheep which remains at the farm represents an additional activity. This section will be examined using the following four sub-sections:

1. Crop Production.
2. Dairy Cattle Production.
3. Poultry Production.
4. Sheep Production.

4.2.1. Crop Production

Since 1978 both the Al-Wahda and the 7 of Nissan cropland has been oriented to specialising in feed-crop production, with a limited area for malting barley. In 1979, 50 hectares formed the commencement area for wheat production on the Al-Wahda cropland. In 1981 wheat became an essential product of the Al-Nahrawan State Farm.

The annual mean of winter and summer crop areas of the farm for the period 1979-1983, are shown in Table 4.1

Table 4.1. The Annual and the Average Crop Areas for the Period 1979-1983. (Hectares)

	1979	1980	1981	1982	1983	Average	Percent
Winter Crop							
Wheat	50.00	-	125.00	125.00	700.00	200.00	8.18
Green Feed Barley	190.25	125.00	225.00	150.00	225.00	183.00	7.49
Malting Barley	400.00	711.75	375.00	325.00	375.00	437.25	17.89
Grain Barley	401.75	375.00	375.00	250.00	275.00	335.25	13.71
Alfalfa	145.00	179.00	100.00	175.00	179.00	155.50	6.36
Clover	500.00	355.25	650.00	750.00	900.00	631.00	25.81
Mixed Crops	475.00	532.00	405.00	475.00	625.00	502.50	20.56
Total for Winter Crop						**2444.50**	**100.00**
Summer Crop							
Alfalfa	115.00	134.00	300.00	175.00	254.00	195.50	16.70
Maize	437.75	211.25	181.25	382.50	550.00	352.50	30.10
Sorghum	500.00	779.00	762.50	537.50	537.00	623.25	53.20
Total for Summer Crop						**1171.25**	**100.00**

Source: Farm records for the period 1979-1983.

The average yield per hectare varies from crop to crop, according to the variety, species and purpose (e.g. for grain or for green feed production). Yield also varies from one year to another. Moreover, grazed quantities by animals give additional difficulties in the calculation of the actual products. Table 4.2 shows the average yield per hectare, which represents a standard level for various products under the farm practices and circumstances. Table 4.3 gives the composition of feeds per hectare of each fodder crop activity.

Table 4.2. The Average Yield per Hectare, for the Period 1980-1983.(kgs)

Crop	Green Feed	Grain	Straw	No.of Cuts
Wheat		1200	2000	
Malting Barley		2120	2000	
Grain Feed Barley		1220	2000	
Green Feed Barley	18000			2
Winter Alfalfa	25600			4
Clover	32000			3
Mixed Crop	30000			3
Summer Alfalfa	19200			3
Maize	33200			3
Sorghum	28000			2

Based on the actual yields of the farm, over the period 1980-1983.

Source: Farm records for the period 1980-1983.

Table 4.3. The Composition of Feeds per Hectare of Each Crop Activity

	Yield	T.D.N.		Protein		Calcium		Phosphorus	
	Kgs/hec.	%	total	%	total	%	total	%	total
Green Barley	18,000	17.1	3,078	2.32	417.6	0.03	5.4	0.02	3.6
Grain Barley	1,220[a]								
	2,000[b]	74.66	1,773.2	8.04	105.08	0.24	10.73	0.20	6.84
Clover	32,000	11	3,320	2.62	838.40	0.13	41.6	0.01	3.20
Mixed Crop	30,000	14.05	4,215	2.47	741	0.08	24	0.15	4.50
Wint.Alfalfa	25,600	16.01	4,098.56	3.6	921.6	0.15	38.4	0.02	5.12
Maize	33,200	17.26	5,730.32	1.23	408.36	0.04	13.28	0.026	8.63
Sorghum	28,000	29.75	8,330	0.68	190.4	0.29	81.2	0.18	50.40
Sum. Alfalfa	19,200	16.01	3,073.92	3.6	691.2	0.15	28.8	0.02	3.84
Straw (Wheat)	2,000	35.57	711.4	0.17	3.4	0.50	2	0.33	6.6
"(Malt.Barley)	2,000	43.12	862.4	0.35	7	0.39	7.8	0.22	4.4

[a] = Grain; [b] = Straw

Source: (1) Table 4.2.

(2) KHAWAJA A.K., BAYATY E.A. and MATTY S.A., The Composition and Nutrient Value of Iraqi Fodder Crops, Ministry of Agriculture and Agrarian Reform, Administration of Animal Production, Department of Nutrition, Baghdad, 1978; pp.19-30 (in Arabic).

The farm does not follow the principle of crop rotation, in spite of its importance for productivity. Cropland is allocated according to the required crop, with no consideration of the efficacy of a regular system of rotated planting.

4.2.2. Dairy Cattle Production

The farm keeps Friesian dairy cattle with fresh milk a main product; meat and surplus animals represent a secondary product. Most heifers are home-reared, and surplus heifers are sold to the surroundings farmers. Calves and surplus cows (herd depreciation) are sold for slaughter. For the period 1979-1983, the average size of the herd was 2,246 dairy cattle (see Table 4.4).

Table 4.4. The Average Size of the Cattle Herd for the Period 1979-1983. (Head)

Year	Date 1 Jan.	Date 31 Dec.	Average
1979	1895	2232	2064
1980	2232	2378	2305
1981	2387	2463	2425
1982	2463	2212	2337
1983	2212	1984	2098
Average			**2246**

Source: Farm records for the period 1979-1983.

In order to study the dairy cattle requirements, costs and revenues, it is evident that the total number of all livestock cannot be used unless they are all of a uniform class. As this is seldom the case, each class must be converted to some comparable basis. The usual animal "unit" is the internationally recognised unit based on the relative amounts of feed consumed by different classes of livestock [MAFF, 1980; pp.45-46].

Because of the availability of data for this study, I shall not use the above animal "unit". Instead, various classes and numbers of dairy cattle can be converted to a "new" convenient unit which is an animal "group unit". This takes into account the natural and the actual numbers within the different classes of animals, and the ratios of these numbers between the classes. According to world experience and the Iraqi circumstances, the General Organisation for Animal Project scheduled an optimum combination for self-contained dairy cattle (cows and followers combined). All the Iraqi cow stations and farms should follow this combination. At average stocking rates, one calf, yearling and heifer are required for every four cows. Of the cow stock, about 75 percent are milking cows and about 25 percent are dry cows. This ratio allows for a few extra calves reared to allow for culling and death. Surplus youngstock are often reared and frequently the actual replacement rates are less intensive, often being 4:1:1.2:1.4 for cows, heifers, yearlings (allowing for culls and deaths), calf-heifers up to one year old (allowing for deaths), respectively.

The animal "group unit" which I shall use in this study is based on the previous replacement rates as shown in Table 4.5.

Table 4.5. Self-Contained Dairy Cattle and the Animal "Group Unit" Combination.

Class of animal	Replacement Ratio	Ratios of combined class of a "group unit"	and Notes
Cows	4	1	20% for replacement (of which 32% for culling and death
Heifers	1	0.25	4% mortality, and surplus for culling
Yearlings	1.2	0.3	4% mortality, and 10% assumed to be barren
Calf-Heifers	1.4	0.35	10% mortality ratio assumed

Source: GOAP, Personal communication; June 1984.

In fact, the number of calves does not appear in the combination of self-contained dairy cattle, because they are reared for sale during a year period. However, their ratio must be taken into account whenever we set up the animal "group unit" requirements, costs and revenues. The calves ratio is about 0.35. In addition, a ratio of 0.02 for bulls (one per each 50 cows) must be added.

For the period 1979-1983 the number of new born calves reached an average of 945 per year, which is about 80 percent of the total number of the farm's adult cows (see Table 4.6). Of the average number of calves, about 50 percent are female and 50 percent male. The average yield per cow is about 8.63 kgs of milk per day (300 milking days per year). An average of about 734 head per year of various classes of animals were sold for the same period. Annual mean mortality reached about 316 head per year, or about 14 percent of the average cattle stock, of which about 4 percent were adult animals, heifers and yearlings, and about 10 percent were calves and newborn calves.

Table 4.6. Total, Average and Percentage of Newborn, Milkyield, Sales Animal and Mortality.

Year	Adult cows	New born calves	Milk yield (Tonnes)	Sales Animals	Mortality
1979	1012	950	2844	550	230
1980	1269	1058	2866	732	280
1981	1275	1052	2357	709	387
1982	1180	887	1948	1007	354
1983	1135	780	1375	670	331
Total	**5871**	**4727**	**11390**	**3668**	**1582**
Average	**1174***	**945**	**2278**	**734**	**316**
Percentage		**80.5%**	**8.63kgs per** cow per day.		**14%**

*Of which 75% milking cows (880)
Source: Farm records for the period 1979-1983.

4.2.3. Poultry Production

The Al-Nahrawan State Farm has 16 units for poultry production. Eight of these were established in 1973 at the Al-Wahda farm, for commercial egg production, with a total capacity of 24,000 laying hens. The other eight were constructed in 1975 at the 7 of Nissan area for producing broiler meat, with a total capacity of 280,000 birds over the year. By the middle of 1981 the 7 of Nissan poultry farm specialised in commercial egg production, and therefore the overall farm activity for poultry became completely specialised in commercial egg production. At present the farm poultry station comprises 16 units, with a total capacity of 48,000 laying hens. For the period 1979-1983, the average number of laying hens was 20,078 for the Al-Wahda poultry unit, which is 83.6 percent of its capacity. The average size of the bird stock at the 7 of Nissan unit for the period 1982-1983, was 15,951 laying birds, which is 66.5 percent of its capacity. The average of 174 eggs per bird per annum is an accepted rate for laying hens. Approximately 87 percent of the bird stock are sold every year. The average mortality rate is 11 percent.

As mentioned in Chapter 3, the poultry station has no land to produce feed. Feed is supplied by the General Establishment for poultry feed production, at supported prices.

Table 4.7. <u>Total, Average and Percentage of the Existing Number of Birds, Egg Production, Number of Birds Sold, and Deaths</u>

Year	Existing Number of Birds	Egg yield (millions)	No.of Birds Sold	Deaths
1979	23338	4.050	10720	3636
1980	22348	4.180	10179	3439
1981	23075	3.720	20574	4599
1982	39970: 20086 at the 7 of Nissan unit and 19884 at the Al-Wahda unit.	5.965	37778	7669
1983	23562: 11816 at the 7 of Nissan unit and 11746 at the Al-Wahda unit.	5.118	35933	4495
Total	132293	23.033	115184	27318
Average and %	20078 for the Al-Wahda unit and 15951 for the 7 of Nissan unit. (360,300)	174 eggs per bird per anum	87% of stock	11% of existing and sold

Source: Farm records for the period 1979-1983..

4.2.4. Sheep Production

Sheep breeding for meat and wool production was an important activity at the dissolved 7 of Nissan state farm, with 11,794 head at the beginning of the 1981. By the middle of 1981 the farm, as with the other state farms, the size of the sheep herd was reduced as a result of a Government decision to encourage sheep breeding by private farmers rather than by state farms. As a result, only an average of 758 head were kept during 1982-1983 (see Table 4.8).

Table 4.8. The Size of the Sheep Stock for the Period 1982-1983 (Head).

Year	Total Sheep Stock
1982	776
1983	740
Average	**758**

Source: Farm records for the period 1979-1983.

At average replacement rates, it is assumed that 22 percent of the ewe flock is culled each year; also a 3 percent allowance is made for mortality. The required 25 percent for replacement are home-reared ewes, with only one ram required per 50 ewes. Therefore the sheep unit of measurement is assumed to be a combination of one ewe, 0.25 weaned lambs and 0.02 rams. This unit relates to the requirements over a twelve-month period.

For the period 1982-1983, the average rate of new born lambs was about 85 percent of the ewe flock; 10 percent mortality is assumed, with 65 percent for sale at one year old. The average wool and milk production is about 1.5 kgs and 100 kgs respectively, per adult head per annum.

4.3. The Required Resources of the Farm Activities

This section deals with the required quantities of each resource per unit of various activities. On the following pages data on water for irrigation and drinking water for livestock, machinery hours, labour hours, feedstuffs, fertiliser, seeds, sprays material and veterinary medicine requirements for various farm crops and types of livestock are given. These requirements are discussed in the following five subsections.

4.3.1. Water Requirements

For the farm crops the required quantities of water for irrigation varies from one crop to another, according to the variety, date of sowing, lifetime and purpose of the crop. The annual needs of water for irrigation and livestock are shown in Table 4.9.

Table 4.9. Water Requirements (m^3 per unit of measurement)

	Unit of measurement	Jan.	Feb.	Mar.	Apr.	May	June	July
Green Feed Barley	Hectare	900	1012	1352	1900			
Malting Barley	"	828	1220	1364	-			
Grain Feed Barley	"	828	1220	1364	-			
Clover	"	520	764	1636	1976			
Mixed Crop	"	592	852	1340	1772			
Winter Alfalfa	"	900	1012	3952	1900			
Wheat	"	828	1120	1364	1166			
Maize	"	-	-	-	-			3180
Sorghum	"	-	-		-	3220	3840	4360
Summer Alfalfa	"	-	-	-	-	3252	4432	5580
Cows	Unit	1.86	1.86	1.86	1.8	1.86	1.8	1.86
Sheep	Unit	0.465	0.42	0.465	0.45	0.465	0.45	0.465
Laying Hens	100 birds	0.93	0.84	0.93	0.9	0.93	0.9	0.93

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	Unit of measurement	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Green Feed Barley	Hectare		-	-	1452	1052	7668
Malting Barley	"		-	-	972	820	5204
Grain Feed Barley	"		-	-	972	820	5204
Clover	"		-	794	784	1084	7560
Mixed Crop	"		-	-	1152	420	6128
Winter Alfalfa	"				4352	1052	13168
Wheat	"				1012	820	6300
Maize	"	1900	1764	1548	1240		9632
Sorghum	"	3900	2600	2600	-		26372
Summer Alfalfa	"	5020	3700	2440	-		24424
Cows	Unit	1.8	1.8	1.86	1.8	1.86	21.90
Sheep	Unit	0.465	0.45	0.465	0.45	0.465	4.475
Laying Hens	100 birds	0.93	0.9	0.93	0.9	0.93	10.95

Sources:

(1) AOAD (Arabic Organisation of Agricultural Development), Studies of the Evaluation of Crop Production and the Possibility of Setting up Seed Oil Specialised State Farms in the Republic of Iraq, Arab League, Khartoum, 1978, pp.213-220 (In Arabic).

(2) AOAD (Arabic Organisation of Agricultural Development), A Study in Proposing Specialised Crop Rotations Systems for the Production of Indistrial Crops in the Iraqi State Farms, Arab League, Al-Khartoum, 1983 (in Arabic).

(3) AL-KHATAH A.K., Irrigation; Water Requirements for Farm Crops, Library of the General Administration of Irrigation, Baghdad, 1974; pp.3-10, (In Arabic).

(4) Al-Kawaz K.M., A Guide to the Estimation of the Required Quantities of Water for Irrigation of Irrigated Crops, Ministry of Agriculture and Land Reform, General Administration of Agricultural Guidance, Baghdad 1974, pp.1-4. (In Arabic)

(5) Al-Kawaz K.M., Water requirements for irrigated crops, Agricultural Revolution, 6 (54), 1979, pp.13-21.

(6) Ministry of Irrigation, Studies of Water Budget, Baghdad, 1975; p.43.

4.3.2. Machinery Work-Rate Requirements for Crops and Livestock

The required machinery hours vary widely, according to many factors. For instance, they will obviously vary between seasons, soil types and topography, latitude and altitude. Knowledge of the performance of the machinery in its various operations is essential for detailed planning. The figures given below are mainly based on the work rates for various sizes of tractors, harvesters and their related implements, based on previous studies. In 1981 the Committee for State Farms Development in Iraq assessed the average productivity per hour for the various machines and equipment as shown in Table 4.10. Moreover, these averages were obtained as a result of field investigations at the 7 of Nissan and the Al-Wahda farms in 1981.

Table 4.10. <u>Rates of Work for Various Farm Operations.(Hours)</u>

	Type of machine		Barley			Clover
			Green	Malting	Grain	
Ploughing	Medium-sized	Hectare	2	2	2	2
Harrowing(1st)	Tractor	"	1	1	1	1
Rolling	"	"	3.32	3.32	3.32	3.32
Leveling	"	"	0.5	0.5	0.5	0.5
Harrowing(2nd)	"	"	0.696	0.696	0.696	0.696
Ditching	Large-sized	"	1.428	1.428	1.428	1.428
Straightening	"	"	1	1	1	1
Harvesting*	Forage harvestor	"	1.776	-	-	2.664
Feedingstuffs pressing	Medium-sized	"	3.2	-	-	4.8
" transporting	Tractor	"	9	2	2	16.2
Seed & Fertiliser "	"	"	0.21	0.21	0.21	0.17
Fertiliser distributing	"	"	0.264	0.264	0.264	0.264
Seed Drilling	"	"	0.4	0.4	0.4	0.4
Grain harvesting	Combine	"	-	0.75	0.75	-

	Type of machine		Mixed crop	Alfalfa	Wheat (winter)	Maize
Ploughing	Medium-sized	Hectare	2	2	2	2
Harrowing (1st)	Tractor	"	1	1	1	1
Rolling	"	"	3.32	3.32	3.32	3.32
Leveling	"	"	0.5	0.5	0.5	0.5
Harrowing (2nd)	"	"	0.696	0.696	0.696	0.696
Ditching	Large-sized	"	1.428	1.428	1.428	1.428
Straightening	"	"	1	1	1	1
Harvesting	Forage harvestor	"	2.664	3.552		1.776
Feedingstuffs pressing	Medium-sized	"	4.8	6.4		3.2
" transporting	Tractor	"	15	12.8	2	14
Seed & Fertiliser "	"	"	0.174	0.2	0.21	0.18
Fertiliser Distributing	"	"	0.264	0.264	0.264	0.264
Seed Drilling	"	"	0.4	0.4	0.4	0.4
Grain harvesting	Combine	"			0.75	

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			Sorghum (summer)	Alfalfa	Cows	Sheep	poultry
Ploughing	Medium-sized	Hectare	2				
Harrowing (1st)	Tractor	"	1				
Rolling	"	"	3.32				
Leveling	"	"	0.5				
Harrowing (2nd)	"	"	0.696				
Ditching	Large-sized	"	1.428				
Straightening	"	"	1				
Harvesting	Forage harvester	"	2.664	2.664			
Feedingstuffs pressing	Medium-sized Trac.	"	4.8	4.8			
" transporting	"	"	16.2	9.6			
Seed & Fertiliser "	"	"	0.18	0.15			
Fertiliser Distributing	"	"	0.264	0.264			
Seed Drilling	"	"	0.4				
Livestock services	"	unit**	-	-	24	2	4

* According to the number of cuts (each cut requires 0.888 hours).
** Unit of measurement as used in this thesis.

Sources:
(1) MAAR (Ministry of Agriculture and Agrarian Reform), Results of the Application of the System of Economic Use of Agricultural Machinery: 7 of Nissan State Farm, Committee of State Farm Development, Baghdad, 1981; p.16 (in Arabic).
(2) MAAR (Ministry of Agriculture and Agrarian Reform), Results of the Application of the Agricultural Machinery System: Al-Wahda State Farm, Committee of State Farm Development, Baghdad, 1981; p.12 (In Arabic).
(3) Al-KHAFFAF A.A., KATHEM A. and KAMEL A.A., Agricultural Machinery in the State Farms, Publication No.5, High Agricultural Council, Baghdad, 1979, pp.50-53 (In Arabic).
(4) AZIZ A.K., KAMEL A.A. and KHOTHAIER M.I., Agricultural Machinery System: Al-Khaliss State Farm, Ministry of Agriculture and Agrarian Reform, Committee of State Farm Development, Baghdad, 1980; p.11.12 (In Arabic).

Since the medium-sized tractors are used for the vast majority of the field operations, and the usual times of year when each operation takes place are mainly related to the sowing dates of various crops, seasonal medium-sized tractor hour requirements are computed in order to avoid machinery shortages during the peak seasons. These are shown in Table 4.11. The large-sized tractors and the harvesters are used for limited operations, their required hours are listed according to the annual requirements of the various crops (these are shown in Table 4.10).

Table 4.11. Seasonal Medium-sized Tractor Hour Requirements for the Farm Crops (Hours per Hectatre).

Crops	Barley			Clover	Alfalfa		Mixed	Sorghum
Operations	Green	Malting	Grain		Winter	Summer	crop	
First Season (from 1/1 to 31/3)								
Ploughing								2.000
Harrowing(1st)								1.000
Rolling								3.320
Levelling								0.500
Harrowing(2nd)								0.696
Feedingstuffs transporting	4.500			5.400	6.400		10.00	
Feedingstuffs pressing	1.600			1.600	3.200		3.20	
Seed & fertiliser transporting								0.180
Fertiliser distributing								0.264
Seed drilling								0.400
Total	6.100			7.000	9.600		13.20	8.360

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Crops / Operations	Barley Green	Barley Malting	Barley Grain	Clover	Alfalfa Winter	Alfalfa Summer	Mixed crop	Sorghum	Maize	Wheat
Second Season (from 1/4 to 30/6)										
Feedingstuffs transporting	4.500	2.000	2.000	5.400	6.400		5.00	5.400	2.00	
Feedingstuffs pressing	1.600			1.600		3.200	1.600	1.600		
Total	**6.100**	**2.000**	**2.00**	**7.000**		**9.600**	**6.60**	**7.000**	**2.00**	
Third Season (from 1/7 to 30/9)										
Ploughing	2.000	2.000	2.000	2.000	2.000		2.000			2.00
Harrowing(1st)	1.000	1.000	1.000	1.000	1.000		1.000			1.00
Rolling				3.320					3.320	
Levelling	0.500	0.500	0.500	0.500	0.500		0.500			0.50
Harrowing(2nd)				0.696		6.400			0.696	
Feedingstuffs transporting								5.400	7.000	
Feedingstuffs pressing						3.200		1.600	1.600	
Seed & fertiliser transporting				0.170					0.180	
Fertiliser distributing				0.264					0.264	
Seed drilling				0.400					0.400	
Total	**3.500**	**3.500**	**3.500**	**8.350**	**3.500**	**9.600**	**3.500**	**7.000**	**13.46**	**3.50**
Fourth Season (from 1/10 to 31/12)										
Rolling	3.320	3.320	3.320		3.320		3.320			3.320
Harrowing(2nd)	0.696	0.696	0.696		0.696		0.696			0.696
Feedingstuffs transporting				5.400		3.200		5.400	7.000	
Feedingstuffs pressing				1.600		1.600		1.600	1.600	
Seed & fertiliser transporting	0.210	0.210	0.210		0.210		0.174			0.210
Fertiliser distributing	0.264	0.264	0.264		0.264		0.264			0.265
Seed drilling	0.400	0.400	0.400		0.400		0.400			0.400
Total	**4.890**	**4.890**	**4.890**	**7.000**	**4.890**	**4.854**	**7.000**	**8.600**	**4.890**	**4.800**

Sources:

(1) Table 14.10

(2) AZIZ A.K., KAMEL A.A. and KHOTHAIER M.I., Agricultural Machinery System: Al-Khaliss State Farms, Ministry of Agriculture and Agrarian Reform, Committee of State Farm Development, Baghdad, 1980; p.5 (In Arabic).

4.3.3. Labour Requirements

The man-hour requirements for each unit of the various crops and types of livestock have never been calculated, and there is a lack of good data and useful information for the whole period 1979-1983. At the Al-Nahrawan state farm, annual labour requirements for the farm is assessed by calculating the total number of standard man-hours required for various farm crops and types of livestock, according to previous studies of Iraqi state farms.

As a rough guide, where no better evidence is available, it is suggested that basic information on the required man hours for each standard unit of the existing activities might be equivalent to those given in Table 4.12, where the average rates for many operations are listed with gangs of different sizes and for good and bad conditions throughout the year.

Table 4.12. Labour-Hours Requirements for Crops and Livestock.

Activities	Unit of measurement	Man/hours Requirements
Wheat	Per Hectare	40.64
Malting Barley	" "	36.80
Grain Feed Barley	" "	36.80
Green Feed Barley	" "	29.44
Clover	" "	39.36
Maize	" "	63.00
Sorghum	" "	68.20
Winter Alfalfa	" "	78.60
Summer Alfalfa	" "	42.28
Mixed Crops	" "	39.36
Cows	Per Unit	380.00
Sheep	Per Unit	5.84
Laying Hens	Per Unit	60.00

Source:

(1) AOAD (Arabic Organisation of Agricultural Development), A Study in Proposing Specialised crop Rotations System for the Production of Industrial Crops in the Iraqi State Farms, Arab League, Al-Khartoum, 1983; p.223 (in Arabic).

(2) Farm records, 1979-1983.

4.3.4. Feedstuff Requirements

Feed nutrient contents requirements for various types and groups of dairy cattle and sheep are taken from NRC [1971] and NRS [1975] as shown in Table 4.13.

Table 4.13. Daily Requirements of Feed Nutrient Contents for Various Group of Dairy Cattle and Sheep.

Type & group of livestock	Body Weight Kg	Digestible Protein Grammes	T.D.N Grammes	Calcium Grammes	Phosphorus Grammes
Dairy Cattle:					
Dry cows	400	820	5700	25	19
Milking cows*	-	1520	8500	50	37
Adult heifer**	-	820	5700	25	19
Yearling heifer	100	260	2000	10.9	8.4
Bulls	500	455	5600	26	20
Calves	40	100	500	2.2	1.7
Calf-heifer	40	100	500	2.2	1.7
Sheep:					
Rams	60	122	1.38	7.2	4
Ewes	60	64	0.72	3.1	2.9
Lamb & Weaned	30	87	0.83	4.8	3

* 10 kgs. of milk per day (3% fat).
** More than 15 months old

Sources:

(1) NAS-NRC (National Academy of Sciences-National Reasearch Council), Nutrient Requirement of Dairy Cattle, Washington, 1971; pp.26-28.

(2) NAS-NRC (National Academy of Sciences-National Research Council), Nutrient Requirements of Sheep, Washington, 1975; pp.42-43.

Note. This Table was selected from the above sources with the assistance of Dr. Ali S.M., Department of Animal Production, University of Baghdad, 1984. (Digestible protein for cows and heifers were calculated by him).

The requirements for each unit of measurement of dairy cattle and sheep are stated in Table 4.14. Because poultry birds receive only concentrated feed, containing a complete combination of nutrients, the task of setting up a standard requirement of concentrate feedingstuffs for a laying bird unit is straightforward. The annual requirements for a unit of laying birds averages about 3,000 kgs under the farm conditions.

Table 4.14. **Feed Nutrient Contents Requirements for Various Classes of Livestock.**

	T.D.N Kgs.	Protein Grammes	Calcium Grammes	Phosphorus Grammes
Cow Unit.				
Milking cows	25.500	4560.000	150.000	111.000
Adult dry cows	5.700	820.000	25.000	19.000
Adult heifers	5.700	820.000	25.000	19.000
Yearling heifers*	2.400	312.000	13.080	10.080
Bulls	0.448	36.400	2.080	1.600
Calves	0.700	140.000	6.160	2.380
Calf-heifers	0.700	140.000	6.160	2.380
Total for cow unit per a day.	41.148	6828.400	221.320	165.440
Total per a year	15019.020	2492.366	80.7818	60.385
Sheep Unit.				
Rams	0.0276	2.440	0.144	0.080
Ewes	0.830	87.000	4.800	3.000
Lamb and Weaned	0.180	16.000	0.775	0.725
Total for sheep unit per a day.	1.0376	105.440	5.719	3.805
Total per a year	378.724	38485.600	2087.435	1388.825

* Average of 15 months old

Based on Tables 4.5 and 4.13.

4.3.5. The Physical Input Requirements

The quantity and type of physical input requirements (seed, fertilisers, sprays and veterinary medicines) differs from product to product and sometimes from season to season. Comparison of averages over several years can be a useful check on technical efficiency. Because of the occasional use of different quantities and types of spray materials and veterinary medicines, which might be used according to the appearance of diseases, the farm crops and livestock receive irregular sprays and medicines. Therefore, there is no useful evidence to set up any standard rate for various numbers, quantities, and types of sprays and veterinary material requirements (average costs can be assumed as we will see in the next section). However, seed and fertiliser requirements have been recorded in the farm records.

From the fully detailed cash analysis book it has been possible to get information of seed and fertiliser rates per hectare. Allocation of quantity and type of seed and fertiliser is shown in Table 4.15.

Table 4.15. Seed and Fertiliser Requirements for the Farm Crops

Crop	Seed	Fertiliser	
		Urea	Superphosphate
	Kgs	Kgs	Kgs
Wheat	120	120	60
Green Feed Barley	140	200	80
Malting Barley	120	120	60
Grain Barley	120	120	60
Winter Alfalfa	40	200	80
Summer "	zero	120	60
Clover	48	200	80
Mixed Crop	48 barley 32 clover	200	80
Maize	60	200	60
Sorghum	60	200	60

Source: Farm records, 1979-1983.

4.4. The Farm Costs and Revenues

The use of costs and revenue in connection with the physical output and input of the farm requires their measurement in common terms. Since the revenue and costs of the farm occur in diverse physical forms at different times, and have effects over varying periods of time, it is necessary to bring these effects to a common basis of measurement to permit sound comparison of revenue with costs on a particular farm. The most convenient and widely recognised basis for doing this is the monetary unit. Therefore the Iraqi Dinar (which comprises 1000 Fils) is used to express the values of the farm output and input.

In this section, prices of the products sold are the average annual prices received by the farm for those outputs during 1981. The prices paid for the inputs are the average annual prices paid by the farm for those inputs during the same period. The prices paid and received for selected items are shown in Table 4.16.

Within this section the farm costs and revenues are studied under three subsections; the first deals with the variable costs of the farm activities; the second presents the revenues of various activities; the last subsection deals with the fixed costs in order to calculate the net return of the farm plans.

Table 4.16. The Prices Paid and Received for Selected Items.

A-Prices paid for the inputs.	Unit	I.D.*	B-Prices received for the outputs	Unit	I.D.
1-Labour costs	man/hour	0.300	1-Milk	Tonne	95.00
2-Concentrated feed (Hens)	Tonne	52.20	2-Manure	"	3.000
3-Milk powder	"	364.0	3-Egg	Egg	0.028
4-Young chicks	Chick	1.000	4-Culls hen	Hen	0.900
5-Ammonium Nitrate	Tonne	21.10	5-Malting barley	Tonne	79.00
6-Superphosphate	Tonne	55.00	6-Wheat	Tonne	72.00
7-**Seed**			7-Wool	Tonne	860.0
7.1 Alfalfa	Tonne	210.0	8-Adult cow and	Head	500.0
7.2 Clover	"	837.0	I.D.220 per culled head		
7.3 Wheat	Tonne	72.0	9-Calf-heifer	Head	350.0
7.4 Malting Barley	Tonne	78.0	10-Calve	"	250.0
7.5 Other Barley	"	70.0	11-Ewes and	Ewe	30.00
7.6 Maize	"	300.0	I.D.25 per culled head		
7.7 Sorghum	"	253.0	12-Lamb	Head	20.00
8-Mineral salt	"	24.0			
9-Machinery operations costs					
9.1 Ploughing	tractor/hour	1.880			
9.2 Harrowing	" "	1.988			
9.3 Rolling	" "	1.854			
9.4 Fertiliser distributing	"	2.155			
9.5 Seed & fertiliser carting	"	1.913			
9.6 Seed drilling	"	1.971			
9.7 Straightening	"	2.767			
9.8 Levelling	"	1.809			
9.9 Ditching	"	2.354			
9.10 Feedstuff pressing	"	2.209			
9.11 " carting	"	2.342			
9.12 Livestock services	"	1.913			
9.13 Feedstuffs harvesting	Harvester/hour	2.105			
9.14 Grain combine	Combine/hour	4.500			

* I.D.= Iraqi Dinar which comprises 1000 Fils.

Source: Farm records for 1981.

4.4.1. Variable Costs

The total variable cost of the farm is the total amount of cash needed to finance the variable productive resource requirements for the farm crops and livestock. These vary directly with output and vary considerably between different crop and livestock activities, and between different combinations of these activities. Therefore the variable costs must be specific to the activity and vary in proportion to the size of the activity; i.e. number of hectares or head of stock.

The total variable cost of the Al-Nahrawan state farm is composed of (a) the variable cost per a unit of various farm crops multiplied by the average area of each crop during a given period of time; (b) the variable cost per a unit of measurement of dairy cattle, sheep and laying birds, multiplied by their existing average number for a given period.

The variable costs per unit of various crops represent the agricultural operations costs, such as irrigation, cultivation, seed drilling, feedingstuff pressing, labour wages, seed and sprays prices etc. as shown in Table 4.17. The machinery costs shown in this table represent depreciation, fuel, repairs and maintenance, wages and administration costs, charged for an hour of various operations, as reported by the Committee for State Farm development in Iraq.

The variable costs per unit of measurement of the various kinds of livestock represent the cost of concentrate feed for poultry, labour and machinery services, veterinary services and medicines, milk powder for young calves, and miscellaneous variable costs (see Table 4.18).

Table 4.17. **The Variable Costs of the Farm Crops.** (I.D. per Hectare)

	Barley			Clover	Mixed Crop
	Green	Malting	Grain		
Ploughing	3.760	3.760	3.760	3.760	3.760
First harrowing	1.988	1.988	1.988	1.988	1.988
Rolling	6.155	6.155	6.155	6.155	6.155
Levelling	0.9045	0.9045	0.9045	0.9045	0.9045
Second harrowing	1.384	1.384	1.384	1.384	1.384
Ditching	3.3615	3.3615	3.3615	3.3615	3.3615
Feedstuff carting	17.217	3.826	3.826	30.991	28.695
" pressing	7.069	Zero	Zero	10.603	10.603
Fertiliser distribution	0.568	0.568	0.568	0.568	0.568
Seed drilling	0.788	0.788	0.788	0.788	0.788
" and fertiliser carting	0.402	0.402	0.402	0.325	0.333
Straightening	2.767	2.767	2.767	2.767	2.767
Feedstuff harvesting	3.733	Zero	Zero	5.600	5.600
Grain "	Zero	3.375	3.375	Zero	Zero
Total machinery costs	50.097	29.279	29.279	69.195	66.907
Labour	8.832	11.040	11.040	11.808	11.808
Irrigation	1.100	1	1	1.25	1.25
Seeds	9.800	9.36	8.4	40.176	30.144
Sprays	Zero	0.72	0.48	Zero	Zero
Ammonium Nitrate	4.220	2.532	2.532	4.22	4.22
Superphosphate	4.4	3.3	3.3	4.4	4.4
T.V.C per hectare	78.449	57.231	56.031	131.049	118.729
Size of each activity (Hectare)	183	437.25	335.25	631	502.5
T.V.C of each activity	14356.167	25024.25	18784.393	82691.919	59661.3

(continued)

(Continued)

	Alfalfa Winter	Alfalfa Summer	Wheat	Maize	Sorghum
Ploughing	3.760	Zero	3.760	3.76	3.76
First harrowing	1.988	Zero	1.988	1.988	1.988
Rolling	6.155	Zero	6.155	6.155	6.155
Levelling	0.9045	Zero	0.9045	0.9045	0.9045
Second harrowing	1.384	Zero	1.384	1.384	1.384
Ditching	3.3615	Zero	3.3615	3.3615	3.3615
Feedstuff carting	24.486	18.365	3.826	26.782	30.991
" pressing	14.138	10.603	Zero	7.069	10.603
Fertiliser distribution	0.568	0.568	0.568	0.568	0.568
Seed drilling	0.788	Zero	0.788	0.788	0.788
" and fertiliser carting	0.383	0.287	0.402	0.344	0.344
Straightening	2.767	Zero	2.767	2.767	2.767
Feedstuff harvesting	7.466	5.600	Zero	3.733	5.600
Grain "	Zero	Zero	3.375	Zero	Zero
Total machinery costs	68.149	29.279	59.604	59.604	69.214
Labour	23.580	12.684	12.192	18.9	20.46
Irrigation	1.25	2.25	1	2.25	2.5
Seeds	8.40	Zero	8.64	18.00	15.18
Sprays	Zero	Zero	0.60	0.44	2.00
Ammonium Nitrate	4.22	2.532	2.532	4.22	4.22
Superphosphate	4.4	3.3	3.3	3.30	3.30
T.V.C per hectare	109.999	77.297	56.943	106.714	115.314
Size of each activity (Hectare)	155.5	195.5	200	352.5	623.25
T.V.C of each activity	17104.845	15111.564	11388.60	37616.7	71869.45

Notes

1- Machinery Costs are based on the current reported costs of one machinery hour of various operations.

2- Labour, seed, sprays and fertiliser costs are based on their required quantities multiplied by the 1981 prices.

3- Irrigation costs are based on the 1981 farm cost calculation.

Sources:

(1) MAAR (Ministry of Agriculture and Agrarian Reform), The Optimum Use of the Agricultural Machines of the 7 of Nissan and Al-Wahda State Farms, Commitee of State Farm Development, Baghdad, 1981; pp.41-43 (in Arabic).

(2) Farm Records for 1981.

Table 4.18. **The Variable Costs of the Farm Livestock.**

Items	Dairy cattle unit I.D.	Sheep unit I.D.	100 laying hens I.D.
Feed*	...	...	156.600
Labour	114.000	1.752	18.000
Machinery services	45.912	3.826	7.652
Veterinary, medicines	16.000	0.750	5.000
Milk powder	5.460	...	...
Miscellaneous V.C.**	12.850	1.650	16.500
V.C per unit of measurement.	194.222	7.978	203.752
No of units	292.500	597.000	360.300
Total V.C of each activity	56809.935	4762.866	73411.846

*Assuming that all requirements for cows and sheep are obtained from the forage area (none is bought in). Therefore, the actual distribution of forage variable cost per unit of cows or sheep will obviously vary according to any variation in stocking density or crop combination.

**Miscellaneous variable costs comprise mainly bedding, fuel, gas, mineral salt and material contents.

Notes

1- Costs of concentrate feed for poultry and labour and machinery services are based on their required quantities multiplied by their 1981 prices.

2- Other costs are based on an estimated figure from the existing farm plans.

Source: Farm records, 1981.

4.4.2. The Net Revenue

Since net revenue is revenue less variable costs, the net revenue for each activity is the contribution to the farm's objective by each activity. This represents the value of the production of that activity less those specific costs which vary in direct proportion to the level of the activity. The net revenue of an enterprise will differ from season to season, partly because of yield and price differences affecting output and partly because variable costs may vary. Comparison of net revenues, particularly for the output and input averages over several seasons with standard prices, can be a useful check on technical efficiency. Accordingly, the net revenue for each unit of measurement of the farm livestock and cash crops are shown in Table 4.19, while the total revenue of the whole farm is shown in Table 4.20. The fodder crops are assumed to represent an implicit function within the dairy cattle and sheep activities.

Table 4.19. The Total and the Net Revenues for Each Unit of Livestock and Cash Crop.

Total and Net Revenue for Various Unit of Measurement.	I.D.
1-Poultry (100 birds)	
Egg returns (17400 egg at 28 Fils per egg)	487.200
Manure (0.5 tonnes at I.D. 3 per tonnes)	1.500
Total revenue	488.700
Less V.C + herd depreciation	-223.652
Net Revenue	265.048
2-Sheep (per unit of measurement)	
Sold lambs	11.475
Milk returns (100 kg at 95 Fils per kg)	9.500
Wool returns (1.5 kg at 860 Fils per kg)	1.290
Manure returns (0.3 tonnes at I.D. 3 per tonnes	0.900
Total Revenue	23.165
Less V.C. + (herd depreciation - appreciation) (7.978 - 1.29)	-6.688
Net Revenue	16.477
3-Dairy cattle (per unit of measurement)	738.000
Milk returns (7767 kg. at 95 Fils per kg.)	738.000
Sold animals (calves, surplus heifers and calf-heifers)	524.000
Manure (12 tonnes at I.D. 3 per tonnes)	36.000
Total revenue	1928.000
Less V.C. + (herd depreciation - herd appreciation)	-139.300
Net revenue	1158.700
4-Malting barley (per hectare)	
Total revenue (2120 kg. at 79 Fils per kg.)	167.480
Less V.C.	-57.231
Net revenue	110.249
5-Wheat (per hectare)	
Total revenue (1200 kg. at 72 Fils per kg.)	86.400
Less V.C.	-56.943
Net revenue	29.457

Notes:

1- Prices are based on 1981 data. Yields based on the average yield for the period 1979-1983.

2- Net revenue per unit of dairy cattle or sheep are net revenues before deducting forage variable costs.

3- (a) Net annual replacements for poultry:
Cost of replacement I.D.100.
Less value of culls (89% of herd per year at I.D.80.1 (allowing for 11% mortality)).
Herd depreciation I.D.19.9

(b) Sheep costs of replacement:
Sheep cost of replacement 25% of herd per year at I.D.7.5 (allowing for 3% mortality).
Less value of culls: 22% of herd at I.D.5.335 (allowing for 3% mortality).
Herd depreciation I.D.-2.165.
Less increasing value of the herd stock (appreciation at 10% of the stock value) I.D.3.455.

c- Dairy cattle costs of replacement:
Cost of replacements: 20% of herd per year at I.D.400
Less value of culls: 20% of herd per year at I.D.168.96 (allowing for 4% mortality).
Herd depreciation I.D.-231.04
Less increasing value of the stock (appreciation at 10% of the stock value). I.D.286

4- Sold animals are based on:
a- Sold lambs: 85% of newborn rate allowing for 10% mortality and 25% for replacement purposes. The remainder assumed to be sold at I.D.20 per head.

b- Sold calves: 80% newborn rate allowing for 10% mortality, and a ratio of 1.4 of calf-heifer which have to be kept for replacement purposes.
Remainder are assumed to be sold at I.D.250 per head.

c- Surplus heifers at I.D.500. Surplus yearling heifer at I.D.350. Surplus calf-heifer at I.D.250.

Table 4.20. The Net Revenue of the Farm Activities.

The Productive Activities	Net Revenue per unit	No. of The Existing units of measurement	Total Net Revenue
Poultry	265.000	360.300	95479
Dairy cattle	1158.700	292.500	338919
Sheep	16.500	597.000	9850
Malting barley	110.250	473.250	52175
Wheat	29.460	200.000	5892
Total	-	-	502315
Deducting the V.C. of the fodder crops			317196
The farm net revenue			185119

Based on Tables 4.1, 4.4, 4.5, 4.7, 4.8, 4.17, and 4.19.

4.4.3. The Fixed Cost and the Net Returns

The net revenue is only one relevant feature of an enterprise, although an important one for farm planning. It says nothing about the call the enterprise makes on the basic farm resources which have to be taken into account in the planning process. This is not to argue that the fixed costs should not be allocated, but because these costs will not vary directly in proportion to the size of the farm (the per unit fixed costs can and will alter when substantial changes are made in a farm plan), allocating them on a per hectare or per head basis will not aid, and may positively confuse, planning decisions.

Since the fixed costs are unallocated in detemining enterprise net revenues, they have to be covered by the total net revenue of the whole farm activities before arriving at the profit or loss figure.

Since the farm net revenue is about 201,250 Iraqi Dinar (after deducting the variable costs of the fodder crops), and the total fixed costs (as shown in Table 4.21) are about 133,302 I.D., the net profit of the existing farm plan is about 67,948 I.D., as an average for the period 1979-1983, at 1981 prices.

Table 4.21. The Fixed Costs of the Al-Nahrawan State Farm.

	Productive units		
	The 7 of Nissan Station.	The Al-Wahda Station.	Poultry Station.
Fixed assets depreciation	53,835	9,290	7,236
Salaries	26,577	5,466	3,850
Management charges*	18,248	6,440	2,360
Total	98,660	21,196	13,446
Grand total		133,302	

Based on the 1981 cost calculation for the Al-Nahrawan state farm.

*Management charges comprise mainly: recording fees, insurance, water and electricity, maintenance, repairs and training expenses.

Source: Farm Records for 1981.

The next step is to examine the possibility of improving the farm profit by maximising the total gross margin. A more refined process of maximising gross margin is referred to as programme planning. The following three chapters are devoted to the theoretical tools used in this thesis.

CHAPTER 5

OPTIMISATION AND MATHEMATICAL PROGRAMMING

5.1. Introduction

In the search for ways of identifying the "best" allocation of resources, optimisation and mathematical programming methods have received considerable attention. Optimisation problems seek to optimise a numerical function of a number of variables, with the variables subject to certain constraints. Therefore, optimality analysis seeks to assess an array of alternative possibilities, often infinite in number, and to ask which of these possible sets of decisions will come closest to meeting the objectives [BAUMOL, 1977; p.4]. Correspondingly, programming problems deal with determining optimal decisions and patterns of limited resource allocation to meet given objectives. KOOPMANS [1951] defined programming as:

> "...the construction of a schedule of actions by means of which an economy, organizations, or other complex of activities may move from one defined state to another, or from a defined state toward some specifically defined objective. Such a schedule implies, and should explicitly prescribe, the resources and the goods and services utilized, consumed, or produced in the accomplishment of the programming actions" [p.15].

A rational procedure for solving a problem of economic optimisation consists of two stages: the first stage is to determine the set of alternatives to choose from, the feasible region; the second stage is to establish a criterion of economic optimality in the form of an objective function. The optimal allocation can then be determined by comparing the values of the objective function associated with the feasible alternatives. The optimal allocation is that alternative for which the objective function is a maximum (or minimum). The optimal solution can be determined by several methods. Those given below are the most relevant to this thesis.

5.2. Lagrange Method and Constrained Maximisation

Consider first the following problem:

$$\text{Max } r = r\,(x_1, x_2, \ldots, x_n)$$

subject to $g_i\,(x_1\,, x_2, \ldots, x_n) = 0 \quad (i = 1, 2, \ldots, m;\ m<n)$ (1)

Where $g_i=0$ defines the feasible region.

Since this problem involves only equality constraints, it can be approached by the classical method of undetermined multipliers, due to Lagrange. The Lagrangean expression is:

$$L = r\,(x_1, x_2, \ldots, x_n) + \sum_{i=1}^{m} \lambda_i g_i\,(x_1, x_2, \ldots, x_n) \qquad (2)$$

Here λ_i are provisionally undetermined constants. Then the constrained maximisation problem (1) will be equivalent to that of finding an unconstrained optimum of L, treating $x_1, x_2, \ldots, x_n\,, \lambda_i, \ldots, \lambda_m$ as independent variables. If the function is assumed to be differentiable, necessary conditions for a maximum of L with respect to the x_j are:

$$\partial L/\partial x_j = \partial r/\partial x_j + \sum_{i=1}^{m} \lambda_i\ \partial g_i/\partial x_j = 0 \quad (j = 1, 2, \ldots, n) \qquad (3)$$

Which together with the side conditions (4) determine the x_j and the λ_i:

$$(\partial L/\partial \lambda_i) = g_i\,(x_1, x_2, \ldots, x_n) = 0 \quad (i = 1, 2, \ldots, m) \qquad (4)$$

Unfortunately, this "classical" method fails to deal with inequalities, and this is serious because most economic optimisation problems contain constraints in inequality form. Also, economic variables are generally defined over the non-negative region. Consequently, the optimum cannot be an interior solution but will be a boundary (or "corner") solution, that is, a point on the boundary of the feasible region where one or more of the inequalities is "binding" (or effective).

The more general problem of finding a maximum subject to inequalities rather than equalities is called a **mathematical programming (MP) problem**. The general MP problem can be written as follows:

$$\text{Max } r = r(x_1, x_2, \ldots, x_n)$$

$$\text{subject to} \quad g_i(x_1, x_2, \ldots, x_n) \geq 0 \quad (i = 1, 2, \ldots, m) \qquad (5)$$

$$g_h(x_1, x_2, \ldots, x_n) = 0 \quad (h = m+1, m+2, \ldots)$$

$$x_j \geq 0 \quad (j = 1, 2, \ldots, n)$$

Here the feasible region is defined by the side conditions $g_h = 0$ $g_i \geq 0$ and the non-negativity requirements $x_j \geq 0$. The inequalities $g_i \geq 0$ may be transformed into equations by introducing non-negative slack variables; conversely, an equality constraint $g_h = 0$ can be replaced by the equivalent pair of inequalities, $g_h \geq 0$ and $-g_h \geq 0$. If the functions r, g_h, and g_i are all linear we have the special case of **Linear Programming (LP)**. Otherwise (5) is a problem of **Nonlinear Programming**. A nonlinear programming method has been provided using generalised Lagrange multipliers by KUHN and TUCKER [1950], which deals with all of the inequalities simultaneously and in a symmetrical manner.

5.3. Kuhn-Tucker Optimisation

As many people have contributed to Kuhn-Tucker optimisation in many different ways, I shall review this subject in the following sub-sections: Kuhn-Tucker optimisation and the general mathematical programming problem; interpretation of the dual problem; Kuhn-Tucker conditions and LP. I shall follow the treatment of BAUMOL [1977; pp.156-176] in defining Kuhn-Tucker analysis and the interpretation of the dual problem, and the treatment of DANO [1975; pp.12-20] in deriving the Kuhn-Tucker conditions in the general mathematical programming and LP problems.

5.3.1. Kuhn-Tucker Optimisation and the General MP Problem

Kuhn-Tucker analysis tells us that, for a wide class of programming problems, whatever values of the variables maximise the value of the original objective function, subject to its equality or inequality constraints, will maximise the value of the Lagrangean expression (subject only to the nonnegativity conditions for the variables) [BAUMOL, 1977; p.157]. Suppose we treat the Lagrange multipliers as variables, the original problem is solved when one has found the values of the original problem's variables (x's) which maximise the value of the Lagrangean expression and the values of the Lagrange multipliers (λ's) which minimise that value. This duality relationship leads to the minimax property as BAUMOL [1977] stated:

> "If we find a combination of x's and λ's which constitutes a solution to the primal and the dual problems respectively, then for these values the Lagrangean expression will have the lowest value which any λ's can give it and the highest value which any x's can give it" [p.158].

To demonstrate the Kuhn-Tucker conditions, assume that the general mathematical programming problem is in the following form:

$$\text{Max } C = C(x_1, x_2, \ldots, x_n) \tag{6}$$

$$\text{subject to} \quad g_i(x_1, x_2, \ldots, x_n) \geq 0, \ \forall_i \quad (i = 1, 2, \ldots, m)$$

$$x_j \geq 0, \ \forall_j \quad (j = 1, 2, \ldots, n)$$

In solving the problem one uses the Lagrangean function:

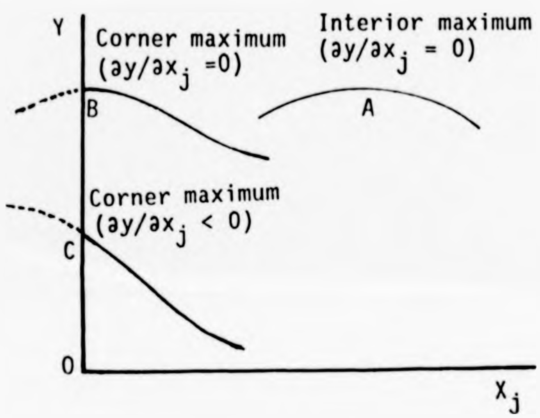
$$L = C(x_1, x_2, \ldots, x_n) + \sum_{i=1}^{m} \lambda_i \, g_i(x_1, x_2, \ldots, x_n) \tag{7}$$

Then the problem (6) can be shown to be equivalent to that of determining a saddle point for L (a point which represents a maximum with respect to the x_j and a minimum with respect to the λ_i), subject to $x_j \geq 0$ and $\lambda_i \geq 0$. For any differentiable function $L(x_1, \ldots, x_n, \lambda_1, \ldots \lambda_m)$ where the variables are not confined to the nonegative region, a saddle point is characterised by:

$$\partial L/\partial x_j = 0, \qquad \partial L/\partial \lambda_i = 0$$

These take account of the possibility that the optimum can occur at boundary point rather than at an interior point. When the x_j and the λ_i are required to be nonnegative, these necessary conditions must be modified. If some x_j, happens to be zero at the saddle point, $\partial L/\partial x_j$ may be negative instead of zero, as illustrated in Figure 5.1.

Figure 5.1. **The Possibility of a Corner Maximum when some $x_j = 0$ at the Saddle Point.**



Similarly, $\partial L/\partial \lambda_i$ must be nonnegative. Hence the necessary conditions for a saddle point are:

$$\partial L/\partial x_j \begin{cases} = 0 \text{ for } x_j>0 \\ \leq 0 \text{ for } x_j=0 \end{cases} \qquad \partial L/\partial \lambda_i \begin{cases} = 0 \text{ for } \lambda_i>0 \\ \geq 0 \text{ for } \lambda_i=0 \end{cases}$$

which may be written in the form:

$$\partial L/\partial x_j \leq 0, \qquad x_j \geq 0 \qquad (8)$$

$$x_j.(\partial L/\partial x_j) = 0, \qquad (j=1, 2, \ldots, n) \qquad (9)$$

$$\partial L/\partial \lambda_i \geq 0, \qquad \lambda_i \geq 0 \qquad (10)$$

$$\lambda_i.(\partial L/\partial \lambda_i) = 0, \qquad (i=1, 2, \ldots, m) \qquad (11)$$

Where:

$$\partial L/\partial x_j = \partial c/\partial x_j + \sum_{i=1}^{m} \lambda_i . (\partial g_i/\partial x_j) \text{ and } \partial L/\partial \lambda_i = g_i \qquad (12)$$

Now, if we think of a particular programme, say (x_1*, x_2*, ..., x_n*), which we assume to be optimal, then conditions (8), (9), (10) and (11) are also necessary for a maximum of C subject to $g_i \geq 0$ and $x_j \geq 0$. In other words, in order for a point (x_1*, x_2*, ..., x_n*) to be an optimal solution to (6) there must exist non-negative multipliers λ_i* which, with the x_j*, satisfy the saddle point conditions (8), (9), (10) and (11), the Kuhn-Tucker conditions.

The inequalities $x_j \geq 0$ and $\partial L/\partial \lambda \geq 0$, of which the latter represent the side conditions $g_i \geq 0$, are the feasibility conditions of the problem. The other conditions in (8), (9), (10) and (11) characterise an optimal solution; observe that Lagrange multipliers associated with non-binding side conditions ($g_i>0$ in the optimum) are zero, just as $\partial L/\partial x_j=0$ if the corresponding sign restriction is not binding ($x_j>0$). Sufficient conditions for a point (x^*, λ^*) satisfying the necessary conditions (8), (9), (10) and (11) to be saddle point are:

$$L(x, \lambda^*) \leq L(x^*, \lambda^*) + \sum_{j=1}^{n} (\partial L/\partial x_j)^* . (x_j - x_j^*) \qquad (13)$$

$$L(x^*, \lambda) \geq L(x^*, \lambda^*) + \sum_{i=1}^{m} (\partial L/\partial \lambda_i)^* . (\lambda_i - \lambda_i^*) \qquad (14)$$

For all $x_j \geq 0$, $\lambda_i \geq 0$. It can be proved that (8), (9), (10) and (11) and (13) are sufficient conditions for a global maximum of C subject to $g_i \geq 0$ and $x_j \geq 0$. Moreover, if the functions C and g_i are all concave for $x_j \geq 0$, conditions (13 and 14) are automatically satisfied, so that in this case the Kuhn-Tucker conditions (8), (9), (10) and (11) are necessary and sufficient for a global maximum of C subject to $g_i \geq 0$ and $x_j \geq 0$ (as well as for a saddle point of L).

To summarise, the role of the requirements (9) and (11) is to determine whether the interior or corner maximum rules apply. The Kuhn-Tucker condition (8) is the requirement for a corner maximum, while condition (10) tells us that $\partial L/\partial \lambda_i \geq 0$. Here the inequality is reversed from that in (8) because we seek a saddle point of L(x, λ).

5.3.2. <u>Interpretation of the Dual Problem</u>

Consider the following primal problem:

$$\text{Max } r = r(x_j, \ldots, x_n)$$

subject to $g_i(x_j, \ldots, x_n) \leq b_i$

<u>or</u> $b_i - g_i(x_j, \ldots, x_n) \geq 0, \qquad (i=1, \ldots, m) \qquad (15)$

$x_j \geq 0, \qquad (j=1, \ldots, n)$

with the Lagrangean:

$$L = r(x_j, \ldots, x_n) + \sum_{i=1}^{m} \lambda_i [b_i - g_i(x_j, \ldots, x_n)] \qquad (16)$$

By direct differention of L, this becomes:

$$\partial L/\partial \lambda_i = b_i - g_i(x_j, \ldots, x_n) \geqslant 0 \qquad (17)$$

which is equivalent to the original constraint (15).

Thus the Kuhn-Tucker condition $\partial L/\partial \lambda_i \geqslant 0$, is the i_{th} constraint itself.

Now, if we add the i_{th} primal slack variable, u_i, to the preceding constraint, (15) may be rewritten as:

$$g_i(x_j, \ldots, x_n) + u_i = b_i, \quad \underline{\text{or}} \quad u_i = b_i - g_i(x_j, \ldots, x_n) \qquad (18)$$

Comparison with (17) shows that condition (10) can now be rewritten as:

$$\partial L/\partial \lambda_i = u_i \geqslant 0$$

Thus the derivative of the Lagrangean with respect to the i_{th} Lagrange multiplier is the i_{th} slack variable, and so the Kuhn-Tucker condition (10) amounts simply to the requirement that the values of the slack variables be non-negative. Substituting $\partial L/\partial \lambda_i = u_i$ into Kuhn-Tucker condition (11) gives:

$$\lambda_i \partial L/\partial \lambda_i = \lambda_i u_i = 0$$

This is the familiar duality theorem, which states that either u_i, the unused capacity of resource i, equals zero, or that λ_i, the marginal valuation of that resource, is zero (or both).

Let T_j represent the dual slack variable in the j_{th} dual constraint. This can be interpreted as the opportunity loss incurred by the production of a unit of output j. It can be shown that the j_{th} Kuhn-Tucker condition (8) is equivalent to the j_{th} constraint of the dual problem, and condition (8) may be rewritten as:

$$-\partial L/\partial x_j = T_j \geqslant 0 \qquad (j = 1, \ldots, n)$$

This is the nonnegativity requirement for the dual slack variable and the partial derivative of L with respect to x_j is simply minus one times the slack variable T_j. Condition (9) may be rewritten as:

$$T_j x_j = 0 \ (j=1, \ldots, n)$$

This is the standard proposition of duality theory, stating that output j should not be produced ($x_j = 0$) unless it incurs no opportunity loss ($T_j=0$), i.e., it states that $x_j=0$ or $T_j=0$ (or both).

We can now see why a set of values of the x's and λ's that solve the Lagrangean problem must also be solutions for the primal and dual problems, respectively. Since the solution of the Lagrangean problem must satisfy Kuhn-Tucker conditions (8) and (10), it must satisfy the original primal and dual constraints as well. Moreover, the objective function of the Lagrangean problem may be written as:

$$L = P + \sum_{i=1}^{m} \lambda_i [(b_i - g_i(x_j, \ldots, x_n)]. \qquad (19)$$

But Kuhn-Tucker condition (13) asserts that for any i:

$$\lambda_i \partial L / \partial \lambda_i = \lambda_i [b_i - g_i(x_j, \ldots, x_n)] = 0$$

Hence, the objective function of the Lagrangian problem becomes:

$$L(x^*, \lambda^*) = P$$

This is the value of the objective function of the original problem. In exactly the same manner we can show that this values of x and λ must yield:

$$L(x^*, \lambda^*) = \alpha$$

So that the Lagrangean then takes the value of the dual objective function. Thus, a solution which satisfies the Kuhn-Tuker conditions for the Lagrangean must satisfy the constraints for the original problems and equate the value of the Lagrangean to that of the objective function of the primal (the dual).

$$\text{Thus } \alpha = L(x^*, \lambda^*) = P$$

The duality theorems tell us that this is a necessary and sufficient condition for optimality of the solution. Any pair of feasible solutions to the primal and dual that yield $\alpha = P$ must also be optimal solutions to those problems. Hence, x^* and λ^* must be the optimal solutions for the original primal and dual problems.

The dual variables and the dual constraints have very important economic interpretations in terms of shadow prices. Since the variables of the dual system are associated with the constraints of the primal problem, the i_{th} dual variable gives the marginal value of the i_{th} constraint of the primal problem, measured in the same units as the objective function of the primal problem. If in an optimal solution, an inequality in one problem involves less than full use of capacity, then the optimal value of the corresponding variable of the dual problem will be zero. It will be positive if the corresponding constraint is satisfied as an equality. The dual variables, which are sometimes referred to us imputed values or shadow prices for the resources, provide a way of measuring the contribution at the margin to the profit of each resource. They have nothing to do with the actual costs of the resources. Moreover, the dual variables are the rates by which the initial objective function would be increased per unit increase of each of the inputs considered individually. They may be also interpreted as imputed input prices. The dual constraints state that unit cost equals or exceeds price for each output. The imputed input prices lead to efficiency in the sense that it is not possible for the farmer to increase his profit by changing his output levels. The dual objective function gives the value of the farmer's input stocks in terms of the imputed input prices. If the owners of the input stocks were paid the imputed prices, total revenue would be exhausted, and total profit would equal zero. If the optimal outputs satisfy the i_{th} input constraint as a strict inequality, the farmer will have an unused quantity of the i_{th} input, and its imputed price will be zero. Only scarce inputs can have positive prices [HENDERSON, 1971; pp.345-349].

The important thing about the imputation of value of resources is that the farmer can afford neither to overvalue nor to undervalue them. In the former case, he will tend to employ additional units at too high prices, whereas in the latter case he would stop using the resource even at profitable prices. In either case the profit of the farmer is less than the maximum. For the primal linear programming problem, the dual problem consists of imputing values to the inputs that serve as effective constraints on the farm. The imputed values of the total amounts available of such inputs must be such that their sum will not exceed the farm's total rent. This involves finding the combination of minimum valuations at which a pound's worth of any one input yields a pound in rent in any one of the products it is used to produce [LEFTWICH, 1970; pp.385-392].

5.5. Kuhn-Tucker Conditions and Linear Programming

Now linear programming is a special case of the mathematical programming problem and therefore the Kuhn-Tucker conditions will apply. A linear programming problem can be expressed as:

$$\text{Maximise } r = \sum_{j=1}^{n} p_j x_j$$

$$\text{subject to } \sum_{j=1}^{n} a_{ij} x_j \leq b_i \quad (i = 1, 2, \ldots, m) \qquad (20)$$

$$x_j \geq 0 \quad (j = 1, 2, \ldots, n)$$

With the Lagrangean

$$L_1 = \sum_{j=1}^{n} p_j x_j + \sum_{i=1}^{m} \lambda_i . (b_i - \sum_{j=1}^{n} a_{ij} x_j) = \text{max. with respect to } x_j \text{ and min. with respect to } \lambda_i. \quad (21)$$

The Kuhn-Tucker conditions become:

$$\partial L_1/\partial x_j = p_j - \sum_{i=1}^{m} a_{ij}\lambda_i \leq 0, \quad x_j \geq 0 \quad (22)$$

$$x_j . \partial L_1/\partial x_j = 0 \quad (23)$$

$$\partial L_1/\partial \lambda_i = b_i - \sum_{j=1}^{n} a_{ij} x_j \geq 0, \quad \lambda_i \geq 0 \quad (24)$$

$$\lambda_i . \partial L_1/\partial \lambda_i = 0 \quad (25)$$

(22-25) are necessary and sufficient conditions for a global maximum (concave as well as convex) since all functions involved are linear.

To identify the Lagrange multipliers λ_i with the dual variables u_i in the optimum (which can be interpreted as shadow prices associated with scarce resources represented by the constraints in (20)), one can utilise the dual problem corresponding to (20) as:

$$\text{Minimise } Y = \sum_{i=1}^{m} b_i u_i$$

$$\text{subject to } \sum_{i=1}^{m} a_{ij} u_i \geq p_j, \quad u_i \geq 0 \quad (26)$$

Recalling that min Y= max (-Y), the Lagrangean with multipliers v_j is:

$$L_{11} = -\sum_{i=1}^{m} b_i u_i + \sum_{j=1}^{n} v_j.(\sum_{i=1}^{m} a_{ij} u_i - p_j) = \max (u_i) \text{ and } \min (v_j). \quad (27)$$

Which is seen to be equivalent to:

$$-L_{11} = \sum_{j=1}^{n} p_j v_j + \sum_{i=1}^{m} u_i.(b_i - \sum_{j=1}^{n} a_{ij} v_j) = \max.(v_j) \text{ and } \min.(u_i). \quad (28)$$

This is seen to be identical with (21) for $\lambda_i = u_i$ and $v_j = x_j$. Furthermore, it is the same problem we solved in deriving Kuhn-Tucker conditions from (21) and (28). Thus the variables of the primal problem (20) are Lagrange multipliers of the dual (26) and vice versa. Reformulating the common Lagrangean:

$$L = \sum_{j=1}^{n} p_j X_j + \sum_{i=1}^{m} u_i.(b_i - \sum_{j=1}^{n} a_{ij} x_j) = \max (x_j) \ \& \ \min (u_i). \quad (29)$$

With the introduction of nonnegative slack variables x_i^* and u_j^* in the side conditions of (20) and (26), the Kuhn-Tucker conditions (22-25) can be rewritten in the form:

$$\sum_{i=1}^{m} a_{ij} u_i - u_j^* = p_j, \quad (30) \qquad \sum_{j=1}^{n} a_{ij} x_j + x_i^* = b_i, \quad (31)$$

$$x_j, u_i, x_i^*, u_j^* \geq 0, \quad (32) \qquad x_j.u_j^* = u_i.x_i^* = 0 \quad (33)$$

The corresponding Kuhn-Tucker conditions for both problems will be the same as (22-25) with λ_i replaced by u_i. That is, for every LP problem, there exists an equivalent problem called the dual, and the solution of the two problems are equivalent (equations 30 and 31). The Simplex Method is one technique which provides a procedure for finding a solution satisfying these requirements.

5.6. Maximisation with Linear Programming

Among the methods of the general theory of the firm, for use at the field level, the LP method can be used in solving economic problems involving the following components:

a) An objective function which has to be precisely defined and expressed in quantitative terms, so that we can obtain relevant and sensible results.

b) Alternative methods or processes for attaining the objective function. For a problem of production, this implies the existence of several enterprises and/or different methods of production, otherwise we do not have a problem of selection.

c) Limited resources and constraints which limit how much can be produced.

The LP technique incorporates the following assumptions (for details see AGROWAL and HEADY [1973; pp.31-33] and BARNARD and NIX [1979; pp.364-368]):

1. Linearity of the objective function: The production function in linear programming problems is taken as being homogeneous of degree one. For this study, the farm's input-output, output-output, and input-input relations are assumed to be linear and independent of the level at which the activity operates. In addition the linear model employs an assumption of competitively or otherwise fixed input and output prices and constant returns to scale in production.

2. Additivity of resources and activities: The property of additivity means the possibility of adding product values of several productive activities, or, the sum of resources used by different activities must equal the total quantity of resources used by each

activity for all the resources individually and collectively. This implies absence of any interaction among the activities or the resources.

3. Finiteness of the activities and resource restrictions: In LP problems, the farm is viewed as facing various limitation on its activities; these may be quantity limitations on particular kinds of inputs or facilities used by the farm. The farm is viewed also as facing a limited number of alternative production processes. Moreover, any one process is defined in terms of a constant ratio of inputs. Thus if there are an infinite number of alternatives and resource constraints, they cannot be programmed or an optimal solution computed. But, according to AGROWAL and HEADY [1973; p.32], this is a mathematical consideration; it is only realistic to suppose that typical farm and agricultural sector situations always involve a finite number of activities and constraints.

4. Divisibility of activities and resources: This property means the possibility of changing input and/or output by very small increments, such as 0.32 kgs of phosphate or 0.12 hours of labour and so on. Thus this assumption implies continuity of resources and outputs.

5. Single-valued expectations: This assumption means that resource supplies, input-output coefficients, prices of resources and activities, and so forth are known with certainty.

6. Proportionality of activity levels to resources: This assumption implies constant resource productivity and constant returns to scale with linear relationships between activities and resources.

One of the most important conditions of using linear programming is the impossibility of yielding negative activities.

Linear programming effectively approximates optimal organisation decisions of an individual farm. It chooses a combination of activities which will yield maximum net revenue to a given set of fixed resources, when prices, costs and production coefficients are specified. Therefore, it relies primarily on technical production or input-output coefficients, and the prices of the inputs and outputs. However, the solution of a LP problem can be reached when scarce resources are allocated to production processes in such a way as to maximise a certain predetermined objective. For the optimal solution will always either be a corner "tangency" point or, if the straight line isorevenue curves are parallel to one of the segments of the feasible region's boundary, then the entire segment including the corner points will be optimal. This result is called the basic solution of the linear programming probleme. BAUMOL [1977] has stated the basic theorem of linear programming as follows:

> "in any linear programming problem an optimal solution can be found by considering only the basic solutions. That is, there will always exist an optimal solution in which the number of nonzero-valued variables (both ordinary and slack) is exactly equal to the number of constraints in the problem." [p.84]

While the theorem which gives the criterion for telling whether a given programme is optimal depends on the concept of an "equivalent combination", has been stated by DORFMAN, SAMUELSON and SOLOW [1958] as follows:

"a feasible programme is an optimal feasible programme if and only if it contains a list of included activities such that no excluded activity is more profitable than its equivalent combination in terms of those included activities". [p.164]

To demonstrate the optimum programme with linear programming as used in this study, I shall use the following example. Suppose that a farmer aims to maximise his total net returns from raising sheep and clover in a part of his own farm, subject to certain constraints. What combination of sheep and clover should he grow?. Let x_1 be the number of sheep (each unit is 10 sheep) raised and x_2 be the number of hectares of clover grown. Then the farmer's primal problem can be written as:

$$
\begin{array}{lll}
 & \text{Maximise} & X_0 = 4x_1 + 3x_2 \\
\text{Subject to:} & \text{Labour} & 2x_1 + 3x_2 \leqslant 6 \\
 & \text{Foodstuffs} & -3x_1 + 2x_2 \leqslant 3 \\
 & \text{Water} & 2x_2 \leqslant 5 \\
 & \text{Land} & 2x_1 + x_2 \leqslant 4 \\
 & & x_1 \geqslant 0,\ x_2 \geqslant 0
\end{array}
\qquad [1]
$$

Where:

-The values 4 and 3 shown in the objective function represent net returns per unit of sheep and clover respectively.

-The number shown in the right-hand-side of each resource constraint is the quantity available of that resource, measured in units (e.g.,man/hour, kg, m^3 or hectares)

-The values shown in the left-hand-side of each resource constraint can be explained as follows:

1. Positive and zero values represent the units of the resource required per unit of sheep or hectare of clover respectively.

2. In the foodstuffs constraint, the value -3 attached to the sheep activity means that each unit of sheep requires 3 units of clover (per unit of time), while the value 2 attached to the clover represents the production ability of this resource e.g. each acre of clover gives 2 units of foodstuffs. According to this constraint, the farmer will use clover to feed sheep and the quantity of clover produced should be at least as great as the required quantity.

The dual problem to [1] is:

$$\text{Minimise } Y_0 = 6y_1 + 3y_3 + 5y_3 + 4y_4$$

$$\text{Subject to:} \quad 2y_1 - 3y_2 + 0y_3 + 2y_4 \geq 4 \qquad [2]$$

$$3y_1 + 2y_2 + 2y_3 + 1y_4 \geq 6$$

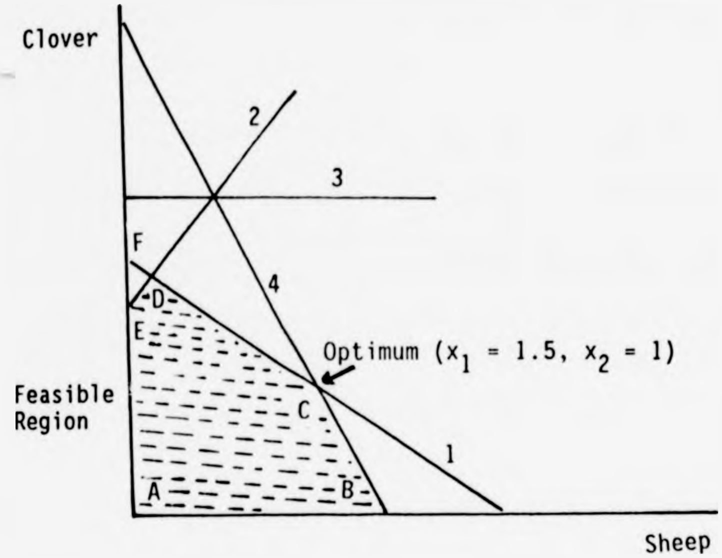
$$y_1 \geq 0, \; y_2 \geq 0, \; y_3 \geq 0, \; y_4 \geq 0$$

By solving either the primal or the dual, we can get the solution to both.

The feasible region for the above example farm problem is determined graphically in Figure 5.2 by the area ABCDE. In this area all the constraints are satisfied. The optimal solution can be seen at the point C, which lies on the frontier of the feasible production space (ABCDE). Any point inside this region gives a lower net return. At point C the product mix is 1.5 units of sheep (x_1) and 1 hectare of clover (x_2) and the maximum net return is to £9, as can be verified from the objective function:

$$X_0 = 4x_1 + 3x_2 = 4(1.5) + 3(1) = 9$$

Figure 5.2. **Graphical Representation of the Example Farm Solution**



The final solution as obtained by the Simplex Method of linear programming for the example farm model is shown in Table 5.1. Here, the optimal plan specifies also 1.5 units of sheep (x_1) and 1 hectare of clover (x_2), the value of the objective function being 9.

Table 5.1. **Summary of LP Results for the Example Farm Model.**

Variables	Row No.	Status	Activity Level	Opportunity Cost
X1	-	B	1.5	zero
X2	-	B [1]	1	zero
Slack	1	LB	zero	0.50
Slack	2	B	5.5	zero
Slack	3	B [2]	3	[3] zero
Slack	4	LB	zero	1.50

Maximum value of the objective function = £9 [4]

The interpretation and use of the information available in Table 5.1 can be summarised as follows (the numbering coincides with that in Table 5.1):

1. **The levels of those activities included in the solution.** These should be regarded only as a guide to the future development of the farm.

2. **The remaining quantities of partially used resources.** Resources in excess supply could with advantage be discarded or contracted.

3. **The marginal value products (MVP) of those resources or constraints that are fully utilised and thus limit the further development of the solution**; e.g. an extra hectare of land permits another £1.5 net revenue to be generated, or an extra hour of labour permits another £0.5 to be generated. They should be either used in a more technically efficient manner and/or be expanded in the longer term. The imputed values of scarce resources may serve to illustrate the need for readjustment of resource combinations. If all the major resources in a solution are fully utilised and their marginal value products are low, the implication is that a sound balance has been achieved between the different resources with regard to the opportunities available [BARNARD and NIX, 1979; p.363]. Moreover, marginal value products can be used to determine whether the inclusion of some activity not included in the original matrix can be justified. They can also show the amount of change necessary in the net revenue of excluded activities for them to merit inclusion in the solution.

4. **Total farm net revenue:** This is often the same as total farm gross margin, with profit derived by deducting the fixed costs.

CHAPTER 6

POST-OPTIMALITY AND DEMAND CURVE ANALYSIS

6.1. Introduction

In the last chapter I set up a simple example of the profit maximisation problem, solved it and examined the primal and dual solutions. I interpreted the primal solution as indicating what action should be taken in order to achieve a single optimal plan. I also interpreted the dual solution as shadow prices or Lagrangean multiplier values. This analysis can be extended to trace out an entire family of optimal outputs by permitting the input parameter values to change. The extension will begin by elaborating a little more the interpretation of shadow prices in terms of their economic meaning and policy implications in resource allocation. Then I shall consider sensitivity analysis, using "parametric linear programming" of an optimal programming solution. In the last section of this chapter I shall study the demand curves for factors of productions.

6.2. Shadow Price

In examining the interpretation of the dual solution, discussed in Chapter 5, one can indicate the meaning of shadow prices as follows:

1) The shadow price of a constraint is a marginal value which indicates how much the objective function changes with a unit change in the associated right-hand-side constraint, provided the current optimal basis remains feasible; i.e. the opportunity cost of one unit of that constraint.

2) The shadow price of an activity (also called **Shadow cost**) represents the decrease in the optimal value of the objective function resulting from a unit increase in a nonbasic variable (an activity not in the current plan), assuming the current solution remains feasible.

As demonstrated below, four classes can be differentiated: the first two are connected with the Column of Activities and the next two are connected with the Rows of Constraints.

Class I: Shadow prices are always zero for those activities associated with real or productive activities recommended in the optimal solution. Clearly, the marginal revenue will equal zero if an activity is recommended in the optimal solution under the maximisation criteria.

Class II: Shadow prices are always positive for those activities not recommended in the optimal solution. Net revenue would be reduced for each unit of the activity by that shadow price if that activity not recommended was brought into the programme. Clearly, if that activity was brought in, it would displace some other higher earning activity recommended in the optimal solution within the given resource limits.

Class III: Shadow prices are positive for those constraints with resources that have been used up. Total net revenue would increase by that shadow price if one more unit of the limited resource was made available.

Class IV: Shadow prices are zero for the constraints with resources not fully used. A resource in excess supply is indicated by the slack variable in the final basis of optimisation. One would expect the corresponding shadow price to be zero because additional excess supply of resources is of no value.

In summary, shadow prices in the activities not only indicate which activities are not profitable, but also how much personal preference might be worth if the planner insisted on the recommendation of an activity which is not associated with the optimal programme. Also, shadow prices in the resource constraints indicate which resources are restricted, with some idea of how valuable are additional amounts of the restricting resources. However, one cannot recommend a policy based only on the shadow price, because considerations of the reality of the model are also very important.

6.3. Sensitivity Analysis

After an optimal solution has been obtained, one would want to determine the effect of changes in technical coefficients and price or resource constraints on optimal solutions. In other words, one would want to know how far the input parameter values can vary without causing violent changes in a computed optimal solution. For example, what would happen if the availability of a resource changes? What would happen if an activity is constrained? What would happen if the net revenue of a particular basic activity changes? Does the curent solution remain optimal? Such an investigation is termed a sensitivity or post-optimality analysis [WAGNER, 1975; p.127].

To arrive at an efficacious optimal plan, one must explore both the sensitivity of an optimal programme with respect to changes in resource constraints, and the variation of the optimal programme with respect to changes in objective functions and/or in the imposition of the optimal activities. As to the criteria in evaluating the variation of an optimal programme in the sensitivity analysis, it can be gauged by the extent of the changes in shadow price, the optimal values, etc..

One can recommend the optimum organisation with a certain amount of assurance if the effects of the optimisation are relatively insensitive to these parameter changes. Since these parameter changes would not disturb the equilibrium in the optimisation, this optimal organisation will follow more or less the same pattern as in the original optimal plan.

On the other hand, if plans are found to be quite sensitive to changes in constraints or objective functions, it implies that these alternative organisations would not follow the same course. Therefore, more careful scrutiny of goals and constraints is required before one can reasonably make planning recommendations.

These investigations are to be studied within this section under the so-called range analysis. Range analysis extends the information provided in the conventional solution. It has the effect of making more useful the interpretation of the shadow prices by providing an estimate of the range of the values of the components of the constraints and the objective function over which a shadow price is relevant.

To deal with the simplest case, the example farm planning model given in Chapter 5 will be reconsidered here. The range output can be obtained with ease with the parametric programming method of post-optimality analysis. This routine can be used to determine within what ranges of the values of the components of B (constraints) and C (objective function) vectors, or even of supply of a specific resource or price of a specific activity, the solution to the original problem remains optimal. The optimality ranges for cost coefficients and right-hand-side constants coupled with the activity levels and the fully used resources of the solution obtained for the example farm model are shown in Table 6.1.

Table 6.1. Optimality Range for Cost Coefficients and Right-Hand-Side Constants.

Identification and activity	Unit	Level	Net Revenue	Optimality Range For cost coefficient Z-Lower	Z-Upper
X_1 (Sheep)	unit	1.50	4	2	6
Max-Z	£	-	9	6	12
X_2 (Clover)	acre	1.00	3	2	6
Max-Z	£	-	9	8	12

Resource fully used	Unit	Amount	M.V.P	For right-hand-side Min. Bi Z-Lower	Max. Bi Z-Upper
B_1 (Labour)	hour	6	0.5	4	9
Max-Z	£	9	-	8	10.50
B4 (Land)	acre	4	1.5	2	6
Max-Z	£	9	-	6	12

An examination of Table 6.1 shows that the solution appears to be relatively stable. The ranges on the net revenues of sheep and clover are very wide. For example, Table 6.1 shows that 1.5 units of sheep and 1 acre of clover are included in the plan, with a net revenue range of 2 to 6 for both activities. These values indicate the stability of sheep and clover in the plan to changes in their net revenues. The net revenue of sheep is £4 per unit, while the net revenue of the clover is £3 per acre. Hence the range given indicates that these figures could fall to £2, or rise to £6 per unit of sheep or acre of clover, without the plan being affected. Of course, the profitability would be directly influenced by a change in the revenue of any activity, but the levels of the activities in the plan would remain the same. These ranges apply only in respect of an isolated change in the net revenue of each activity in turn. In practice, this information may be of rather limited value since a change in the net revenue of one activity will often be accompanied by changes in the net revenues of other activities.

The final section of Table 6.1 relates to the exhausted resources. B1 relates to labour and all 6 units of labour are used up in the plan. The value of £0.5 indicates the marginal value product of labour; one extra man hour would increase the total net revenue by £0.5. The range attached to this value shows the range in man hours over which this value applies. Thus the farm utilises 6 man hours and the productivity of one man hour is £0.5 per hour from 4 to 9 hours. A similar interpretation applies to the land resource (B4), where the farm cultivates 4 acres and the productivity of one acre of land is £1.5 per acre from 2 to 6 acres.

The optimality range for cost coefficients provides insight into the sensitivity of the plan to changes in price relationships; it can be implemented with little added effort or computer time. One can define an infinite number of Cj rows (the objective function which indicates the revenue received for one unit of each activity), all representing reasonable combinations of price expectations or alternative price assumptions. The planner must be discriminating in selecting the relationships he attempts to analyse lest he generate a greater volume of output than he can interpret. Therefore, one may carry the analysis a stage further, and investigate the effects of changing the assumed levels of prices and resource constraints, to give an indication of the kind of adjustments which would then be necessary to continue to maximise profits. The most profitable adjustments to follow in moving from the optimal solution obtained for that model to a new organisational plan should be determined in a complete programming analysis to provide the farmer with a definite course of action. A number of modifications on prices and resource constraints could be imposed both singly and jointly on the model to provide a package of alternative solutions for the farmer's evaluation in terms of the relative profitability of each.

However, linear programming cannot help the operator in the difficult task of formulating price expectations. The process can only indicate the best way to use resources once a judgment has been made as to future prices, or as suggested above, it can indicate how the optimum plan shifts with alternative price assumptions. The success of the plan finally emerging is a function of the accuracy with which prices are predicted.

In linear programming, emphasis must be placed on accurate relative prices. If all the prices are too high, the net income estimate will be incorrect. But if relative prices are approximately correct, the farm plan developed may be a useful device. However, any plan based on prices which in retrospect prove wrong, could turn out to be less profitable than would have some other plan. This problem is not peculiar to planning with linear programming technique; any type of planning requires price projections. Serious mistakes in estimating prices, especially relative prices, will lead to poor results with any planning method.

6.4. Demand Curves for Factors of Production

The emphasis shifts in this section from the sensitivity analysis of the optimum solutions to the demand curves of factors for production. Demand curves for the resources used in producing the farm outputs show how products will vary when different quantities of a particular resource are used with all other factors being constant. They play a key role in showing the effect of varying a single parameter. They are important in determining the employment levels of resources and can be used to advantage in analysing the determination of the price and employment level of a given resource, and show the allocation of resources among different uses, guiding them away from less important uses towards more important ones. Therefore, they guide individual farms towards the use of efficient resource combinations [LEFTWICH, 1970; p.282]. The task of this section is largely that of constructing the individual farm demand curve and the farm employment level of employment of the most critical productive resources.

To deal with the simplest case, I assume that the farm holds fixed the quantities of all but one factor. Thus this analysis concerns "short run" considerations. So I will be dealing with relations between the Marginal Value Products of various levels of a single factor of production (which can be attained from several levels of input quantities of that factor), and the input quantity of that single variable factor. To determine the optimal employment of a particular factor (say A for example), the farm must balance the quantity of A used with its marginal value product. Two elements are involved in calculating this relationship:

(1) The physical productivity of A as an input to production, and

(2) the revenue gained from the units of commodities produced.

In successively choosing whether or not to use one more unit of a factor it is evident that, so far as physical productivity is concerned, only the marginal product will be relevant to the farm's decision. To deal with the revenues element, by similar reasoning it is only the marginal revenue that is relevant. But where the farm is a price-taker not only in the factor market but also in the product market, the increment to revenue from sale of one more unit of product is simply the given product price. Valuing the factor's physical productivity at this price gives the value of the marginal product of that factor [HIRSHLEIFER, 1980; p.415]. The graph of marginal value product emerges from the conceptual experiment of assigning to the farm different amounts of one input, all other inputs being constant. The management accepts each assigned quantity as fixed and chooses a pattern of production maximising over the combination of outputs. The sequence of optimising decisions determines total gross margin and its slope, marginal value product, as functions of the input that is being varied. Under the appropriate technological and economic conditions, the linear programming model predicts the decisions of the farm for all possible levels of the input.

A demand curve for an input requires a different conceptual experiment. The farm is able to use whatever amount it needs of one input. The amount is fixed for any one decision but varies systematically from decision to decision. The managment accepts each assigned price as given and makes a decision without trying to anticipate changes in prices and without making any allowance for possible effects of its own decisions on the level of prices. It searches for the output combination that is optimal under the given conditions. The given conditions have to be precisely specified since they affect the optimal solution and the amount of the input demanded at each price. Generally, output prices are held constant as are technological conditions. Market structure in the product market is an additional element which affects factor demand; this is also held constant. For the remaining inputs there are two possibilities; either the quantity and/or the price may remain fixed. When there are many inputs, some may have fixed prices, others fixed quantities. Each specific combination determines a different demand curve [VANDERMEULEN, 1971; p.103]. In this section I shall take up only the case in which the prices and the quantities of the remaining inputs are held constant. The results show how total net revenue varies with changes in an input, and the input has progressed to the stage of being an independent variable. What we need for calculating the net revenue function is its value in all possible optimal solutions as one scarce input varies with all other conditions constant.

In examining the use of the most critical resources of the preceding farm problem example, it was found that only two resources were fully used, land and labour. In order to derive the demand curves for these scarce resources, I shall generate all possible optimal solutions as one input varies, using parametric linear programming for the right-hand-side constants. The quantity range of each resource was picked up at the level where the marginal value product evaluation shifts from one level to another. One may continue the process and verify the results, for land resource as an example, as shown in Table 6.2. The value of the marginal product schedule for land, as listed in column 2 of Table 6.2, is the farm's demand schedule for land. It shows the different quantities which the farm can use at different marginal value products, assuming the quantities of other resources employed are held constant. The demand curve of the farm for the resource is the demand schedule, or the value of the marginal product schedule, plotted in the usual way.

For the purpose of this section it was assumed that if the marginal value product exceeds marginal cost, it will surely pay the farm to employ an additional unit of land. The gross margin maximising level of employment of land by the farm is that level at which the value of the marginal product of an acre of land is equal to (or exceeds) the price per acre of the resource. Reference to Table 6.2 will help establish this point. The range between 0-1.5 units of land (per unit of time) adds £3 to the farm's total receipts but adds only around £1 to the farm's total cost. Therefore, it adds about £2 to the farm's profits. Additional quantities of land, up to 6 units, adds more to total receipts than to total costs, and consequently makes a net addition to profits. Beyond 6 units, larger quantities add more to the farm's total costs than to its total receipts and cause profits to decrease. In terms of economic logic, to employ only "n" units of land would be to forego the profitable range where the returns from successively using additional units of the factor exceed the costs thereof [HIRSHLEIFER, 1980; p.416].

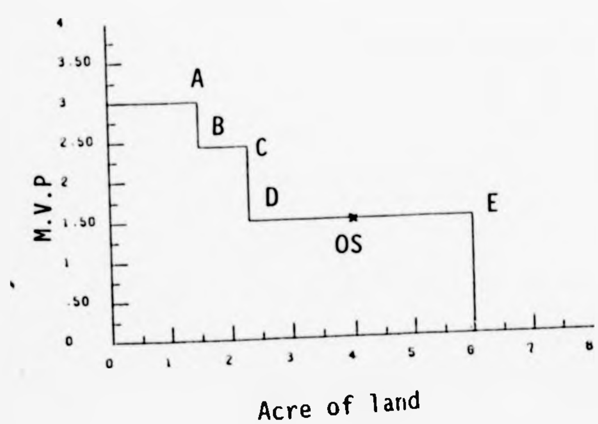
Table 6.2. Demand Schedule for Land of the Example Farm Model

(1) Range of Bi (acre of land)		(2) M.V.P £	(3) Resource Price £
zero	to 1.5	3	1
1.5	to 2.3077	2.4285714	1
2.3077	to 6	1.5	1
6	to infinity	zero	1

Note: The rent per unit of land is assumed to remain constant at £1.

The demand curve from the above schedule is shown in Figure 6.1.

Figure 6.1. Demand Curve for Land



Because of the kinks or corners in the demand curve, the marginal value product curve is discontinuous. Generally, this curve represents the type of price rigidities corresponding to the technical requirements of production. The discontinuous marginal value product curve can be thought of also in terms of elasticity of demand. If the demand curve were a smooth curve, elasticity would be changing continuously as we move from higher to lower marginal value products. However, at the points A, B, C, D, and E of Figure 6.1 the demand curve breaks. Elasticity at an input infinitesimally below 1.5 (that is at point A) is substantially greater than the elasticity at an input infinitesimally above 1.5. Thus, it becomes clear that marginal value product must drop sharply at input 1.5.

The horizontal line segments indicates that the quantity demanded is indeterminate within a range at these prices. The non-vertical sections of the marginal value product curve shown in Figure 6.1 can be thought of as the appropriate marginal value product curves for several distinct smooth demand curves and there would be no reason to expect them to be equal to each other at any amount of land units.

Each horizontal line segment represents an appropriate combination of products. The activity levels included in this combination vary from one point to another along the segment. The horizontal line segments show how the combination of products will vary when different quantities of land are used, at different marginal value products, with all other factors being constant. The management can utilise any amount of the resource within a horizontal segment by choosing the appropriate combination of products, but all combinations are equally profitable. Once again, when there are ties, optimisation can narrow the range of choice but cannot predict a unique choice.

Each vertical segment of the input demand curve corresponds to a unique quantity requirement for land. The marginal value product curve is downward sloping but not continuous; there are vertical gaps through which the price line may pass. These vertical gaps form parts of the input demand curve but not of the marginal value product curve. Ranges of constant slope imply that the optimum is not unique and that the demand curve does not exist [VANDERMEULEN, 1971; pp.105-106]. The discontinuity in the marginal value product curve of an acre of land can be studied under the following three stages:

1) In stage 1, the MVP curve of land is perfectly elastic up to 1.5 units of land (that is corner at A in Figure 6.1), where clover production is the only possible activity to reach the margin of profitability. Above point A, the MVP of an acre of land declines sharply and the sheep activity enters the solution as further units of land are employed.

2) In stage 2, clover and sheep use additional units of land up to 2.3077 units (that is point at C in Figure 6.1), where the pattern of production reached 0.231 unit of sheep and 1.85 acre of clover. So long as the MVP of an acre of land remains in the range from £3 to £2.42, the sheep and clover activities will increase. Above point C, the marginal value product of an acre of land declines sharply and the sheep activity becomes the first to reach the verge of profitability. Thus more sheep but smaller quantities of clover are to be entered into the optimal solution.

3) In stage 3, the MVP curve of land is also perfectly elastic up to 6 units of land (corner E), where sheep rearing dominates and becomes the only possible activity for the optimum pattern of production of the farm. Beyond this point larger quantities add zero MVP to the farmer's output. The optimal solution of the original problem can be seen at point OS.

CHAPTER 7

SURVEY OF SELECTED LITERATURE

7.1. Introduction

This chapter looks at the various applications of linear programming in agriculture management. In Section 7.2, it gives a brief historical review of the development of the technique. It then supplies a brief description of the use of the technique in the field of farm management, and the types of models constructed and some of the methodology behind them. It concentrates on how the maximising technique assists us with the farm planning problem. In Section 7.3, it focuses on applications relating to the Iraqi situation. It then discusses the main points arising from this and from earlier models.

7.2. Brief Historical Review and Survey of Selected Literature

The theoretical concepts on which the Linear Programming Method depends have been known for many years. The first publication on linear programming in the contemporary sense is the book by KANTOROVICH [1939]. The author gives an algorithm for the solution of the linear programming problem, and remarks that methods of this kind can be used extremely well for a planned economy. According to BEALE [1970; p.8], this pioneering work did not find much response for a long time. The general problem of linear programming was first worked out during the second world war to allocate scare shipping resources when moving supplies to armies. It was carried on by GEORGE DANTZIG, MARSHAL WOOD, and their associates at the U.S. department of the Air Force [GASS, 1958; p.ix]. As a result, the simplex method was developed by DANTZIG by the end of the summer of

1949 [KOOPMANS, 1951; p.339]. Interest in linear programming spread quickly among economists, mathematicians, statisticians, and government institutions.

In the summer of 1949 a conference on Linear Programming was held under the sponsorship of the Cowles Commission for Research in Economics. The papers presented at that conference were later collected in 1951 by KOOPMANS into the book **Activity Analysis of Production and Allocation** [1951]. Since then many people have contributed to the field of Linear Programming in many different ways including theoretical developments, computational aspects and exploration of new applications of the subject.

The method, which grew out of applied mathematics, is constantly being refined so that it can be applied with greater precision to a wider range of problems. Like many innovations, its usefulness would have been limited without a parallel technological development, the electronic computer. Subsequent improvements in the method and in the development of electronic computers and effective computing routines to guide them have made Linear Programming a useful tool for analysing the optimum organisation of the farm business [BENEKE & WINTERBOER, 1973; p.3]. In a recent paper BUTTERWORTH [1985] assessed the practical application of linear programming in agriculture, and indicated the importance of the re-examination of the technique:

> "Today it might be argued that the use of linear programming in farm planning has been tried, tested, used, abused and forgotten. In many respects, this statement has a lot of truth in it. On the other hand, there are people around who still use the method, not because it is fashionable or likely to lead to fame and fortune, but because they still find it to be a great asset in the work.

> A time of diminishing agricultural profits is approaching. Those who argued 10 years or so ago that maximising techniques were no longer appropriate are not shouting quite so loudly. A re-examination of the system and its current uses does therefore appear to be timely." [p.99]

Along with this statement one would recognise that in the current economic climate, linear programming could well be worth reconsidering as an optimising technique in the field of farm management.

However, fully to review the literature available on linear programming would be a full-time task and require an extremely long list. It would also include much repetition and excessive detail on individual case-studies, often with little application to the appropriate objectives of this thesis. The task becomes manageable only when one is able categorically to sort the literature into a meaningful classification.

In the field of farm management, Linear Programming has been applied to two principal classes of problems. Firstly to the maximising of a revenue function which is subject to limitations of farm resources, and secondly to the minimising of a cost function subject to specified requirements as to the nature of the process. This thesis is concerned with the first class of problem, namely, with the determination of the gross margin-maximising combination of activities on an Iraqi state farm which has an array of limiting resources. The second type of technique has been used for determining the least cost mixture for feeding stuffs which have certain specified nutritional requirements. Illustrations of this application of linear programming may be found in WAUGH [1951], MACKENZIE and GODSEL [1956], McALEXANDER and HUTTON [1957], GODSELL [1960], DENT [1964], TAYLOR [1965], DENT and GASEY [1967], RAHMAN and BENDER [1971] and KEARNEY [1971]. For the first class of problems a comprehensive description on the use of linear programming methods in agriculture can be found in HEADY [1954], HEADY and CANDLER [1958], GASS [1958], CLARK and SIMPSON [1959], CANDLER and MUSGROVE [1960], McFARQUAR [1961], BARNARD and WESTON [1963], NIX [1967], RICHARDS [1967], CASON [1971], HARDAKER [1971], AGRAWAL and HEADY [1973], YANG [1965], BENEKE and WINTERBOER [1973], BARNARD and NIX [1973], UPTON [1973], GOTSCH [1975], BARNARD and NIX [1979], NIX [1979], M.A.F.F [1980], HARSH, CONNOR and SCHWAB [1981], and AUDSLEY [1985].

When linear programming was first used in the field of farm planning, work was concentrated on individual farms with the objective of working out the optimum farming system. Research workers attacked the farm organisation problem with great vigour in the nineteen fifties and sixties. A number of books and articles were published about linear programming and its application to the farm and to farm organisation. A complete and exhaustive review of previous literature studies is to be found in McFARQUAR [1962], HUTTON [1965], NIX [1969], and HARDAKER [1979]. For recent work, AUDSLY [1985] and BUTTERWORTH [1985] review the kind of the applications and the usefulness of linear programming to the development of arable-farm linear-programming models. With reference to new publications, the linear programming technique in the field of agriculture was also used to incorporate risk into the analysis.

Examples of this approach can be found in ANDERSON, DILLON and HARDKER [1977]. It has also been used to examine new cultivation systems, irrigation systems, farm transport systems, automatic ploughing, sugar beet harvesting systems, and numerous other smaller studies. It is currently in use on projects concerned with straw burning and reduced inputs (for further information see AUDSLEY [1985]). There are many other applications of this technique which are not discussed here. Studies of maximising farm plans for an individual farm have, for the most part, used farm survey data to:

(1) define the individual farm's resource base, both in quantity and quality;

(2) determine the input-output coefficients of the production processes for each enterprise considered feasible; and

(3) determine pertinent input and output prices.

The basic procedure in this type of study has been to determine initial and alternative optimum plans for the farm's resource situation. A resource and/or a price is then varied and a series of optimum farm plans determined. The sensitivity of the optimal solution to the major parameters can be determined, thus providing a way of checking the stability of the optimal solution. Studies by BOLES [1955], PUTERBAUGH, KEHRBERG and DUNBAR [1959], TYLER [1960], CLARK and SIMPSON [1959], BARNARD and SMITH [1959], STEWART [1961], SIMPSON [1960], and TYLER [1966], are examples of this approach.

It has been generally considered that linear programming can help the individual farm operator, and enable him to select a combination of livestock and crop enterprises which would maximise his expected profit subject to his limited resources. However, only a few farmers had benefitted directly from the use of linear programming. A primary reason that linear programming has not been employed extensively as an individual farm decision making guide is its heavy demands on both time (expense) and skill required per farm. As an alternative to individual farm linear programming, the linear programming model has been used to devise plans for typical, or modal, farming types, in order to guide planning on individual farms. Accordingly, a considerable expense and professional staff time can be justified in matrix building, data coding, computing and interpreting optimum plans and post-optimality analysis for representative farms. "Typical farm" linear programming has been thought particularly useful in areas where there is reasonable homogeneity in at least some of the major resources, especially with respect to natural factors, such as soil type, topography and climate. Here the choice of enterprises is often similar for all farms. Optimum plans for individual farms can then be calculated from a series of tables, according to its own particular resource pattern; that is, size of farm, number of men, etc.. In respect of this, BARNARD and NIX [1979] stated,

> "This is not to imply that the availability of such solutions makes individual farm planning unnecessary. Instead they provide a basis for the formulation of 'management objectives' that complement, rather than substitute for individual planning. In short, use is made of the inferences drawn from modal solutions and not the solutions themselves." [p.372]

Further, FIELDER [1961] and FIELDER and LONDHE [1966] show that the optimum solutions obtained for a typical farm resource situation can be improved by varying, either independently or jointly, the resources and/or prices; a series of alternative optimum farm plans can thus be determined. The results are useful in individual farm planning when taken by a farm adviser to the individual farm level and adapted for the specific farm resource situation. On the other hand, BARNARD [1963] carries this approach a step further than the type of studies referred to above. Following the development of optimum organisations for farms of selected typical farm resource situations, the farm adviser working with the enterpreneur uses these organisations to establish his management objectives. On the basis of the farmer's resource structure and management objectives the individual farm is matched to one of the programmed typical farm resource situations; the farm management constraints are then imposed on the planning model, and the optimum organisation for the farm determined. The adviser can then discuss the plan with the farmer, rather than have the added chore of adapting a typical plan to his farm.

A study presented by WADSWORTH [1962] shows an application of an approach which is a slight variation of previous techniques. This approach is to survey a type of farming area and calculate the usual measures of central tendency for the sample data. From the farms surveyed, an actual farm resource situation is selected which embodies as nearly as possible all of the characteristics of the average of the farms surveyed. The farm is then programmed and a series of optimum plans determined. This procedure is followed for several different resource situations. The results are used in individual farm planning in the same manner as those obtained from studies in which "typical" resource situations for an area are programmed.

An alternative methodology was suggested by BARKER [1964]. This was to use the farmer's own data from a detailed set of farm accounts to establish the resource constraints, and develop the enterprise budgets for the planning model of two New York farms. Although data were available in the farm records, much of this information was not in a form that could be used readily for budgeting or linear programming, and the labour records were not sufficiently accurate or detailed. To overcome the data problem, BARKER discussed at length with the farm operators in order to (1) separate the precise enterprise variable and fixed costs, (2) establish exact resource specifications and enterprise resource requirements, and (3) establish precise individual enterprise yields. Where data gaps existed, they were completed by drawing on pertinent research sources. The initial solutions were then obtained, presented to the farm operator and through interpretation and discussion evaluated for realism. Where changes in the initial coefficients and/or resource specifications used in the programme model were indicated, they were made, and additional solutions obtained.

Another methodological approach, namely the system of computerised farm planning, has been developed to simplify and organise the use of linear programming techniques. An example is MASCOT [BEALE, 1970; BOND, CARTER and CROZIER, 1970], which is an linear programming based farm planning system, operated by ICI as part of their Farm Advisory Service. A matrix generator is used to assemble the constraints from input data, and an output analyser allows the results to be presented in agricultural and financial terms [WHEELER and RUSSELL, 1977]. An alternative approach [JAMES, 1972] uses standard matrices which are representative of typical farm situations in a region. Right-hand side values and cost coefficients are inserted to suit the individual farm.

Another example for this approach is Purdue's "Top Farmer" program of management education [McCARL, 1977], which is also a computerised linear programming package with input form, matrix generator and report writer. The motives behind the above mentioned systems was stated by BOND, CARTER, and CROZIER [1970] as follows:

> "Using traditional methods of farm planning there is some difficulty in coping with today's complex situation and many farmers simply have to play hunches. There tends to be a gap between theoretical farm planning methods and those that are actually available and used on farms." [p.17]

The studies which are most relevant and helpful to this thesis, and that deal directly with the application of linear programming techniques to crops and livestock farm enterprises, are selected and reviewed briefly here. An early publication on the planning of an optimum combination between crops and livestock was by SWANSON and FOX [1954]. They showed how an optimum combination of livestock enterprises may be selected with a given crop rotation. The use of linear programming to identify a profit-maximising feed pattern for dairy cows was investigated by VINCENT [1961]. GUNN and SILVEY [1967] have examined one factor not considered in VINCENT's paper which is the variability in forage crop yield from year to year. The simultaneous determination of economically optimal cropping, feeding and breeding programmes within the confines of available resources could have a major impact on the profitability of an integrated livestock and feedlot operation. Optimal feeding programmes for the feedlot phase of production have been considered by PETERSON [1955], BROKKEN [1971], McDONOUGH [1971] and SCOTT and BROADBENT [1972] using linear programming. The effects of choices of both feeding and breeding programmes for an integrated cow herd and feedlot operation have been reported by LONG and FITZHUGH [1970] and CARTWRIGHT, LONG and FITZHUGH [1972], also using linear programming.

There has not been extensive consideration of either the optimal combination of cropping, feeding and breeding programmes or of the extent to which optimal programmes might be changed by varying resource limitations. Such limitations could exist for land, building, machinery, labour and etc.. The comprehensive analysis of the interplay between these characteristics within such a framework is essential, to provide objective guidelines to managers of integrated beef farms for choices of breeds and cross-breeding plans. Many aspects of a linear programming model of this type were described by LEIGH [1972]. WILTON, MORRIS, JENSON, LEIGH and PEEIFFER [1974] extended and modified this approach, and described (1) the use of linear programming in beef production planning on an integrated farm unit and, (2) the set of animal and crop production values, including numbers and weights of animals of various ages, feed and labour requirements and crop yields.

To summarise, it has already been indicated in the discussion above that many researchers have found the technique well suited to planning small-scale agriculture, and the applications of linear programming for planning small farms are numerous (e.g. further applications can be found in, CLAYTON [1965], JOHL and KAHLON [1967], JOHNSON [1969], HUFFMAN and STANTON [1969], OGUNFORWORA [1970], HEYER [1971], WILLS [1972], YARON and HOROWITZ [1972], HEYER [1972], LOW [1974], HARDAKER [1975; 1979], NUTHALL and MOFFATT [1975], MARTIN, WISE and MUSSER [1976], TREDE, BOEHLJE and GEASLER [1977], McCARL, CANDLER, DOSTER and ROBBINS [1977], WICKS and GUISE [1978], BRINK and McCARL [1979], FOX and DRIVER [1980], ANGIRASA, SHUMWAY, NELSEN and CARTWRIGHT [1981], NAGARAJA and VENKATARAM [1983], and GAINES [1984]). These illustrate the appeal of the method, at least to academic researchers. To date, linear programming models in the field of agriculture has been used also on several projects to examine new cultivation systems, farm-transport systems, automatic ploughing, sugar beet harvesting systems and numerous other smaller studies. The input to a model of this types allows a wide variety of situations to be examined and takes the form of a booklet into which the operator has to enter his data. The usefulness of this technique, as AUDSLEY [1985] stated:

> "...stems from the fact that the effect of many of the developments in agriculture is to alter the number of men and cropping because farmers are continually attempting to maximise their profit. Reducing labour on one particular operation does not in itself save any money, but by making changes to the farm, made profitable by this new operation, money is saved. Hence, looking at the whole farm is better than just looking at a single enterprise. Also the true value of a change can only be assessed by assuming that you are operating under optimal conditions before and after the change. The linear programming method determines a present optimum and a new optimum - the difference being the profit attributable to the new operation."[p.119]

From the flood of literature on planning individual farm resource situations, the only available publications on state farms were found in Iraqi publications. The reason why this sort of model is not available might involve either (1) the problem of language, or (2) the farming system in Western Europe and America, which is radically different from the sort of farming system under study. Nevertheless, the technique to be used in either case has the same power to cope with the specific objectives of this study, taking into account the appropriate situation of the farm under study, the local experience of Iraqi farm planning, and the philosophy behind the system of Iraqi state farms.

7.3. Application of Linear Programming to Iraqi Farms

Although, Linear Programming has an undoubted attraction for those interested in the problems of farm management, Iraqi agricultural economists have only in recent years shown a growing interest in the application of this technique to farm management problems. It therefore follows that, with its heavy demands of detailed and precise data, computer facilities and skill, there is a shortage of people who can apply the technique realistically and successfully. The two agricultural economics departments of the universities of Baghdad and Al-Musel have a few members of staff with some knowledge of the technique. However, they have many doubts as to whether in fact this approach has much practical application in the field of farm management, at least in Iraq. Consequently they have rarely tried to use the technique in economic research unless they are either looking for further experience, or can fit the technique into their teaching or research programmes. Hence, the assessment of the potential value of linear programming is made harder by the scarcity of good examples relating to Iraqi farms. It is not easy for those without sufficient knowledge of the technique to judge the practical worth of the plans presented in publications from abroad, especially if many of such publications refer to comparatively simple farm situations, particularly those where the bulk of the labour is provided by the farm family. The question may well be asked as to whether linear programming can usefully be applied to the complexities found on many of the large and different types of Iraqi farms.

To be more precise, an attempt was made to cover every possible reference of Iraqi resources, and these are reviewed briefly in this section. Some of these programming model applications have treated the livestock and crop rotations separately. ALAA [1976] and KHALIFA [1978] constructed models to select the optimum combination of crop rotation; no consideration was given to livestock enterprises. ALWARD [1980] indicated in his model the possibility of including sheep rearing activity as well as crop production. ZOUBEIR [1977], SHARIF , NAJAFI and SALIM [1980], and ABDEL KADER [1980], have shown how an optimum combination of livestock enterprises may be selected with a given crop rotation.

According to the above mentioned studies, the application of linear programming to farm planning in Iraq could be termed research. The authors have been looking for ways to apply simple forms of linear programming technique to obtain initial and alternative farm plans, without taking into account the extensions of the technique, such as the various implications of shadow prices, post-optimality analysis and so on.

However, in the next phase of the farm planning work, attention was directed to aiding the state farming establishment to propose a number of crop rotations suitable for the production of industrial crops in Iraqi state farms. This required the analysis of the economic feasibility of each of the proposed rotations, as related to factors influencing crop production in these farms such as land, water, human and financial resource availability. Therefore the Iraqi government asked the Arab Organisation for Agriculture Development (AOAD) of the Arab League to explore alternative opportunities for increasing the production of industrial crops in the country's state farms. The AOAD group's work was completed by June 1983 [AOAD, 1983], and they proposed three alternative crop rotations for each of the state farms.

The economic analysis indicated that total net farm income is inversely proportional to the increase in intensification of industrial crops. In the case where two alternatives are found to be equal in net income, the study favoured the rotation with the higher degree of intensification in industrial crops, in order to supply raw material for agro-industry production and achieve self-sufficiency in this area.

7.4. Conclusion

To date most linear programming in the field of farm management has dealt with representative farm situations rather than actual individual farms. This thesis describes the application of linear programming on an individual state farm in Iraq. Programming of the modal farm for Iraqi agriculture, which might have greater scope in development schemes in some countries, is made harder by the wide variation between farms in the resources available, choice of activities, managerial ability and government programmes, even within areas of similar natural attributes. Indeed it is this dissimilarity between individual state farms that is one of the main arguments for using linear programming, which can handle variations in individual circumstances. Therefore in a large-scale farm system, especially since the introduction of very cheap computers, the potential value of using mainly the actual farm circumstances (standardised data can be used when appropriate) might be worthwhile.

Of the literature reviewed, a combination of the methodologies employed is the most relevant for this study. Whereas some authors used the farmer's own data primarily, others used research generated "average" performance data. Both, however, used detailed programming models for planning individual farms. The use of a limited information programming model based on a farmer's own data, could be another methodology, however. The development of a series of enterprise production processes and cost-return budgets, for categorised resource and management situations, is the most generally used and accepted approach in individual farm planning. The budgetary data used are typically drawn from several sources, such as farm surveys, farm account project summaries, farm case studies, and research studies in the agricultural science disciplines. After analysing and modifying the data, and by selecting the appropriate enterprise budgets for the individual farm, the program matrix is (1) established for the farm's own resource situation and planning problems, and (2) transformed into computer input and processed by computer. The results are interpreted, discussed and an alternative solution is determined. This second solution requirement frequently results from the operator and management adviser determining that one or more of the budgets used in the planning model, and for certain resource specifications, were insufficiently specified. Thus the initial solution was too radically different from either the existing farm organisation or management preferences to be acceptable. In the end, it could be worth investigating both (1) the stability of the plan in terms of alternative price or resource variations and, (2) the demand curves for the most crucial resources.

The presentation of a programming model in which the livestock enterprises and crop rotations are selected simultaneously may provide a more complete and therefore more realistic approach to the use of activity analysis in farm planning. Thus, an individual state farm was selected which has a relatively good set of financial and physical records over a large number of years and the programming technique was applied to its problems. Although the farm under study might be representative of many others, it is not suggested that the optimum programme could be applied to them without modification.

It is hoped that the analysis in this thesis of the application of linear programming to a cash and forage crop, and livestock state farm will be of value in helping the Iraqi farm management specialists to make their own assessment of the potential of this approach. The specific methods used in the application may be of interest to others who are either using or hoping to use linear programming in this context. Therefore the value of the solution lies mainly in its indication of certain principles that should be capable of application to similar farms. For example, that it does not pay to grow grain for feeding on the farm, or again, that it is worth obtaining more accommodation to breed chickens.

CHAPTER 8

THE BASIC PROGRAMMING-PLANNING MODEL OF THE AL-NAHRAWAN STATE FARM

8.1. Introduction

The basic planning model of the Al-Nahrawan state farm, developed to take account of all the circumstances described previously, is given in this chapter. Planning the farm programme involves building a whole farm planning model which gives particular attention to forage production and livestock breeding activities. The model also contains production possibilities for laying hens and cash crop activities. The production of each of these activities takes place within the yearly availability of resources.

The model assumes that the raising of dairy cattle, sheep and laying hens are the only feasible livestock activities, while wheat and malting barley are the only feasible cash crops activities. The forage programme is given special treatment because of the critical role played by the time dimension in a realistic analysis of optimum forage production. It will be organised to provide forage for the dairy cattle and sheep by the most efficient means, given the constraints and the range of forage alternatives available; the forage programme has a choice among a wide range of forage crops.

The objective of this model is maximisation of the farm's net revenue. Achieving this objective implies that the farm programme will be organised so as to choose the optimum combination between cash crops, forage and livestock activities, so as to make the most profitable amounts of the different products by the most efficient means, subject to the capacity or resource availability constraints.

8.2 The Farm Planning Model

The basic objective function of the farm is:

$$Z = \sum_{c=1}^{10} r_c x_c + \sum_{\ell=11}^{13} r_\ell x_\ell$$

Where:

x_c = Area of crop c. (c = 1, 2, ..., 10)

X_ℓ = Number of livestock ℓ. (ℓ = 11, 12, 13)

r_c = The net revenue of crop c per unit.

r_ℓ = The net revenue of livestock ℓ per unit.

This objective function represents net revenues before deducting the forage variable costs from the dairy cattle and the sheep revenues. It is therefore more convenient to extend this function to a new one (as shown below) where forage variable costs could be considered when we maximise the farm net revenue. Thus, The linear programming objective function for the Al-Nahrawan state farm can be rewritten as follows:

$$Z = \sum_{c=1}^{2} r_{c\varepsilon c}\, x_{c\varepsilon c} + \sum_{\ell=11}^{13} r_\ell x_\ell - \sum_{c=3}^{10} v_{c\varepsilon f}\, x_{c\varepsilon f}$$

Where:

$x_{c\varepsilon c}$ = Area of cash crops $c_{\varepsilon c}$. ($c_{\varepsilon c}$ = 1, 2) where εc is the cash crops index.

x_{ℓ} = Number of livestock ℓ. (ℓ = 11, 12, 13)

$x_{c\varepsilon f}$ = Area of forage crops $c_{\varepsilon f}$. ($c_{\varepsilon f}$ = 3, 4, ..., 10) where εf is the forage crops index.

$r_{c\varepsilon f}$ = The net revenue of cash crops $c_{\varepsilon c}$.

r_{ℓ} = The net revenue of livestock ℓ.

$V_{c\varepsilon f}$ = The variable cost of forage crops $c_{\varepsilon f}$.

8.3. Subject to the following constraints

1- The ploughable area for winter crops.

$$\sum_{\varepsilon\alpha} x_c \leq A_1$$

Where:

α = winter crops index

A_1 = ploughable area available for winter crops.

2- The ploughable area available for summer crops.

$$\sum_{\varepsilon\beta} x_c \leq A_2$$

Where:

β = summer crops index.

A_2 = Area available for summer crops.

3- Quantities of water available for irrigation in months i.

(i = 1, 2, ..., 12).

$$\sum_{c=1}^{10} w_{ic}x_c + \sum_{\ell=11}^{13} w_{i\ell}x_\ell \leq W_i$$

where:

w_{ic} = The amount of water needed to irrigate a hectare of crop c during month i.

$w_{i\ell}$ = The amount of drinking water needed for a unit of measurement of livestock ℓ during month i.

W_i = Maximum amount of water available during each month i.

4- Medium-sized tractor hours available:

$$\sum_{c=1}^{10} t_{ic}x_c + \sum_{\ell=11}^{13} t_{i\ell}x_\ell \leq T_i$$

where:

t_{ic} = seasonal requirements of tractor/hour, i, required for a crop c.

$t_{i\ell}$ = seasonal requirements of tractor/hours, i, required for a livestock ℓ.

T_i = Tractor/hours available during seasons i. (i= 1, 2, 3, 4)

5- **Large-sized tractor/harvester hours available:**

$$\sum_{c=1}^{10} h_{ic}x_c + \sum_{\ell=11}^{13} h_{i\ell}x_\ell \leq H_i$$

where:

h_{ic} = The annual machine/hours i required for each hectare of crops c.

$h_{i\ell}$ = The annual machine/hours i required for each unit of livestock ℓ.

H_i = Annual machine/hours available of type i. (i= 1, 2, 3)

(1= large-sized tractor, 2= forage harvester, 3= cereal harvester)

6- **Labour available:**

It has been indicated in Chapter 3 that there is a lack of technical studies in seasonal labour requirements. These are needed to construct accurate and adequate assumptions for solving the seasonality problem in the Al-Nahrawan state farm. As a result, yearly aggregate demand figures are used for hired manpower. Therefore this constraint states that the annual number of man/hours required for crops and livestock is less than or equal to the hours available during the year:

$$\sum_{c=1}^{10} l_{ic}x_c + \sum_{\ell=11}^{13} l_{i\ell}x_\ell \leq L_i$$

where:

l_{ic} = The annual man/hours i required per each hectare of crops c.

$l_{i\ell}$ = The annual man/hours i required per each unit of livestock ℓ.

L = The annual number of man/hours available.

7- **Dairy cattle accommodation available:**

$$X_{\ell_{\varepsilon o}} \leq O$$

where:

εo = cattle index.

O = The maximum capacity of the existing cow buildings.

8- **Laying hens accommodation available:**

$$X_{\ell_{\varepsilon k}} \leq K$$

where:

k = Laying hens index.

K = The maximum capacity of the existing buildings.

9- **Forage crop availability:**

$$\sum_{c=1}^{10} n_{ic}x_c + \sum_{\ell=11}^{13} n_{i\ell}x_\ell \geq 0$$

where:

n_{ic}= Amount of nutritive elements from each hectare of crops c. (i= 1, 2, 3, 4) (1= T.D.N, 2= Digestible protein, 3= Calcium, 4= Phosphorus)

$n_{i\ell}$= Average requirements for each unit of measurement of the livestock ℓ (ℓ= 1, 2) (1= dairy cattle, 2= sheep)

10- **Government constraint on Malting Barley production:**

$$X_{c_{\varepsilon b}} \geq B$$

where:

εb = Malting barley index.

B = The minimum limit of hectares to be used for malting barley production.

11- **The area of summer alfalfa should be equivalent to the area of winter alfalfa.**

$$X_{c_{\varepsilon g}} - X_{c_{\varepsilon g}o} = 0$$

where:

$c_{\varepsilon g}$ = Winter alfalfa index.

$c_{\varepsilon g}o$ = Summer alfalfa index.

12- **Government constraint on wheat production:**

$$X_{c_{\varepsilon y}} \geq Y$$

where:

εy = Wheat index.

Y = The minimum area to be used for wheat production.

Since all the variables (x_c and x_ℓ) have to be non-negative, any of them could be at the zero level, indicating that production is unprofitable.

8.4. Building the Matrix

To establish an appropriate programming matrix, enough information has been accumulated and set out in tabular form, following the pattern which will be used throughout the rest of this study. This is a suitable method of presenting data for computer planning.

The matrix is shown in Table 8.2. Its structure follows the pattern outlined in Sections 8.2 and 8.3. In this layout the **thirteen** enterprises are entered as possible activities and listed in columns, on a per unit basis. The units used for these activities are hectares for the farm crops, animal group units for dairy cattle and sheep, and 100 birds in the case of laying hens.

The farm crops and livestock activities are subdivided, identified and presented into the matrix as shown in Table 8.1.

Table 8.1. Classification and Identification of the Farm Activities

(as presented to the original Matrix - Table 8.2)

Identification	Farm Activities
	A- CROPS
	i- Winter Crops:
	1- Cash Crops:
X_1	Wheat
X_2	Malting Barley
	2- Forage Crops:
X_3	Green Barley
X_4	Grain Barley
X_5	Alfalfa
X_6	Mixed Crop
X_7	Clover
	ii- Summer Crops:
X_8	Maize
X_9	Sorghum
X_{10}	Alfalfa
	B- LIVESTOCK
X_{11}	Dairy cattle
X_{12}	Sheep
X_{13}	Poultry

The net revenues of these activities are entered in row 0 of the matrix with appropriate signs to indicate gains or losses.

In the B column the available quantity of each resource is listed, followed by the appropriate sign. The signs represent relationships in the form = , $\leq$, $\geq$, with $\leq$ being by far the most widely used type. This kind of constraint has been used where a number of the farm activities are in competition for a fixed supply of available resource, as in planning the use of land, water, labour and machinery (R_1 to R_{22}). Alternatively, it can be used to impose an upper limit on one single activity, as we shall see in the next chapters. In using this kind of constraint, it is not necessary that the whole of any resource supply must be fully used up. The minimum activity levels are represented in the matrix by use the signs = and $\geq$. Equality signs are used to specify the "obligatory" relationships; as shown in rows R_{27} to R_{31}, while $\geq$ signs are imposed to specify that livestock forage crops should be produced at a level not less than that quantity required by the farm animals, bearing in mind that $\geq$ signs can be changed by altering the signs (- and +) in the body of the matrix.

In the body of the matrix the constraints are listed in rows. It is equally important to declare the units employed for these rows where the resources available and the other constraints are set out.

The first row in the matrix restricts the winter crop activities to the winter ploughable area of 2,844 hectares. The first seven activities are entered on a per hectare basis, and therefore the figure "1" is entered under each of these activities on the winter land row. The last six activities require no such a land, and so zeros are entered on this row.

The second row restricts the summer crop activities to the summer ploughable area of 1687.5 hectare, in a similar way to that described above.

Rows 3-22 contain the requirements per unit of each activity for the various resources listed (water for irrigation, man and machinery hours requirements). Thus on row R_3 under column X_1 the value 828 indicates that each hectare of wheat requires $828m^3$ of water for irrigation during the first month, and so on.

Rows 23-26 are organised to detail the home-nutrient contents for the dairy cattle and sheep requirements. Feed nutrient content requirements for laying birds are not included for the reasons discussed on pages 75-76.

Row 27 is concerned with the rotational restrictions on winter and summer alfalfa, while rows 28 and 29 represent the minimum quota limits of 250 hectares of wheat and 375 hectares of malting barley, respectively.

Rows 30 and 31 restrict the size of the dairy cattle and laying hens herds to the cow and poultry building capacities.

Table 8.2. Linear Programming Matrix for the Al-Nahrawan State Farm.

					CASH CROPS	
					Wheat	Malting Barley
	Column Number				X_1	X_2
Row Number		Unit	B column	Relation		
R_0	Net Revenue	I.D		=	29.46	110.25
R_1	Winter ploughland	Hectare	3844	≤	1	1
R_2	Summmer ploughland	"	1687.5	≤	-	-
	Water for irrigation:					
R_3	(Jan.)	m^3	3335904	≤	828	828
R_4	(Feb.)	"	3487536	≤	1120	1220
R_5	(March)	"	3942432	≤	1364	1364
R_6	(April)	"	3942432	≤	1166	-
R_7	(May)	"	5054400	≤	-	-
R_8	(June)	"	5256576	≤	-	-
R_9	(July)	"	5054400	≤	-	-
R_{10}	(August)	"	4650048	≤	-	-
R_{11}	(Septem.)	"	5256576	≤	-	-
R_{12}	(October)	"	4447872	≤	-	-
R_{13}	(November)	"	3639168	≤	1012	972
R_{14}	(December)	"	4094064	≤	820	820
R_{15}	Labour	Man/hour	482328	≤	40.64	36.80
	Medium sized tractor:					
R_{16}	(1st season)	Machine/hour	21300	≤	-	-
R_{17}	(2nd season)		23100	≤	2	2
R_{18}	(3rd season)		22200	≤	3.50	3.50
R_{19}	(4th season)		21900	≤	4.89	4.89
R_{20}	Large sized tractor (yearly)		8850	≤	2.428	2.428
R_{21}	Forage Harvester		7080	≤	-	-
R_{22}	Grain combine		2336	≤	1.28	1.28
	Feed nutrient contents:					
R_{23}	(T.D.N)	"	0	≥	711.4	862.4
R_{24}	(Digestible Protein)	"	0	≥	3.4	7
R_{25}	(Calcium)	"	0	≥	2	7.80
R_{26}	(Phosphorus)	"	0	≥	6.6	4.40
R_{27}	Alfalfa	Hectare	0	=	-	-
R_{28}	Wheat	"	250	≥	1	-
R_{29}	Malting barley	"	375	≥	-	1
R_{30}	Dairy cattle	Unit	500	≤	-	-
R_{31}	Laying hens	100 bird	480	≤	-	-

(continued)

(continued)

	WINTER CROPS					SUMMER CROPS			LIVESTOCK		
	Barley Green	Barley Grain	Alfalfa	Mixed Crop	Clover	Maize	Sorghum	Alfa.	Dairy Cattle	Sheep	Poultry
	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}
R_0	-78.5	-56	-110	-118.7	-131	-106.7	-115.3	-77.3	1158.7	16.5	265
R_1	1	1	1	1	1	-	-	-	-	-	-
R_2	-	-	-	-	-	1	1	1	-	-	-
R_3	900	828	900	592	520	-	-	-	1.86	0.465	0.93
R_4	1012	1220	1012	852	764	-	-	-	1.68	0.420	0.84
R_5	1352	1364	3952	1340	1636	-	-	-	1.86	0.465	0.93
R_6	1900	-	1900	1772	1976	-	-	-	1.80	0.450	0.90
R_7	-	-	-	-	-	-	3220	3252	1.86	0.465	0.93
R_8	-	-	-	-	-	-	3840	4432	1.80	0.450	0.90
R_9	-	-	-	-	-	3180	4360	5580	1.86	0.465	0.93
R_{10}	-	-	-	-	-	1900	3900	5020	1.86	0.464	0.93
R_{11}	-	-	-	-	-	1764	2600	3700	1.80	0.450	0.90
R_{12}	-	-	-	-	794	1548	2600	2440	1.86	0.465	0.93
R_{13}	1452	972	4352	1152	784	1240	-	-	1.80	0.450	0.90
R_{14}	1052	820	1052	420	1084	-	-	-	1.86	0.465	0.93
R_{15}	29.44	36.8	78.6	39.36	39.36	63	68.2	42.28	380	5.84	60
R_{16}	6.1	-	9.6	13.2	7	-	8.36	-	6	0.5	1
R_{17}	6.1	2	-	6.6	7	-	7	9.6	6	0.5	1
R_{18}	3.5	3.5	3.5	3.5	8.35	13.46	7	9.6	6	0.5	1
R_{19}	4.89	4.89	4.89	4.89	7	-	8.6	4.8	6	0.5	1
R_{20}	2.428	2.428	2.428	2.428	2.428	2.428	2.428	-	-	-	-
R_{21}	1.776	-	3.552	2.664	2.664	1.776	2.664	2.664	-	-	-
R_{22}	-	1.28	-	-	-	-	-	-	-	-	-
R_{23}	3078	1773.25	4098.56	4215	3320	5730.3	8330	3073.9	-15019	-0379	-
R_{24}	417.6	105.1	921.6	741	838.4	408.3	190.4	691.2	-2492	-38.5	-
R_{25}	5.4	10.73	38.4	24	41.6	13.28	81.2	28.8	-80.8	-02.1	-
R_{26}	3.6	6.84	5.12	4.5	3.2	8.632	50.4	3.84	-60.4	-1.4	-
R_{27}	-	-	1	-	-	-	-	-1	-	-	-
R_{28}	-	-	-	-	-	-	-	-	-	-	-
R_{29}	-	-	-	-	-	-	-	-	-	-	-
R_{30}	-	-	-	-	-	-	-	-	1	-	-
R_{31}	-	-	-	-	-	-	-	-	-	-	1

CHAPTER 9

THE INITIAL PLANNING RESULTS AND THE EFFECT OF ADDING CROPPING ROTATION CONSTRAINTS

9.1. The Initial Planning Results

The results obtained from the planning model as initially formulated are shown in Tables 9.1, 9.2, and 9.3 (Solution 1). (For details of computation see Appendix 1). Table 9.1 shows that the optimum plan includes 250 hectares of wheat (activity X_1), 1237.8 hectares of malting barley (activity X_2), 77.2 hectares of winter alfalfa (activity X_5), 1052.6 hectares of mixed crop (activity X_6), 119.9 hectares of clover (activity X_7), 434.8 hectares of maize (activity X_8), 280.5 hectares of sorghum (activity X_9), and 77.2 hectares of summer alfalfa (activity X_{10}). Turning to the livestock activities, the optimum values of rearing dairy cattle and laying hens are 500 and 480 units respectively.

The farm net revenue of this plan was computed to be I.D.616528. Of course, the profitability would be directly influenced by a change in the revenue of any activity, but the level of some activities in the plan would remain the same. The reason why the dairy herd and the laying hens are not expanded is that the plan already includes the maximum amount of these activities determined by constraints R_{30} and R_{31}. Competition for cash crops area between wheat and malting barley shows that the malting barley is the more profitable. The wheat activity is included in the optimum plan with a cost penalty of I.D.78.64 per hectare (the value of the shadow price). This shows the fall in costs (or rise in revenue) needed to cause this activity to enter the plan. Therefore if a hectare of wheat is "forced" into the final plan, the value of the programme would be reduced by I.D.78.64. But the reason the wheat area is not excluded from the optimum plan is that the plan already includes the minimum amount of wheat area determined by constraint R_{28} for the reason discussed previously.

Comparison between dairy cattle and sheep breeding activities shows that the dairy cattle are the more profitable. Thus the size of the dairy herd was found to be at the maximum capacity of the cow buildings, while the sheep herd was excluded from the optimum result.

Before examining Table 9.1 it is convenient to remind the reader that the distribution of the forage programme area is to be organised to satisfy the whole dairy cattle and sheep requirements for the four given nutrient contents, and of course by the most efficient means. Therefore one or some of the nutrient contents have to be equivalent to the farm livestock requirements. The others are expected to be abundant as a result of differences between their existing ratios, which vary from one crop to an other, and their required ratios, which differ between livestock.

The information given in Table 9.1 is followed by a list of activities not in the solution. In this planning result green feed barley, grain barley and sheep (activities X_3, X_4, and X_{12} respectively) are excluded from the optimum plan. The figures 63.115 and 127.768 and 1.915 are given opposite activities X_3, X_4, and X_{12}

respectively, which indicate how much the value of this plan would be reduced if an additional unit of these activities were forced into the plan (see Table 9.1).

Table 9.1. Activity Levels and Marginal Opportunity Costs of the Excluded Activities.- Solution 1

Identification	Description	Unit	Level
a) Activities:			
X_1	Wheat	Hectare	250.0
X_2	Malting barley	"	1237.8
X_5	Winter alfalfa	"	77.2
X_6	Mixed crop	"	1052.6
X_7	Clover	"	119.9
X_8	Maize	"	434.8
X_9	Sorghum	"	280.5
X_{10}	Summer alfalfa	"	77.2
X_{11}	Dairy cattle	Group unit	500.0
X_{13}	Laying hens	100 birds	480.0
	Total net revenue	I.D.	616528
b) Marginal oportunity costs of the excluded activities (shadow prices)			
	Activities:	Unit	M.O.C
X_3	Green feed barley	Hectare	63.115
X_4	Grain barley	"	127.770
X_{12}	Sheep	Unit	1.915
c) M.V.P. of the included wheat		**Hectare**	**78.64***

* M.V.P. of included activity is a cost penalty.

Table 9.2 deals with the quantities of unused resources and is quite straightforward.

Table 9.2. Resources unused - Solution 1

Identification	Description	Unit	Level
R_1	Winter ploughable area	Hectare	1106.5
R_2	Summer " "	"	895
R_3	Water for irrigation (Jan.)	m^3	1347688
R_4	(Feb.)	"	1084565
R_6	(April)	"	1400769
R_7	(May)	"	3898684
R_8	(June)	"	3835885
R_9	(July)	"	2016486
R_{10}	(August)	"	2340958
R_{11}	(September)	"	3473248
R_{12}	(october)	"	2760476
R_{14}	(December)	"	2219432
R_{15}	Labour	Man/hour	105812
R_{17}	Medium size tractor(2nd season)	Trac./hour	6153
R_{19}	" " " (4th season)	"	2040
R_{20}	Large-size tractor	Trac./hour	4466.6
R_{21}	Forage harvesters	Harv./hour	1957
R_{22}	Combine "	"	431.7

Table 9.3 relates to the exhausted resources and operative planning constraints. The values below M.V.P indicate the marginal value product of each given resource. For example, one extra unit of dairy cattle would increase the total revenue by 151.8 Iraqi Dinars. The main value of these computed marginal value products is to indicate the relative importance of the various planning constraints. In this plan Digestible Protein has a relatively high marginal product of I.D.1058.5 per unit, indicating that it would be worth investigating the possibility of obtaining more units of digestible protein.

Table 9.3. The Marginal Value Products of the Operative Constraints

(Solution 1)

	Resource fully used	Unit	M.V.P (I.D)
R_{30}	Maximum dairy cattle	Group unit	151.800
R_{31}	Maximum laying hens	100 bird	259.900
R_{24}	Digestible protein	Kg	1058.500
R_{26}	Phosphorus	"	139.900
R_5	Water for irrigation (March)	m^3	388.000
R_{13}	" " " (November)	"	49.300
	Medium/sized tractor:		
R_{16}	1st season	Tract./hour	45.200
R_{18}	3rd season	"	65.300

9.2. The Present and Optimum Organisations Compared

In Table 9.4, the plan determined from Model 1 is compared with the actual organisation of the farm to provide an answer, at least in part, to the specific objective (resource use for a maximum net revenue) of this research study.

The financial data is presented in the form of trading accounts. Total net revenue is 233 percent greater in the optimum solution as the result of an increase in the scale of six established enterprises: Wheat, Malting Barley, Mixed Crop, Maize, Dairying and Poultry, and the reduction of four others: Winter Alfalfa, Clover, Sorghum and Summer Alfalfa. Three enterprises are excluded: Green Feed Barley, Grain Barley and Sheep. Although these changes may seem far-reaching they do not, in fact, call for a radical shift in the use of running costs, e.g. variable cost is only 3.1 percent greater under the optimum organisation.

In examining Table 9.4, it can be seen that the area of wheat, in the present plan, is 50 hectares less than that obtained by the optimum solution. This is because the wheat area in the present plan represents the average area for the period 1979-1983, while the area shown in the optimum solution represents the required projected area stated by Constraint 12 (Section 8.3). Omitting this constraint, the figure will change substantially as we shall see in Section 10.2.1b.

Table 9.4. Present and Optimum Plans Compared

Physical Data	Present Plan		Optimum Plan	
Crops	Hectares	% of ploughland	Hectares	% of ploughland
Wheat	200.00	5.48	250.00	7.07
Malting Barley	473.25	12.96	1237.80	35.02
Green Feed Barley	183.00	5.01	0.00	0.00
Grain Barley	335.25	9.18	0.00	0.00
Winter Alfalfa	155.50	4.26	77.20	2.18
Mixed Crop	502.50	13.76	1052.60	29.78
Clover	631.00	17.28	119.90	3.40
Maize	352.50	9.65	438.80	12.42
Sorghum	623.25	17.07	280.50	7.95
Summer Alfalfa	195.50	5.35	77.20	2.18
	3651.75	100.00	3534.00	100.00

Livestock	Units	Units	% of present plan
Dairy cattle	292.50	500.00	170.94
Sheep	597.00	0.00	0.00
Poultry	360.00	480.00	133.20

Financial Data						
Receipts	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.
Cereals	17280			21600		
Malting Barley	79260			207307		
		96540			228907	
Dairy cattle product	379665			649000		
Sheep herd products	13850			-		
Poultry products	176078			234576		
		569593			883576	
			666133			1112483
Variable costs						
Wheat	11388			14235		
Malting Barley	27084			70839		
Fodder products	317137			233855		
Dairy cattle	40745			69650		
Sheep	4000			-		
Poultry	80599		480953	107376		495955
Net Revenue			185180			616528

In comparing the use of the farm resources in the present plan with that suggested in the optimum solution, as Table 9.5 shows, the farm plan for Model 1 differed in nearly every respect. For example, in the case of land use, whereas an additional 257 hectare of the winter croppable area is put under cultivation, about 379 hectares of the summer area is taken out of cultivation. Taking the hectareage changes, about 1,365 and 461 hectares of the winter and summer ploughland, respectively, are turned from one use to another, as shown in Table 9.5.

Table 9.5. Hectareage Changes in Winter and Summer Ploughland

Increase	Hectares	Decrease	Hectares
a) Winter Ploughland*			
Wheat	50.00	Green feed barley	183.00
Malting Barley	764.55	Grain barley	335.25
Mixed crop	550.10	Winter alfalfa	78.30
		Clover	511.10
		Total	1107.65
		unused land	257.00
	1364.65		1364.65
b) Summer Ploughland*			
Maize	86.30	Sorghum	342.75
Unused land	374.75	Summer alfalfa	118.30
	461.05		461.05

* Calculated from Table 9.4.

Table 9.6. Resource Requirements for the Present and the Optimum Plan Compared.

Resource	Unit	Quantity Required present	optimal	% of present
Land				
Winter ploughland	Hectare	2480.50	2737.50	110.36
Summmer ploughland	"	1171.25	792.50	67.66
Water for irrigation				
(Jan.)	m^3	1736635.00	1988216.00	114.49
(Feb.)	"	2420268.00	2857866.00	118.08
(March)	"	3895263.00	3942432.00	101.21
(April)	"	1992623.00	2541663.00	127.55
(May)	"	2663786.00	1155716.00	43.37
(June)	"	3260853.00	1420691.00	43.57
(July)	"	4930365.00	3037915.00	61.62
(August)	"	3048395.00	2309090.00	75.75
(Septem.)	"	2808462.00	1783328.00	63.50
(October)	"	3611500.00	1687397.00	46.72
(November)	"	2859063.00	3639168.00	127.28
(December)	"	2049761.00	1874632.00	91.45
Labour	Man/hour	296015.00	376516.00	127.19
Medium sized tractor:				
(1st season)	Machine/hour	21283.00	21300.00	100.08
(2nd season)	"	19520.00	16947.00	86.82
(3rd season)	"	25140.00	22200.00	88.30
(4th season)	"	24189.00	19860.00	82.10
Large sized tractor(yearly)	"	8392.00	8384.00	99.90
Forage Harvester	"	6704.00	5123.00	76.42
Grain combine	"	1291.00	1904.00	147.48
Concentrate feed for poultry	Kgs	1080900.00	1440000.00	133.22
Feed nutrient contents:				
(T.D.N)	"	4619320.00	7509500.00	162.57*
(Digestible Protein)	"	751602.00	1245500.00	165.71*
(Calcium)	"	24888.00	40400.00	162.33
(Phosphorous)	"	18854.00	30800.00	163.36*
Ammonium Nitrate	"	634030.00	580800.00	91.60
Superphosphate	"	248545.00	236794.00	95.27

* Ratio differences are due to the exclusion of sheep rearing in the optimum plan, while sheep requirements are included in the present plan.

In the case of livestock building use, where restrictions of maximum building space and capacities were included, both dairy cattle and poultry rise to their maximum permissible number. These increases represent 170.9 percent and 133.2 percent of the present use of dairy cattle and poultry accommodation, respectively. Although these changes call for a similar percentage increase in the feedingstuff requirement, it is sufficient to supply the exact requirement necessary for the dairy cattle being produced from a fodder crop area of 2,046 hectare, which is 932 hectare (or 31.3 percent) less than the present fodder land (2,978 hectare).

As a result, changes in the use of the other farm resources are expected. Table 9.6 shows the percentage changes in most farm resources. In the case of labour requirement per annum, a considerable increase in the requirement of 27 percent of the time worked by the labour force in the original programme is required by the optimum programme.

Similarly with the water requirement. Taking the six peak months (from November to April), a range between 91.5-127.5 percent of the present water use is required for the optimum production patterns. For the period between May and October, a range between only 43.3-75.75 percent of the current requirement is needed for the optimum solution (see Table 9.6).

In the case of machinery use, whereas a slight increase in the medium sized tractor hours during the first season is required, there are decreases of 13.18 percent, 11.7 percent, and 17.9 percent in medium sized tractor hours requirement for the optimal plan during the second, the third, and the fourth seasons, respectively. In the case of large sized tractor requirement per annum, there is a very small reduction in the requirement of 0.1 percent of the time worked by this kind of tractor at the optimum from the original programme.

As a result of the decreased fodder allotment, only 76.42 percent of the present use of forage harvesters is required. Conversely, because of the increased area of cereal and malting barley, the optimum organisation requires 47.48 percent more combine hours than at present.

In the last two rows of Table 9.6 are shown the quantities of fertiliser required. In comparing these requirements, the optimum solution would include the use of 91.6 percent and 95.27 percent of the present use of ammonium nitrate and phosphate, respectively.

Undoubtedly, the solution obtained from Model 1 is the optimal solution consistent with the specified constraints and the assumptions of the linear model. In farm planning the solution identified as optimal by the linear programming procedure might well be less desirable in practice than some other plan which gives a slightly lower total net revenue, but which has other advantages to better satisfy some aspects of the farm's true planning objectives, which are not incorporated in the programming model.

In developing Solution 1 into an operational farm plan, it is evident that a number of additions and modifications would need to be made to the information contained in the original matrix. The first aspect requiring our attention is the need to convert the hectareages of crop activities into operational crop rotations which the farm can follow. A further aspect is the use of a number of variants on the original model, which can be used to investigate the effects of changing some of the planning constraints. Therefore, there may exist an infinite number of alternative or sub-optimal solutions to the planning model, but of course, many of these would be of no practical interest. In the next section, the introduction of crop rotation will be briefly investigated and a new basic model will be achieved. In the next chapter, bought-in concentrate feed for cattle and adjustments to the new basic original model will be selected on the basis of shadow price, sensitivity analysis, and knowledge of the actual circumstances of the farm, as revisions which are likely to be of practical interest.

9.3. Cropping Rotation and Variants of the Basic Model

Following the discusion above, a total of seven solutions have been computed for the Al-Nahrawan state farm. Solution 1 has already been discused. The variants of the planning model leading to this and to the other six solutions are given in Table 9.7, while all seven solutions are summarised in Table 9.8.

Table 9.7. Summarised Description of the Seven Solutions.

Solution No.	Rotational Constraints*
1	None
2	Clover/Maize (1)
3	Mixed crop/Sorghum (2)
4	(1) and (2)
5	Clover/Sorghum (3)
6	Mixed crop/Maize (4)
7	(3) and (4)

* More discussion of these constraints can be found later on in this chapter.

Table 9.8. Summary of the Seven Solutions

Enterprise	Unit	1	2	3	4
			Solution Number		
Green Fodder Barley	Hectare	zero	zero	zero	zero
Malting Barley	"	1237.8	1237.8	887.7	972.9
Grain Feed Barley	"	zero	zero	zero	zero
Winter Alfalfa	"	77.2	5.5	358.4	328.5
Mixed Crop	"	1052.6	963.5	364	388.4
Clover	"	119.9	366.2	296.2	277.8
Wheat	"	250	250	250	250
Maize	"	434.8	366.2	250.2	277.8
Sorghum	"	280.5	297.3	364	388.4
Summer Alfalfa	"	77.2	5.5	358.4	328.5
Dairy Cattle	Cow unit	500	500	500	500
Poultry	100 birds	480	480	480	480
Sheep	Sheep Unit	zero	zero	758	zero
Total Revenue	I.D.	1112483	1112466	1071407	1068117
Total Variable Cost	"	495955	498824	464927	465375
Total Net Revenue	"	616528	613642	606480	602742
Per Dinar Return	"	2.243	2.230	2.304	2.295

(continued)

(continued)

Enterprise	Unit	Solution Number 5	6	7
Green Fodder Barley	Hectare	zero	zero	zero
Malting Barley	"	1237.7	937.7	938
Grain Feed Barley	"	zero	zero	zero
Winter Alfalfa	"	27	353.7	351.9
Mixed Crop	"	990.2	280.9	279.5
Clover	"	292.3	334.1	339.5
Wheat	"	250	250	250
Maize	"	386.8	280.9	279.5
Sorghum	"	292.3	339.2	339.5
Summer Alfalfa	"	27	353.7	351.9
Dairy Cattle	Cow unit	500	500	500
Poultry	100 birds	480	480	480
Sheep	Sheep Unit	zero	zero	zero
Total Revenue	I.D.	1112466	1062222	1062172
Total Variable Cost	"	497957	457375	457382
Total Net Revenue	"	614509	604847	604790
Per Dinar Return	"	2.234	2.322	2.322

The logical development of these seven solutions can be summarised as follows. Solution 1 was derived for the model as originally formulated. In developing a soil conservation and soil rehabilitation plan, it became apparent that there was a need for converting the hectareages of crop activities into operational crop rotations which the farm can follow. This required that the intial model should be recalculated with additional constraints in a useful form.

As a result, a total of six solutions have been computed with the introduction of the cropping rotation system, for the Al-Nahrawan State Farm. Solution 2 was obtained when the clover and the maize activities were converted into a simple crop rotation, which necessitates that the same area used for growing clover be used after that for growing maize, all within the same year. This new constraint can be expressed in equation form as follows:

$$X_{c_{\varepsilon c\rho}} - X_{c_{\varepsilon ma}} = 0$$

where:

$c\rho$ and ma are Clover and Maize indexes, respectively.

Total net revenue of Solution 2 was depressed by some I.D.2,886 below that of Solution 1 by reallocation of the fodder crop hectareages for a new pattern of crop production.

Similarly, Solution 3 was obtained when the mixed crop and sorghum was converted into a one-year simple rotation and introduced into the original model instead of the clover/maize rotation.

The new constraint of this alternative rotation can be written in the following form:

$$X_{c_{\varepsilon mi}} - X_{c_{\varepsilon so}} = 0$$

where:

mi and so are mixed crop and sorghum respectively.

The important feature of Solution 3 is the appearance of sheep activity in the optimal plan, which is excluded from the other solutions. Total net revenue has been depressed by some I.D.10,048 by the new combination of this farm plan, as shown in Table 9.7.

At this stage, a system of crop rotation was introduced for soil-improvement and maintaining the soil resources in an unimpaired condition.

Since the restored land of the farm is the only land available for summer crops, it must be used to pursue the development strategy of increasing the cropping intensity. Therefore, all the summer crops must be converted into a set of rotational restrictions. In addition to the original restriction on the distribution of the summer and the winter areas for alfalfa, which is the balance between them (X_5-X_{10}), the suggested rotation is based on the two previous rotations of Model 2 and Model 3. Hence, land has to be used for maize and sorghum production in a one-year rotation with clover and mixed crops, respectively.

In other words, as the summer maize will be harvested in autumn the same area of land has to be used for winter clover, and after the summer sorghum is harvested the same land will be used for mixed crops. The remaining hectareage in the reclaimed area is assigned for cropping practices such as summer fallow of wheat, while the remaining hectareage in the unreclaimed area is assigned to barley production, as it is the least productive and most difficult to work. Barley is to be used because this plant is relatively easy to grow on a such land.

As discussed above, the initial model was recalculated with the additional constraints of the previous cropping rotations which were imposed jointly on the model used to obtain Solution 4.

In comparing Solution 4 with Solution 1, one can see that the former has been depressed by I.D.13,786, by reallocation of the farm ploughland into a new combination of crop hectareages.

After this stage, further developments have been made for the initial optimum farm plan to investigate the effect of replacing the previous restrictions of cropping rotations by alternative restrictions, taking into account the available sowing dates of the related crops, and their effects on the soil fertility. Therefore three other alternative solutions were obtained. The variant on cropping restrictions leading to these solutions is shown in Table 9.7. The first solution is Solution 5, which has the highest value of total net revenue among the alternative organisations, but is still I.D.2,019 less than that obtained from Solution 1.

The second and the third solutions in this respect, were Solution 6 and Solution 7, respectively. As can be seen in Table 9.7, these two solutions have similar values of total net revenue, depressed by I.D.11,681 and I.D.11,738, for Solution 6 and Solution 7 respectively, with similar distributions of crop hectareages.

Although the six alternative farm plans have some general similarities among them, and between them and the optimum farm plan of Model 1 (Table 9.8), they varied from the optimum, and between themselves. For example, each of the optimum and the six alternative farm plans included about 250 hectares of wheat production, 500 units of dairy cattle, and 480 units of laying hens. Table 9.8 shows that while both Plan 2 and Plan 5 included the same total hectareage of malting barley production as the optimum plan, total malting barley hectareage decreased in Plans 3, 4, 6, and 7. Compared to the optimum farm plan, each of the six alternative farm plans included more total hectares of clover and sorghum production. In addition, while four of the six plans (Plans 3, 4, 6, and 7) included more total hectares of alfalfa production, two of them (Plans 2 and 5) included less total hectares of this activity. Total mixed crop and maize hectareage decreased in the six alternative farm organisations, ranging from 963 to 279 hectare for the mixed crop, and from 387 to 250 hectare for maize.

Net revenues achieved by the six alternative farm organisations did not differ appreciably, ranging from I.D.614,509 to I.D.602,742. The difference between the lowest net revenues level and that achieved by the optimum farm organisations of Model 1 was I.D.13,786.

In calculating the per Dinar return in relation to the variable costs, as Table 9.7 shows, Solutions 6 and 7 have the highest value of I.D.2.322 return for each Dinar, indicating that it would be worth investigating the possibility of following one of these two farm organisations by the Al-Nahrawan state farm.

In comparing these two alternative farm plans (Plans 6 and 7), it can be seen from Table 9.7 that Plan 7 is the one the operator should follow, as it would be the most rewarding economically in terms of the relative profitability, via soil fertility maintenance. Although this plan does not lead to the highest net revenue, the logic of its choice was premised on two factors; (1) its completeness in detail and precision of cropping rotation specification, and (2) its highest value in the per Dinar return.

Hence, the Model 7 solution was selected and identified as the "best farm plan" to follow in moving toward an efficacious optimal plan for use of the Al-Nahrawan state farm's resources, as we shall see in the next chapters.

CHAPTER 10

THE EFFECT OF CHANGES IN RESOURCE CONSTRAINTS ON THE OPTIMAL SOLUTIONS

10.1. Introduction

As has already been indicated earlier in the discusion, the Al-Nahrawan State Farm operates with both:

(i) Restrictions on some quantities of outputs.

(ii) Given prices for both inputs and outputs.

Therefore, the present results are optimal only under the above assumptions. In comparing the present farm plan with that obtained from Model 7, as an example of the optimum plan, there is no doubt that the so-called optimal farm plan has a better use of farm resources and a better mix of enterprises which increases the farm total net revenue by I.D.419,610 (226.59 percent).

To arrive at an economically efficient optimal organisation, one would want to know what would happen if a possible activity is added to the farm activities? Or what would happen if the farm outputs are not constrained? In other word how far do the current given prices affect the optimal solution? Such investigations can be used by the planner to determine an effective subsidisation policy which can help the farm to produce the required commodity and operate economicaly with such a given price policy.

Since the most profitable adjustments to follow in moving from Model 7, as the "best" modified basic Model achieved up to now, to a new organisational plans should be determined in a complete programing analysis to provide the farm manager with a definite course of action, a number of modifications on prices and resource constraints will be imposed both singly and jointly on Model 7 to provide a package of alternative solutions for a manager's evalution in terms of the relative profitability of each. This analysis is the specific objective of this and the next chapter. The current chapter deals with the effect of changes in resource constraints on the optimal solutions; the next chapter focuses on the effect of using alternative prices on the most important optimal organisations.

These investigations are to be studied within this thesis under the so-called range analysis, discussed in Chapter 6.

10.2. The Effect of Changes in Resource Constraints on the Optimal Solutions

A total of four solutions have been computed for the Al-Nahrawan State Farm along the lines indicated above. Interpretation of the four solutions and the variants of the planning model leading to these solutions are given in the following subsections.

10.2.1. Changes with Short-Run Implications

10.2.1a. The Effect of Adding Bought-in Foodstuffs

In investigating the effect of changing some of the planning information involving short-run considerations, an additional possible activity was considered firstly. Therefore, model A was developed and a new solution was obtained. This model is identical to Model 7 except that a purchasing concentrate feed activity for the farm livestock has been added as we can see in Table 10.1 This permits a choice between buying or producing the requirements of foodstuff in the process of obtaining a solution.

Table 10.1. <u>Summarised Description of the Additional Purchasing Concentrate Feed Activity</u>

Row	B Column Right-Hand-Side)	(X14 Coefficients)
CO		Net price -52.2
R23	≥ 0	+690.9
R24	≥ 0	+167
R25	≥ 0	+ 1.38
R26	≥ 0	+ 6.62

X14 = Bought-in concentrate feedingstuffs activity. The activity unit is one Tonne.
R23 = T.D.N constraint. The B column unit is Kg.
R24 = Protein constraint. The B column unit is Kg.
R25 = Calcium constraint. The B column unit is Kg.
R26 = Phosphorus constraint. The B column unit is Kg.

The CO row entry for X14 is negative because this activity of itself would not add to the value of the programme, but constitutes a cost not accounted for elsewhere in the model.

The X14 coefficients in R23, R24, R25, and R26 carry positive signs, indicating that the purchasing activity will add to the original R23, R24, R25, and R26 supply respectively.

The activity levels and ranges of the solution obtained for this model are shown in Table 10.2. A comparison between this solution and Solution 7 is shown in Table 10.3. At first sight this solution is quite reasonable. It can be seen that the imposition of this further activity increases the total net revenue by I.D.45,210 (see Table 10.3). The main changes in the farm plan in comparison with Solution 7 are as follows:

1: The buying activity has appeared, indicating that some 3,963 Tonnes of concentrate feed for the farm livestock should be bought in.

2: The sheep rearing activity has also appeared in the new Solution A at a level of 5,996 units of sheep. Sheep rearing activity exists at an average level of 758 units by the present performance of the farm objective. This result (the appearance of 5,996 units of sheep) might seem to imply that an extension of the existing limit of sheep breeding activity should be considered. In short-run planning, this would be feasible since there are enough spaces to accommodate over 10 thousand head, as indicated before.

3: The appearance of purchasing concentrate feed results in certain adjustments to the home fodder production (clover, sorghum, and alfalfa are decreased considerably, whilst there is a small increase in mixed crop and maize hectareages). The area of malting barley activity has increased by 637 hectares. The straw obtained from the increased area of malting barley can justify the decreased bulk ratio which resulted from the reduced area of forage crops.

4: The numbers of dairy cattle and laying hens, and the wheat hectareage remain the same as in Solution 7.

Table 10.2. <u>Activity Levels and Ranges</u> - Solution A

Identif-ication	Description	Unit	Level	Net Revenue I.D.	Optimality Range/ Cost Coefficient. Z-Lower	Z-Upper
X1	Wheat	Hectare	250		See Table 10.5	
X2	Malting Barley	Hectare	1575	110.25	108.2 to INF	
Maximum-Z		I.D.		650000	646640	"
X5	Winter Alfalfa	Hectare	235.5	-110.00	-255.47	-103.88
Maximum-Z		I.D.		650000	615740	651440
X6	Mixed Crop	Hectare	316	-118.70	-165.22	-110.87
Maximum-Z		I.D.		650000	635300	652470
X7	Clover	Hectare	58	-131	-140.28	-79.962
MAximum-Z		I.D.		650000	649460	652960
X8	Maize	Hectare	316	-106.70	-153.22	-98.866
Maximum-Z		I.D.		650000	635300	652470
X9	Sorghum	Hectare	58	-115.30	-124.58	-64.262
Maximum-Z		I.D.		650000	649460	652960
X10	Summer Alfalfa	Hectare	235.5	-77.30	-222.77	-71.185
Maximun-Z		I.D.		650000	615740	651440
X11	Dairy Cattle	Unit	500		See Table 10.5	
X12	Sheep	Unit	5996	16.50	16.005	23.184
Maximum-Z		I.D.		650000	647030	690070
X13	Laying hens	100 birds	480		See Table 10.5	
X14	Bought-in foodstuffs	Tonne	3963	-52.2	-52.64	-37.88
Maximum-Z		I.D.		650000	648230	706750

*Positive sign indicates net revenue; negative sign indicates variable cost.

Table 10.3. Solutions A and 7 Compared

	Unit	Solution Number 7	A	Difference	
Obj.Function	I.D.	604,790	650,000	45,210	Increase
Activity level:					
Wheat	Hectare	250	250	-	
Malting Barley	"	938	1575	637	Increase
Winter Alfalfa	"	351.9	235.5	116.4	Decrease
Mixed Crop	"	279.5	316	36.5	Increase
Clover	"	339.5	58	281.5	Decrease
Maize	"	279.5	316	36.5	Increase
Sorghum	"	339.5	58	281.5	Decrease
Summer Alfalfa	"	351.9	235.5	116.4	Decrease
Dairy Cattle	Unit	500	500	-	
Sheep	"	-	5996	5996	Increase
Laying Hens	100 birds	480	480	-	
Bought-in Foodstuffs	Tonne	-	3963	3963	Increase

An examination of Table 10.2 shows that the solution appears to be relatively stable. The ranges on the net revenues of many of the farm activities are very wide. For example, Table 10.2 shows that 235 hectares of winter alfalfa (activity X5) are included in the optimal plan, with a range of -255.47 to -103.88. These values indicate the stability of the winter alfalfa hectareage in the plan to changes in the variable cost of winter alfalfa. Table 10.2 shows also that the variable cost of the winter alfalfa activity was estimated to be I.D.110 per hectare. Hence the range given indicates that this figure could fall to I.D.103.88, or rise to I.D.255.47 per hectare, without the plan being affected. Of course, the profitability would be directly influenced by a change in the cost (or revenue) of any activity, but the levels of the activities in the plan would remain the same. A similar interpretation applies to the other values in this list. The ranges in the other activity net revenue (or variable cost) for which the optimal solution remains stable are set out in Table 10.2. It is important to note that these ranges apply only in respect of an isolated change in the net revenue of each activity in turn. In practice, this information may be of rather limited value since a change in the net revenue of one activity will often be accompanied by changes in the net revenues of other activities.

Table 10.4 deals with quantities of unused resources. They are quite straightforward and followed by a list of the activities not in the solution. It can be seen in that table that the farm land, water for irrigation (except March water), labour and machinery (except the medium size tractor during the third season) are in surplus. The figures 59.55 and 137.75 given in the last section of Table 10.4 opposite activities X3 and X4 respectively (green feed barley and grain barley), show the fall in costs needed to cause these activities to enter the plan. In other words, it would not be worth producing green feed and grain barley unless their costs fall by 59.55 and 137.75 per hectare, respectively. The reason for this is not hard to see. More feedingstuff is available from other crop growing than is required by the farm livestock. Therefore there is no merit in producing green feed and grain barley unless their variable costs are less than the variable costs of other feeding crops.

Table 10.4. Resources Unused - Solution A

Identification	Description	Unit	Amount
Ploughland:			
R1	Winter Land	Hectare	1409
R2	Summer Land	Hectare	1078
Water for irrigation:			
R3	January	m^3	1391474
R4	February	"	1185317
R6	April	"	2524879
R7	May	"	4097330
R8	June	"	3985745
R9	July	"	2478315
R10	August	"	2636919
R11	September	"	3672924
R12	October	"	3182882
R13	November	"	25232
R14	December	"	2150000
R15 Labour		Man/hours	93335
Medium-sized tractor:			
R16	1st season	Hours	7498
R17	2nd season	"	7498
R19	4th season	"	1777
R20 Large size Tractor		Hours	2031
R21 Fodder harvester		Hours	3904

Non-Basic Activities- Solution A

Identification	Description	Unit	M.O.C
X3	Green Feed Barley	Hectare	59.558
X4	Grain Feed Barley	Hectare	137.752

The values assigned in linear programming to the marginal opportunity costs of excluded activities, along with the information on the ranges of the cost coefficients (or net revenues) of activities in the plan, together provide a most useful indication of the economic stability of the solution and of the significance of the assumptions made about yields and prices. If the stability of a plan is not great, it may be worth investigating the effects of changing the assumed levels of returns of some of the activities.

The first section of Table 10.5 relates to the exhausted resources and operative planning constraints. For instance, constraint R22 relates to grain combines; all 2,336 combine hours are used up in the plan. The value of I.D.1.665 indicates the marginal value product of one grain combine hour. That is to say that one extra combine hour would increase the total net revenue by I.D.1.665. The range attached to this value shows the range in machine hours over which this value applies. Thus the farm operates 2,336 machine hours of grain combines and the productivity of one combine hour is I.D.1.665 per hour from 2,304.1 to 2,719.6 hours. A similar interpretation applies to the other values in this list.

In examining the use of the farm resources in Table 10.5, it can be seen that a non-zero marginal value product is attached to water in March only. The medium size tractor hours during the third season and the combine harvesters are also fully used. The figures 0.0765, 4.352 and 1.665 given in Table 10.5 opposite constraints R5, R18 and R22 respectively (March water, medium-sized tractor during the third season, combine), show the marginal value products of these constraints. That is to say that one extra unit of each resource would increase the total net revenue by the value attached opposite this resource. Thereafter, new programmes would have to be run to study the effect of further increases in these resources.

Table 10.5. Resources Fully Used and Optimality Ranges for Right-Hand-Side Constants

Identi-fication	Description	Unit	Amount	M.V.P	Range Lower	Range Upper
First section:						
R5	March Water	m^3	3942400	0.0765	3285200	3959500
Max-Z		I.D.	650000		599710	651300
R18	Medium sized tractor 3rd Season	trac./hour	22200	4.352	19189	24404
Max.Z		I.D.	650000		636890	659590
R22	Grain combine	comb./hour	2336	1.665	2304.1	2719.6
Max.Z		I.D.	650000		649940	650630
Second section:						
X1*	Included Wheat	Hectare	250	86.820		
Third section:						
R30	Cow building capacity.	Unit	500	288.930		
R31	Poultry building capacity.	100 birds	480	260.576		

* M.V.P for including activity is a cost penalty.

The final details of solution A to be considered here are:

(i) the relatively high shadow price attached to the included wheat activity which was forced into the optimal programme. Clearly, net revenue would be reduced for each hectare of the wheat activity by I.D.86.82, and;

(ii) the marginal value products of the operative constraints are also set out in Table 10.5. The main features to note about these results are first, the relatively high marginal value attached to the cow accommodation capacity. The next important feature of Solution A shown in Table 10.6 is the high marginal value product attached to the laying hens accommodation.

10.2.1b. The Effect of Omitting the Limitation on the Wheat Hectareages

At this point it would be useful to carry the analysis a stage further, and programme the problem with the limitation on wheat hectareages omitted. This will give an indication of the kind of adjustments which would then be necessary to continue to maximise profits. This additional solution, Solution B is given in Tables 10.6 and 10.7, and the corresponding marginal product values in Table 10.8.

Table 10.6. Activity Levels and Ranges- Solution B

Description	Unit	Level	Net Revenue I.D.	Optimality Range for Cost Coefficients	
				Z-Lower	Z-Upper
Malting Barley	Hectare	1825.00	110.250	108.120	INF.
Maximum-Z	I.D.		671700	667810	INF.
Winter Alfalfa	Hectare	237.36	-110.000	-255.470	-103.880
Maximum-Z	I.D.		671700	637170	673150
Mixed Crop	Hectare	333.14	-118.700	-165.220	-110.870
Maximum-Z	I.D.		671700	656200	674310
Clover	Hectare	39.45	-131.000	-140.280	-79.962
Maximum-Z	I.D.		671700	671330	673710
Maize	Hectare	333.14	-106.700	-153.220	-98.866
Maximum-Z	I.D.		671700	656200	674310
Sorghum	Hectare	39.45	-115.300	-124.580	-64.262
Maximum-Z	I.D.		671700	671330	673710
Summer Alfalfa	Hectare	237.36	-77.300	-222.770	-71.185
Maximum-Z	I.D.		671700	637170	673150
Dairy Cattle	Unit	500.00			
Poultry	100 birds	480.00			
Sheep	Unit	5934.50	16.500	16.005	23.184
Maximum-Z	I.D.		671700	668760	711370
Concentrate feed	Tonne	3921.61	-52.200	-52.646	-37.880
Maximum-Z	I.D.		671700	669950	727860

This revised solution contains only small adjustments in the fodder crop, bought-in foodstuffs, sheep activities and the replacement of the wheat activity by additional hectareages of malting barley, bringing the latter area to 1,825 hectares (see Table 10.7).

Table 10.7. Solutions A and B Compared

	Unit	Solution Number A	B	Difference	
Objective Function	I.D.	650,000	671,700	21,700	Increase
Activity Level:					
Wheat	Hectare	250	-	250	Decrease
Malting Barley	"	1575	1825	250	Increase
Winter Alfalfa	"	235.5	237.4	1.9	Increase
Mixed Crop	"	316	333	17	Increase
Clover	"	58	39.4	18.6	Decrease
Maize	"	316	333	17	Increase
Sorghum	"	58	39.4	18.6	Decrease
Summer Alfalfa	"	235.5	237.4	1.9	Increase
Dairy Cattle	Unit	500	500	-	
Sheep	"	5996	5934.5	61.5	Decrease
Laying Hens	100 birds	480	480	-	
Bought-in Foodstuffs	Tonne	3963	3921.6	41.4	Decrease

The most interesting aspect in this solution is that the dairy cattle and poultry accommodation resources have now become the crucial limitations, yielding a much higher marginal value products of I.D.288.93 for dairy cattle accommodation and a similarly high figure for poultry accommodation of I.D.260.57 per unit (see Table 10.8 below).

Table 10.8. Resources Fully Used and Optimality Ranges for Right-Hand-Side Constants

Identification	Description	Unit	Amount	M.V.P	Range Z-Lower	Range Z-Upper
R5	March Water	m^3	3942400	0.0765	3203900	3942700
	Maximum-Z	I.D.	671700		615190	671720
R18	3rd Season*	Trac./hour	22200	4.352	21630	24677
	Maximum-Z	I.D.	671700		669220	682480
R22	Combine	combine/hour	2336	1.665	2335.4	2767.1
	Maximum-Z	I.D.	671700		671700	672420
R30	Cow Building capacity.	Unit	500	288.93		
R31	Poultry Building capacity.	100 birds	480	260.576		

*Indicates medium-sized tractor.

10.2.2. Changes with Medium-Run Implications

In considering the marginal value products of the limiting factors of Solution B, it can be seen that the most important limitation to the expansion of net revenue is the restriction on cow and poultry numbers by the building accommodation.

10.2.2a. The Effect of Extending the Cow Buildings Capacity

Table 10.8 shows that the marginal value product of the limit on dairy cow numbers is I.D.288.9 per animal unit. Dairy cows are limited to 500 units by cattle building capacity and at first sight this might seem to imply that the construction of an extension to the cattle accomodation should be considered. However, this would not be feasible since the maximum size of the dairy herds are accepted as fixed data (but not their feeding plan), while this research is limited to short-run considerations.

The effect of increasing the maximum size of the dairy herd by the construction of new accomodation is one of the most complex problems of decision-making, requiring an analysis of the medium term plans which determine the major objectives and orientation of the state farming system and of the state farming sector. These plans should incorporate the investment needs that relate to plan objectives. If they are to be achieved on the basis of annual plans, annual planning should include a methodelogy for preparing such decisions and should be based upon an assessment of available resources and projected capital needs, together with an evaluation of expected efficiency and sources of financing. Medium-term planning is a continuous exercise. Given relatively long production processes, it is crucial to look ahead several years with a view to establishing an efficient agricultural sector.

Introducing capital constraints into the model requires definition of the length and nature of the period involved in the planning process because of the growth in capital investment typical of a successful farm operation.

Thus far in this case study I have been purposely vague about the planning period to which the models apply. Any further treatment of the capital problem requires that we pause to classify the conceptual difficulties surrounding the definition of the planning period.

Although farm production in the Al-Nahrawan State Farm tends to be an annual activity with most operations carried out each year, it is not easy to ignore the medium or the long-run considerations of the production cycle.

Twelve months is the time period I have focused on in the previous models. I have sought to define the set of activities which, given the constraints and price expectations, would maximise the value of the programme for this period. The planning model does not indicate the path to be followed in moving the farming operation from its present organisation to the optimum plan. It assumes implicitly that the same pattern will be repeated year after year. But the plan cannot in reality remain optimal where capital limits the plan when the business is successful, because available capital will increase from one time period to another.

The Al-Nahrawan State Farm's orientation is towards specialisation in dairy production, so the possibility of fully relaxing the maximum limit on cow building capacity was investigated and an alternative solution was found. The activity levels, ranges and the non-basic activities of this solution are shown in Table 10.9.

Table 10.9. Activity Levels, Ranges and Non-basic Activities - Solution C

Description	Unit	Level	Net revenue I. D.	Opt.Range (cost coefficients) Z-Lower I.D.	Z-Upper I.D.
1- Activity Levels and Ranges:					
Malting Barley	Hectare	1611	110.25	80.530	110.56
Max-Z	I.D.		765120	717240	765630
Winter Alfalfa	Hectare	291	-110	-111.05	-18.145
Max-Z	I.D.		765120	764820	791820
Mixed Crop	Hectare	298	-118.70	-119.59	-96.712
Max-Z	I.D.		765120	764850	771670
Clover	Hectare	119	-131	-769.62	-129.27
Max-Z	I.D.		765120	688990	765330
Maize	Hectare	298	-106.70	-107.59	-84.712
Max-Z	I.D.		765120	764850	771670
Sorghum	Hectare	119	-115.30	-753.92	-113.57
Max-Z	I.D.		765120	688990	765330
Summer Alfalfa	Hectare	291	-77.30	-78.346	14.555
Max-Z	I.D.		765120	764820	791820
Dairy Cattle	Unit	831	1158.70	1018	1166.1
Max-Z	I.D.		765120	648210	771300
Poultry	100 birds	480			
Sheep	Unit	-			
Concentrate feed	Tonne	6735	-52.20	-61.906	-52.134
Max-Z	I.D.		765120	699760	765560

2- Non-basic Activities:

	Non-basic Activities	Unit	M.O.C
X1	Wheat	Hectare	90.53 I.D.
X3	Green Feed Barley	-	57.07 I.D.
X4	Grain Barley	-	138.90 I.D.

It can be seen from this solution that fully relaxing the cow building capacity increases the total net revenue by I.D.93,418. The main changes in the farm plan in comparison with solution B are as follows:

1) The total disappearance of sheep from the optimal plan.
2) The numbers of dairy cattle is increased by 331 animal units.

These changes, in dairy cattle and sheep activities, result in certain adjustments to the other farm activities as shown in Table 10.10.

Table 10.10. Solutions B and C Compared

	Unit	Solution Number B	C	Difference	
Objective Function	I.D.	671,700	765,119	93.419	Increase
Activity Level:					
Malting Barley	Hectare	1825	1611	214	Decrease
Winter Alfalfa	"	237.4	290.6	53.2	Increase
Mixed Crop	"	333	298	35	Decrease
Clover	"	39.4	119.2	79.8	Increase
Maize	"	333	298	35	Decrease
Sorghum	"	39.4	119.2	79.8	Increase
Summer Alfalfa	"	237.4	290.6	53.2	Increase
Dairy Cattle	Unit	500	831	331	Increase
Sheep	"	5934.5	-	5934.5	Decrease
Laying Hens	100 birds	480	480	-	
Bought-in Foodstuffs	Tonne	3921.6	6734.6	2813	Increase

This analysis suggests it would be profitable for the future development of the farm to be planned along these lines. It is also possible to obtain a sufficient number of solutions to describe exactly the way the optimal plans are affected by changes in the exhausted resources.

Table 10.11 relates to the exhausted resources. The main feature to note about this final detail of Solution C is the relatively high marginal value products attached to the poultry accommodation. The marginal value product of the limit on laying hen numbers is over I.D.215.58 per unit of measurement.

Table 10.11. Resources Fully Used and Optimality Ranges for Right-Hand-Side Constraints

	Resource	Unit	Amount	MVP	Z-Lower	Z-Upper
R5	March Water	m^3	3,942,432	-	3,695,700	4,087,700
	Max-Z	I.D.	765,120	.0669	748,610	774,840
R13	November Water	m^3	3,639,168	-	3,416,900	3,763,100
	Max-Z	I.D.	765,120	.0003	765,050	765,160
R15	Labour	Man/hour	482,328	-	389,780	493,790
	Max-Z	I.D.	765,120	.8226	688,990	774,550
R31	Poultry Accommodation	Space for 100 birds	480	215.58		

10.2.2b. The Effects of Omitting the Limit on Poultry Production

Laying hens are limited to 480 units by the existing accomodation capacity and this might seen to imply that the construction of an extension to the poultry building should be considered in the medium-run planning process. Poultry production at the Al-Nahrawan State Farm was to be treated as quite rigid because of the government programme, but this high marginal value product would indicate that it would be very worthwhile making further investigations to see if this restriction could not be overcome in some way. Hence, the effect of programming the problem with the limitation on poultry breeding ommited was investigated and Solution D was the result. When laying hens is introduced as a fully relaxed activity, with no restrictions in the other existing enterprises, it changes the farm plan. The optimum farm plan of this model is shown in Table 10.12.

Table 10.12. Summary of Results - Solution D

Activity	Activity level	Opportunity cost
X11 Dairy cattle	zero	519.633 (I.D.)
X12 Sheep	zero	9.293 (I.D.)
X13 Poultry	8038.8	zero

Maximum value of the objective function is I.D.2130282

Activity Optimality Range For Cost Coefficients

X13	Min Cj	Original Cj	Max Cj
	I.D.182.95	I.D.265	I.D.INF*
	Z-Lower	Z-Original	Z-Upper
	I.D.1470700	I.D.2130300	INF*

Source Optimality Range for Right-Hand-Side Constants.

Labour	Min Bi	Original Bi	Max Bi
	.37253E-08	482330	1278000
	Z-Lower	Z-Original	Z-Upper
	.14901E-07	2130300	5644500

Cj = Net revenue; Bi = Right-Hand-Side Constraint;

Z = Value of the objective function.

It can be summarised that laying hens, by virtue of its low capital needs and high net revenues, tends to dominate other enterprises. An inspection of this solution generally provides valuable pointers to the best longer-term economic development of the farm business, but this would not be feasible since the farm objective is not to be specialised in poultry production. Moreover, in this situation it may be clear that major shifts from one activity to another are not feasible and such changes may not be possible because of a lack of facilities and a very great waste in the existing farm resources (Land, Machinery, Water, Buildings, etc.). Further more, the operating programme is not capable of executing drastic shifts in the business. However, as a result of a shortage in poultry domestic supply (913 millions eggs and 43 thousands ton of meat in 1980) in Iraq today, raising poultry is a subsidised activity. Therefore, low costs for major inputs (chicks, food, medicine, etc.) and high prices for outputs (eggs and meat) cause this activity to dominate other enterprises. However, this high profitability of poultry cannot be guaranteed for the future, especialy if we know that the specialised General Establishment for Poultry, and also private enterpreneurs, are facilitating large investments in poultry production.

The analysis of the solution tableau for this farm problem indicated that the farm plan was relatively stable. Poultry, which constituted the whole income enterprise, would have to drop about I.D.82 (or 30.9%) in price before other livestock enterprises could compete. A rise of around I.D.519 (44%) or I.D.9 (54%) in the price of dairy cattle or sheep, respectively, would have changed the picture, however.

10.3. How the Existing Models Might Be Improved

It is apparent that a plan prepared in 1986 and projected until 1990 involves predicting prices, yields, and resource availabilities four years in advance. Because of the uncertainty of such predictions, a plan so projected is not likely to represent the optimum course of action when 1990 actually arrives. Yet there are advantages in extending the planning horizon beyond a single year and updating this projection each year. More accurate information regarding price expectations, production coefficients, and the nature of resource constraints would be available in 1987 than in 1986. One realistic approach to farm planning is preparing a plan every year for the year immediately ahead and at the same time projecting the plan four years into the future, based on the best information currently available.

In these circumstances, if one would want to project a plan into the future, year-to-year changes in the plan may be restricted by a system of flexibility constraints. They may be used with recursive step-by-step models, but because of the compounding of errors in predicting prices, yields, and resource availabilities inherent in such a situation, the plan projected for the future in this fashion is of doubtful value. Therefore, their use is recommended in connection with multiyear (or dynamic) models. The multiyear model defines restrictions, price expectations, production coefficients, and the range of alternative activities for a planning period of four or five years, and a plan for each year emerges from a single optimisation. However, the basic objective of this thesis does not involve projecting medium-term plan guidelines, as mentioned before.

CHAPTER 11

THE EFFECT OF USING ALTERNATIVE PRICES ON THE OPTIMUM SOLUTION

11.1. Introduction

The optimality range for cost coefficients, explained in Chapter 6, provides insight into the sensitivity of the plan to changes in price relationships. One can define an infinite number of C rows, all representing reasonable combinations of price expectations or alternative price assumptions. The planner must be discriminating in selecting the relationships he attempts to analyse lest he generate a greater volume of output than he can interpret.

Linear Programming cannot help the operator in the difficult task of formulating price expectations. The process can only indicate the best way to use resources once a judgment has been made as to future prices, or as suggested above, it can indicate how the optimum plan shifts with alternative price assumptions. The success of the plan finally emerging is a function of the accuracy with which prices are predicted.

11.2. The Use of Local and World Prices in the Planning Models

As mentioned in Chapter 5, in linear programming emphasis must be placed on accurate relative prices. If all the prices are too high, the net income estimate will be incorrect. But if relative prices are approximately correct, the farm plan developed may be a useful device. However, any plan based on prices which in retrospect prove wrong, could turn out to be less profitable than would have some other plan. This problem is not peculiar to planning with linear programming. Any type of planning requires price projections. Serious mistakes in estimating prices, especially relative prices, will lead to poor results with any planning method.

Hence, all the results attained previously are completely dependent on the price estimates and the input-output ratios which the programmer has used. In every case the input-output ratios reported by the farm management were accepted and assumed to be correct. As explained earlier, the average requirements and yields of the farm activities were used rather than the current year's requirement and yield. It was assumed that the average quantities would give better coefficients for planning than those quantities experienced in one given year. If the current year deviated widely from the average yield, it created a certain amount of doubt in the process being developed. In reviewing the prices used for this project, it was assumed that the average level of Iraqi prices during 1981 would be acceptable and these were used. Those were the most recently recorded prices in the farm records. Iraqi prices are given by the central authorities, therefore I wondered what would happen to the optimum solution if alternative price assumptions are used as objective function components. Such an investigation can be used by the planner to indicate optimal farm organisation using prices of international significance. The investigation to be made within this section uses the "world prices" of agricultural commodities. The data used are annual averages for the calendar year and are also given converted into standard units ($U.S.) The exchange rates used to convert the prices into U.S. dollars were obtained from international financial statistics, where the Iraqi dinar was equivalent to $3.386 in U.S.dollars as an average for 1981. The prices used are shown in Table 11.1.

Table 11.1. Prices Paid and Received by Farmers: Farm Product and Commodity Prices; Price Series of International Significance

ITEM	$US	ITEM	$US
A- Farm product prices		**B- Farm commodity prices**	
Wheat, per tonne	177	Ammonium Nitrate,per tonne	187
Barley, per tonne	115	Superphosphate, per tonne	243
Eggs, per Dozen	0.623	Egg-type chicks, per 100	47.7
Chicken,(tonne liveweight)	617	Laying feed, per tonne	210
Wool, per tonne	2086	Seeds:	
Lamb, per tonne liveweight	1079	Barley, per 21.8 kgs	5.94
Ewe, (tonne liveweight)	845	Wheat, per 27.2 kgs	7.33
Ram, (tonne liveweight)	845	Sorghum, per 45.36 kgs	49.4
Milk, per 45.36 kgs	13.8	Alfalfa, per 45.36 kgs	218
Cow, per tonne liveweight	1615	Clover, per 45.36 kgs	115
Calve,per tonne liveweight	1523	Maize, per 27.2 kgs	60

Source:

(1) FAO (Food and Agriculture Organisation, Production Yearbook, United Nations, FAO statistics series No.47, Vol.36; Rome, 1983; pp.305-311.

(2) U.S. Department of Agriculture, Agricultural Statistics, U.S. Government Printing Office, Washington, 1982; pp.423-424.

In order to avoid serious mistakes in estimating prices, especially labour and machinery costs, only the output and the physical input prices are considered. Labour and machinery appear in the model in the form of B column coefficents, and the B column quantities never appear as a charge against the value of the programme. Stated differently, the value of the programme is a return for the inputs which appear in the B Column of the original model. Since the operator's labour, machinery, and land are introduced into the model as B Column quantities and the appropriate costs have not been charged, the value of the programme is a return for the services of these resources.

11.3. The Financial Statement of the Farm Activities by Local and World Prices

In order to make a reasonable comparison between the optimum solutions of using local prices and world prices, the values of the objective functions attached to the farm enterprises components are to be computed for both cases. Table 11.2 shows the financial statement of the farm enterprises as suggested above.

Table 11.2. The Financial Statement of the Farm Enterprises by Local and World Prices.

Enterprise	Description	I.D.	£US
Poultry (100 birds)	Egg return (17400eggs)	487.200	903.350
	Livestock depreciation	-19.900	+7.213*
	Output per year	**467.300**	**910.563**
	Less concentrate food	208.800	840.000
	Gross Margin (over concentrate feed costs).	**258.500**	**70.563**
Sheep (animal unit)	Lamb sales	10.400	16.832
	Milk value per unit	9.500	30.423**
	Wool value per unit	1.290	3.009
	Cull ewe and ram - ewe and ram replacements.	-1.275	-2.198
	Output per animal unit	**19.915**	**48.066**
Dairy cattle (animal unit)	Milk return(7767kgs)	738.000	2363.000
	Net annual replacement gain +output per Dairy followers	521.000	409.936
	Output per animal unit	**1259.000**	**2772.928**
Wheat (Hectare)	Output (1200 kgs)	86.400	212.400
	Less variable costs	-14.472	-69.358
	Gross Margin per hectare	**71.928**	**143.040**
Malting Barley (Hectare)	Output (2120 kgs)	167.480	243.800
	less variable costs	-15.192	-69.720
	Gross Margin per hectare	**152.288**	**174.080**

Source: Based substantially on Table 11.1 (current chapter), and Tables 4.15, 4.16 and 4.18 (Chapter 4).

Notes:

1: Livestock depreciation for poultry = value of purchasing chicks - value of cull chickens (allowing for mortality).

2: Net annual replacement gain for dairy cattle = Cost of replacements (20% of herd per year) less value of culls (20% of herd per year, allowing for mortality) + annual value of calf sales.

3: Dairy followers per heifer reared = Value of heifer (allowing for culls) - value of calf (allowing for deaths).

4: Gross margin for dairy cattle and sheep over feedingstuffs are to be considered by the fodder programme contained in the planning model.

*Assuming that the world price of cull hens (at 2 kg. weight per hen) is 50% of the price of broilers. **Source**: Agricultural Statistics, Uk, 1982, p.77.

**Assuming that the price of sheep milk is the same of the price of the cows milk.

11.4. The Variants of the Planning Models

The basic planning models, selected to take account of all the farm circumstances, are Model B and Model D, as explained in Chapter 8. As has already been indicated in the discussion above, a number of variants of the objective ectsunction were computed to investigate the effects of changing some of the planning circumstances described above. The concept of alternative objective functions is introduced to permit solutions based on differing price expectation. The two alternative objective functions are illustrated in (i) and (ii) as follows:

(i) Maximise Ca = - 18.42X1 + 152.288X2 - 14.232X3 - 17.02X4 - 38.764X5 - 48.786X6 + 71.928X7 - 25.52X8 - 22.7X9 - 5.832X10 + 1259X11 + 258.5X12 + 19.915X13 - 52.2X14.

(ii) Maximise Cb = - 94.79X1 + 174.08X2 - 69.72X3 - 248.88X4 - 483.05X5 - 178.33X6 + 143.04X7 - 184.133X8 - 117.124X9 - 37.02X10 + 2772.928X11 + 70.563X12 + 48.066X13 - 192X14.

where:

- X1, X2, ..., X14 state the level at which each activity is to be carried on (X1=Green barley; X2=Malting barley; X3=Grain barley; X4=Winter alfalfa; X5=Mixed crop; X6=Clover; X7=Wheat; X8=Maize; X9=Sorghum; X10=Summer alfalfa; X11=Dairy cattle; X12=Poultry; X13= Sheep; and X14=Foodstuffs).
- The positive values state the gross margin per unit of each activity of cash crops and livestock.
- The negative values state the running cost per hectare of each fodder crop activity.

- The values given in (i) are in I.D., while those given in (ii) are in $U.S.

However, to illustrate the kind of analysis which can be undertaken along this lines using linear programming, a total of four solutions have been computed for the Al-Nahrawan State Farm. The variants and the logical developments of the planning models leading to these solutions are given in Table 11.3.

Table 11.3. **Summarised Description of the Four Alternative Solutions**

Solution number	£US or I.D.	Maximum Dairy Cattle	Maximum Laying Hens	Descriptions
Da	I.D.	No Limit	No Limit	Fully relaxed capacity limit.
Db	$US	No Limit	No limit	Fully relaxed capacity limit.
Ba	I.D.	500 animal units	480 bird units	Restricted by farm capacity.
Bb	$US	500 animal units	480 bird units	Restricted by farm capacity.

11.5. The Planning Results

The activity levels of the four solutions obtained for these models are summarised and shown in Table 11.4. The marginal opportunity costs for the non-basic activities and the marginal value products for the restricted activities are given in Table 11.5.

Table 11.4. Summary of the Four Alternative Solutions

Enterprises	Unit	Activity Levels for the Four Models Da	Db	Ba	Bb
Green Barley	Hectare		-	-	27
Malting Barley	"		677	1825	773
Grain Barley	"		-	-	-
Winter Alfalfa	"		530	238	513
Mixed Crop	"		-	333	-
Clover	"		481	39	502
Wheat	"		-	-	-
Maize	"		-	333	-
Sorghum	"		481	39	502
Summer Alfalfa	"		530	238	513
Dairy Cattle	Unit		543	500	500
Laying Hens	100 birds	8039	2253	480	480
Sheep	Unit		-	5932	2989
Bought-in Foodstuffs	Tonne		-	3920	-
Value of the obj. Function		**2,078,030**	**1,490,186**	**915,324**	**1,401,028**
unit of money		I.D.	$US	I.D.	$US

Table 11.5. **Marginal Opportunity Cost for Non-Basic Activities and Marginal Value Products for Restricted Activities**

Activity	Unit	Da I.D.	Db £US	Ba I.D.	Bb £US
a) Marginal Opportunity Costs:					
Green Barley	Hectare	145.26	118	42.8	-
Malting Barley	"	6.26	-	-	-
Grain Barley	"	172.78	151.2	136.3	164.8
Clover	"	534.9	-	-	-
Wheat	"	103.2	7.5	84.65	20.9
Maize	"	505.3	880	-	512.7
Alfalfa	"	543.7	-	-	-
Sheep	"	5.25	24.4	-	-
Conc.Feed	tonne	52.2	4.9	-	43.5
b) Marginal Value Products:					
Dairy Cattle	Unit	378.2	-	360.7	595
Laying Hens	"	-	-	246	41.5

It can be seen from Table 11.4 that the imposition of the alternative objective functions influence the farm organisation differently. In omitting all the farm constraints on the activities, Solutions Da and Db were obtained. Solution Da was computed using local prices. This solution is identical to that obtained for the original model D in Chapter 10, where poultry constituted the whole income of the enterprise. The values of opportunity costs given in Table 11.5 opposite the excluded activities indicate how much the value stated in the objective function for these activities would have to change before those activities can enter the solution. With respect to crop activities these changes do not have substantial effects on the optimal solution. But a rise of around I.D.378.2 (or 30%) or I.D.5.25 (or 26.4%) in the price of dairy cattle or sheep, respectively, would have changed the picture, however.

When using the international prices, solution Db results. This solution alters the farm plan substantially, as shown in Table 11.6.

Table 11.6. Solutions Db and Da Compared - Activity Levels

Activity	Activity Levels* Db	Da	Difference	
Green Barley	-	-	-	
Malting Barley	-	677	677	Increase
Grain Barley	-	-	-	
Winter Alfalfa	-	530	530	Increase
Mixed Crop	-	-	-	
Clover	-	481	481	Increase
Wheat	-	-	-	
Sorghum	-	481	481	Increase
Summer Alfalfa	-	530	530	Increase
Dairy Cattle	-	543	543	Increase
Sheep	-	-	-	
Laying Hens	8,039	2,253	5,786	Decrease
Bought-in Foodstuffs	-	-	-	

*Units of measurement are: hectare for crops; animal unit for cattle and sheep; 100 birds for poultry and tonne for bought-in foodstuffs.

The main changes in the farm organisation in comparison with solution Da are as follows:

1. The dairy cattle rearing activity has appeared in the new solution Db at a level of 543 animal units. This is quite reasonable since the dairy cattle housing capacity permits an average of 500 cow units.

2. The appearance of dairy cattle results in certain adjustments to the other farm enterprises. Alfalfa, clover and sorghum have appeared with the dairy cattle requirement, whilst poultry has decreased by 5786 bird units.

3. The malting barley activity has appeared also, at 677 hectares of production area.

4. The sheep and concentrate buying feed, the wheat and some home fodder activities have been excluded from the optimum solution, as they now are less profitable.

Table 11.7 shows a comparison between the levels and ratios of unused resources in Solutions Db and Da. According to Solution Db most of the farm resources (land, water and machinery) are left unused. Conversely, Solution Da implies the use of all the farm resources at levels and ratios as stated in Table 11.7.

Table 11.7. Solutions Db and Da Compared - Resources Unused

Resources	Quantity Available	Resource Unused: Solution Db Quantity	Solution Db %	Solution Da Quantity	Solution Da %	Percentage Decrease
Winter land (Hect.)	3844	3844	100	2156.4	56.1	43.9 %
Summer land "	1687.5	1687.5	100	677.2	40.1	59.9 %
Water for irrigation (m^3):						
Jan.	3335904	3328428	99.8	2045331	61.3	38.5 %
Feb.	3487536	3480783	99.8	1761942	50.5	49.3 %
March	3942432	3934956	99.8	135652	3.4	96.4 %
April	3942432	3935197	99.8	1983321	50.3	49.5 %
May	5054400	5046924	99.8	1781148	35.2	64.6 %
June	5256576	5249341	99.9	1060343	20.2	79.7 %
July	5054400	5046924	99.9	-	-	99.8 %
August	4650048	4642572	99.8	113369	2.4	97.4 %
Sept.	5256576	5249341	99.9	2043994	38.9	61 %
Oct.	4447872	4440396	99.8	1521204	34.2	65.6 %
Nov.	3639168	3631933	99.8	295459	8.1	91.7 %
Dec.	4094064	4086588	99.8	2457371	60	39.8 %
Labour	482328	-	-	-	-	-
Machinery (machine/hour) Medium-sized tractor: 1st season	21300	13261	62.3	3320	15.6	46.7 %
2nd "	23100	15061	65.2	4419	19.1	46.1 %
3rd "	22200	14161	63.8	-	-	63.8 %
4th "	21900	13861	63.3	445	2	61.3 %
Large-sized tractor	8850	885	100	3586	40.5	59.5 %
Fodder harvester	7080	7080	100	1227	17.3	82.7 %
Combine	2336	2336	100	1469	62.9	37.1 %

At this point, it is useful to carry the analysis a stage further and programme the problem with the present limitations on cow and poultry accommodation. This will give an indication of the kind of adjustments which would then be necessary to compare the effect of the alternative use of prices on the optimal solution, taking the present availability of the farm resources into account. The two solutions can be seen in Table 11.4. Solution Ba contains the same combination of farm enterprises as Solution B contained.

In using international prices for model B, solution Bb was found, as described also in Table 11.4. It can be seen from this solution that the farm plan contains the following adjustments in the farm activities:

1. The concentrate feed, the maize and mixed crop fodder have been excluded from the new solution Bb.

2. The green fodder barley has appeared at a level of only 27 hectares.

3. There are considerable adjustments in the malting barley area, in the included fodder crop areas, and in the number of sheep units, as shown in Table 11.8.

Table 11.8. Solutions Ba and Bb Compared- Activity levels

Crops	Unit	Activity Levels Solution Ba	Solution Bb	Difference	
Malting Barley	Hectare	1825	773	1052	Decrease
Winter Alfalfa	"	238	513	275	Increase
Clover	"	39	502	463	"
Summer Alfalfa	"	238	513	275	"
Sorghum	"	39	502	463	"
Sheep	Unit	5932	2989	2943	Decrease

The optimality ranges of cost coefficients are shown in Table 11.9. A study of this table will show that the four solutions appear to be relatively stable. The ranges of the cost coefficients of many of the farm activities are very wide. For example, Table 11.9 shows that the cost coefficient of the green feed barley activity could fall to - $U.S.236.1 or rise to $U.S.57.8 without the plan being affected. The objective function would directly be influenced by these changes. It will be $U.S.1,397,200 for Cj = -$U.S.236.1 and $U.S.1,402,000 for Cj = $U.S.57.8. A similar interpretation applies to the other values in this list.

Table 11.9. Optimality Ranges for Cost Coefficients (Cj)

(Basic Variables Only).

Basic activity	Unit	Da Lower	Da Upper	Db Lower	Db Upper	Ba Lower	Ba Upper	Bb Lower	Bb Upper
		I.D.		£US		I.D.		£US	
Green Barley	Cj per Hectare							-236.1	57.8
max.obj.func.								13972	14020
Malting Barley	"			165.9	174.4	137.4	154.4	154.6	343.8
max.obj.func.				14846	14904	8881	9192	13859	15322
Winter Alfalfa	"	INF.	526.7	-258.6	-136.4	-23.1	28.6	-396.8	373.5
max.obj.func.	"	INF.	20780	14851	15497	9139	9262	13251	17204
Mixed Crop	"	INF.	466.5	INF.	397.1	-46.5	-3.03	INF.	59.7
max.obj.func.	"	INF.	20780	INF.	14902	9127	9272	INF.	14010
Clover	"			-180.1	-130.1	-238.4	-39.6	-663.7	259
max.obj.func	"			14893	15134	9079	9157	11575	16205
Maize	"					-33.3	10.2		
max.obj.func.	"					9127	9272		
Sorghum	"	INF.	512.2	-118.9	-68.9	-212.3	-13.5	-602.5	320.2
max.obj.func.	"	INF.	20780	14893	15134	9074	9157	11575	16205
Summer Alfalfa	"			-46.7	75.4	-11.9	39.7	-184.9	585.3
max.obj.func.				14851	15497	9139	9262	13251	17204
Dairy Cattle	(Cj per Unit)			2769.5	2840.6				
max.obj.func.				14883	15270				
Laying Hens	"	248.3	INF.	66.2	71.4				
max.obj.func.		19960	INF.	14804	14920				
Sheep						17.8	20.4	26.1	73.5
max.obj.func.						9079	9182	13353	14771
Bought-in Foodstuffs	Tonne					-57.2	-51.8		
max.obj.func.						8958	9171		

Note:
Positive sign indicates Output. Negative sign indicates variable cost. The values of the objective function are given in 100 units.

The next details of the four solutions to be considered in this chapter are the figures of the marginal opportunity costs and the marginal value products given in Table 11.5, opposite the farm activities not in the solution and the restricted enterprises. As mentioned above, the marginal opportunity costs show the fall in costs or the rise in output needed to cause these activities to enter the optimum plan, while the marginal value products show the rise in output caused by adding one more unit of these enterprises.

In comparing solutions Da and Db of the fully relaxed models, according to the marginal opportunity cost values along with the information on the ranges of the cost coefficients, one may see how far the economic stability of the two solutions can be influenced by the price assumptions. It might be surprising to achieve an optimum stable solution for the farm organisation with the use of international prices which does not differ substantially from the plan utilised by the present farm management. But it is more confusing to see that the optimum plan with the use of the local prices is also stable but differs substantially from the present one (see Table 11.10).

Table 11.10. Activity Levels for the Present, the Da and Db Plans Compared

Activity	Present Plan (1)	Db (2)	% of (1)	Da (3)
Cash Crops	Hectare	Hectare		
Malting Barley	473.25	677		-
Wheat	200.00	-		-
Total	**673.25**	**677**	**106.2 %**	
Fodder Crops	Hectare	Hectare		
Green Barley	183.00	-		-
Grain Barley	335.25	-		-
Winter Alfalfa	155.50	530		-
Mixed Crop	502.50	-		-
Clover	631.00	481		-
Maize	352.50	-		-
Sorghum	623.25	481		-
Summer Alfalfa	195.50	530		-
Total	**2978.50**	**2099**	**70.47 %**	
Livestock	Unit	Unit		Unit
Dairy cattle	292.50	543	185.6 %	-
Sheep	597.00	-		-
Poultry	360.00	2253	625.8 %	8039 2233 % of (1)

This shows how much the current given price policy affected the profitability of the farm enterprise. Certainly, the Iraqi state farms have not operated as yet for external commerce, therefore they have nothing to do with the world prices in this respect. But of course they have an indirect relationship with the international economy, since they are controlled by the central authorities and operated to achieve many objectives, as stated in Chapter 2. One of the most important economic objectives of the Iraqi State Farms is to reduce the country's imports of many agricultural commodities. This might imply the reason behind the similarity between solution Db and the present farm organisation, where the authorities take the value of the imported commodities into account, rather than the local prices to address the state farm production (further details in Sections 14.2 and 14.3).

Table 11.11 relates to the exhausted resources and operative planning constraints. The value attached opposite each resource indicates the marginal value product of that resource. The range attached to this value shows the range in units of measurement over which this value applies.

Table 11.11. <u>**Resources Fully Used and Optimality Ranges for Right-Hand-Side Constants**</u>

	May Water m^3	Jul.Water m^3	Oct.Water m^3	M.Z.Tractor* Trac./hour	Labour Man/hour
Solution Da					
M.V.P. (I.D.)					4.3080
Min.Bi (Man/hour)					0.0005
Max.Z (I.D.)					0.0015
Max.Bi					1278000
Max.Z					5506000
Solution Db					
M.V.P. ($US)		0.0003		65	0.0917
Min.Bi		4906400		20514	468610
Max.Z		1490100		1380500	1488900
Max.Bi		5181000		22428	583720
Max.Z		1490200		1505000	1499500
Solution Ba					
M.V.P. (I.D.)		0.8508		0.002	12.3358
Min.Bi		3811500		3638700	21630
Max.Z		904180		915320	908290
Max.Bi		3942700		3738200	246984
Max.Z		915350		915530	946090
Solution Bb					
M.V.P. ($US)		0.0749	0.028	29	
Min.Bi		3155000	4904400	22015	
Max.Z		1342000	1396700	1395700	
Max.Bi		4022000	5089200	22382	
Max.Z		1407000	1402000	1406300	

* Medium size tractor during the third season. Bi is the Right-Hand-Side constraint; Z is the value of the objective function.

Along with the ranges of the marginal value product figures, the possibility of studying the demand schedule for the major important farm resources will be investigated in the next chapter.

CHAPTER 12

DEMAND CURVES FOR FACTORS OF PRODUCTION

12.1. Introduction

In the previous chapter I studied the effect of using alternative prices on the optimum solutions. Now I will turn to the demand schedules and therefore to the demand curves for the factors of production. In this chapter I will examine the decisions of the farm concerning the employment of the most critical productive factors and services.

Following with the theory outlined in Chapter 6, I shall examine only the cases in which the prices and the quantities of all inputs are held constant in all possible optimal solutions, as the quantity of one scarce input varies independently. I will therefore be dealing with the relation between the Marginal Value Products of various levels of a single factor of production (say A for example) and the input quantity of that single variable factor. Thus the profit maximising level of employment of A by the farm is that level at which the value of the marginal product of A is equal to (or exceeds) the price per unit of the resource.

In examining the use of the most critical resources at the Al-Nahrawan state farm, it was found that most of the resources were in surplus. According to the previous optimum solutions, only three resources were in deficit. They are the medium sized tractor during the third season and water for irrigation during March and November.

As explained in Chapter 6, parametric programming for the right-hand-side constants was used to establish the demand curves of the employment of labour and of the above mentioned scarce resources. The quantity range of each resource was picked up at the level where the marginal value product evaluation shifts from one level to another. The solutions obtained show how products will vary when different quantities of a particular resource are used with all other factors being constant. However, a similar interpretation, as discussed in Chapter 6, applies to the demand curves of these resources. One may continue the process and verify the results as shown in the following sections.

12.2. Demand Curve for Medium Size Tractor During the Third Season

The value of the marginal product schedule for medium size tractors during the third season, as listed in column 2 of Table 12.1, is the farm's demand schedule for this resource. It shows the different quantities which the farm can use at different marginal value products, assuming the quantities of other resources employed are held constant. Increasing quantities of medium size tractor hours during the third season up to 28,378 hours, adds more to total receipts than to total costs, and consequently makes a net addition to profits. Beyond 28,378 hours, larger quantities add more to the farm's total costs than to its total receipts and cause profits to decrease.

Table 12.1. **Demand Schedule for Medium-Size Tractors During the Third Season**

(1) Range of Bi Tractor hours	(2) M. V. P I.D.	(3) Resource Price I.D.
zero TO 480	258.500	2
480 - 8275.4	50.625	2
8275.4 - 10338	49.331	2
10338 - 14050	43.673	2
14050 - 14575	41.067	2
14575 - 15580	23.320	2
15580 - 16305	17.240	2
16305 - 20126	12.990	2
20126 - 21630	12.347	2
21630 - 24694	12.336	2
24694 - 24703	7.482	2
24703 - 28378	3.589	2
28378 - 29966	1.343	2
29966 - Infinity	zero	2

Note: The average price per unit of the resource is I.D. 2.0034. It is assumed to remain constant.

The demand curve of the Al-Nahrawan state farm was plotted from the above schedule as shown in Figure 12.1.

Figure 12.1. Demand Curve for Medium-sised Tractors During the Third Season

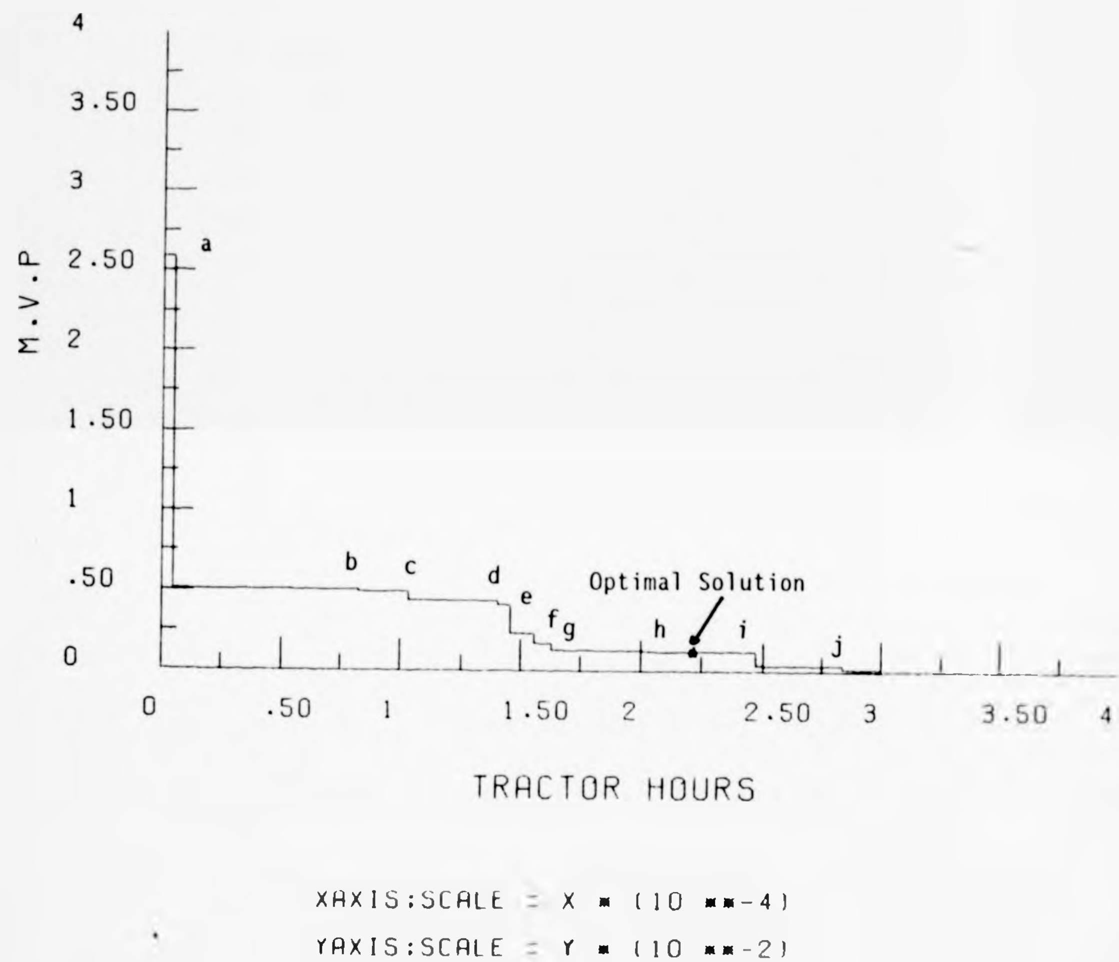
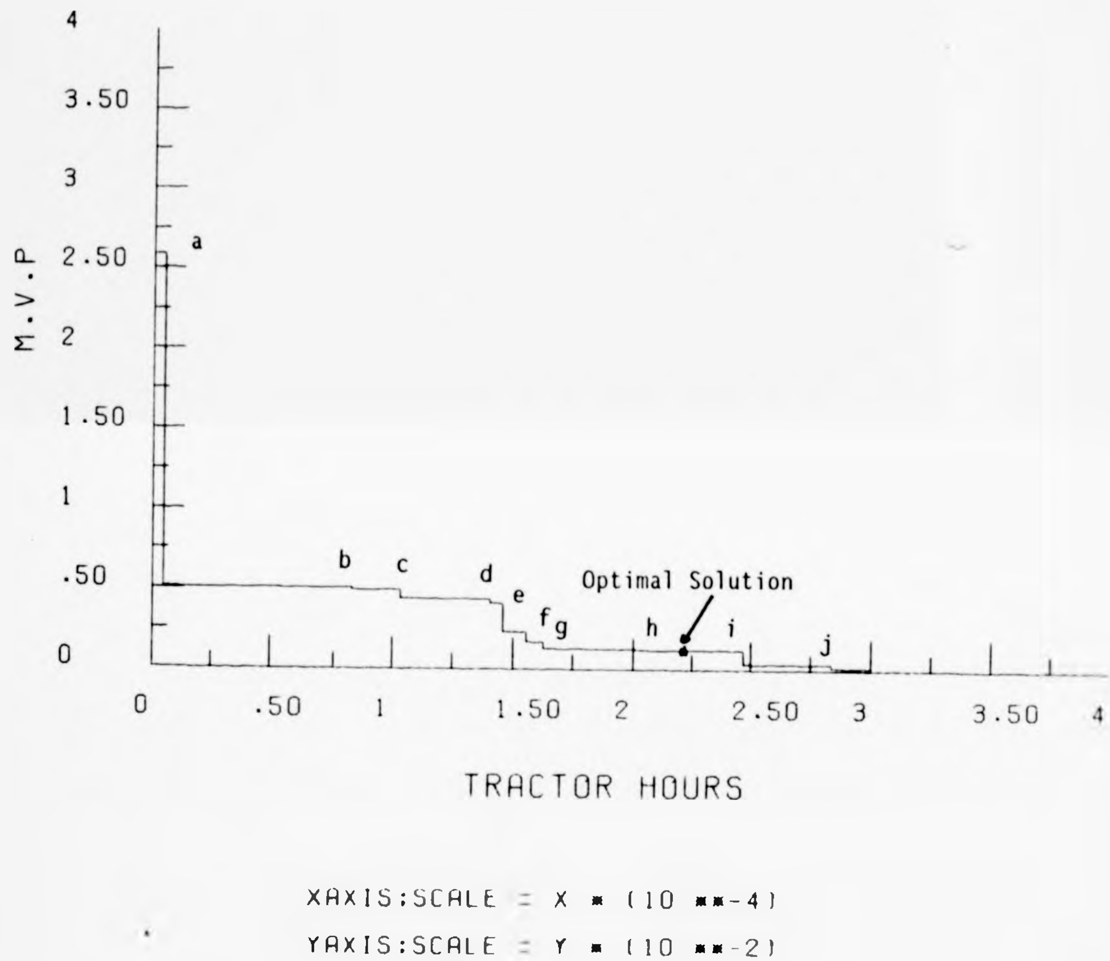


Figure 12.1. Demand Curve for Medium-sised Tractors During the Third Season



At the points a, b, c, d, e, f, g, h, i, and j of Figure 12.1 the marginal value products drop sharply and the demand curve breaks as a result of a substantial changes in the elasticity of the demand at each assigned corner. The farm can utilise any amount of the medium size tractor hours during the third season within a horizontal segment by choosing the appropriate combination of products, but all combinations are equally profitable.

A study of Figure 12.1 shows that the marginal value product of medium size tractor hours during the third season decreases as larger amounts of this resource (per unit of time) are employed and also as hours of the resource are transferred among the farm activities, as mentioned in Stage 3 in this section.

The discontinuities in the marginal value product curve can be studied under three major Stages:

1) In Stage I, the marginal value product curve of medium size tractors during the third season is perfectly elastic up to 480 hours (the corner at point a), where the poultry's demand for this resource dominates all the other farm activities' demands. Above point a, the marginal value product curve declines sharply as the poultry building capacity becomes fully used and more machine hours are employed.

2) In Stage II, dairy cattle and malting barley are the most profitable farm activities to employ additional units of medium size tractor hours during the third season, up to 14,575 machine hours.

At this point the cow building capacity becomes fully used, therefore the marginal value product curve declines sharply. Although there are gradual kinked declines in this stage (as a result of the entry into the optimal solution of the alfalfa at point b, the green feed barley at point c, and clover/sorghum rotation at point d), the next substantial decline does not occur until the cow building capacity became fully used. This is shown at point e.

3) In Stage III, the disappearance of green feed barley and the entry of sheep rearing activity and the mixed crop/maize rotation are the biggest changes to be considered. Here, as units of the resource are transferred among the farm activities, its value of marginal product decreases in the employments to which it is transferred and increases in the employments from which it is transferred. At this stage the optimum solution was found as shown in Figure 12.1. This stage also has a relatively smooth decline. At point j of this stage, the contribution of an hour of the resource adds more to the total receipts than to total cost, and therefore increases profits. The pattern of production reached 1825 hectares of malting barley, 199 hectares of alfalfa, 387 hectares of mixed crop/maize rotation, 87 hectares of clover/sorghum rotation, 500 units of cow, 480 units of poultry and 8666 units of sheep. It implies also the purchasing of 4258 tonnes of concentrate feed. Beyond this point larger quantities add more to the farm's total cost than to its total receipt and cause profits to decrease.

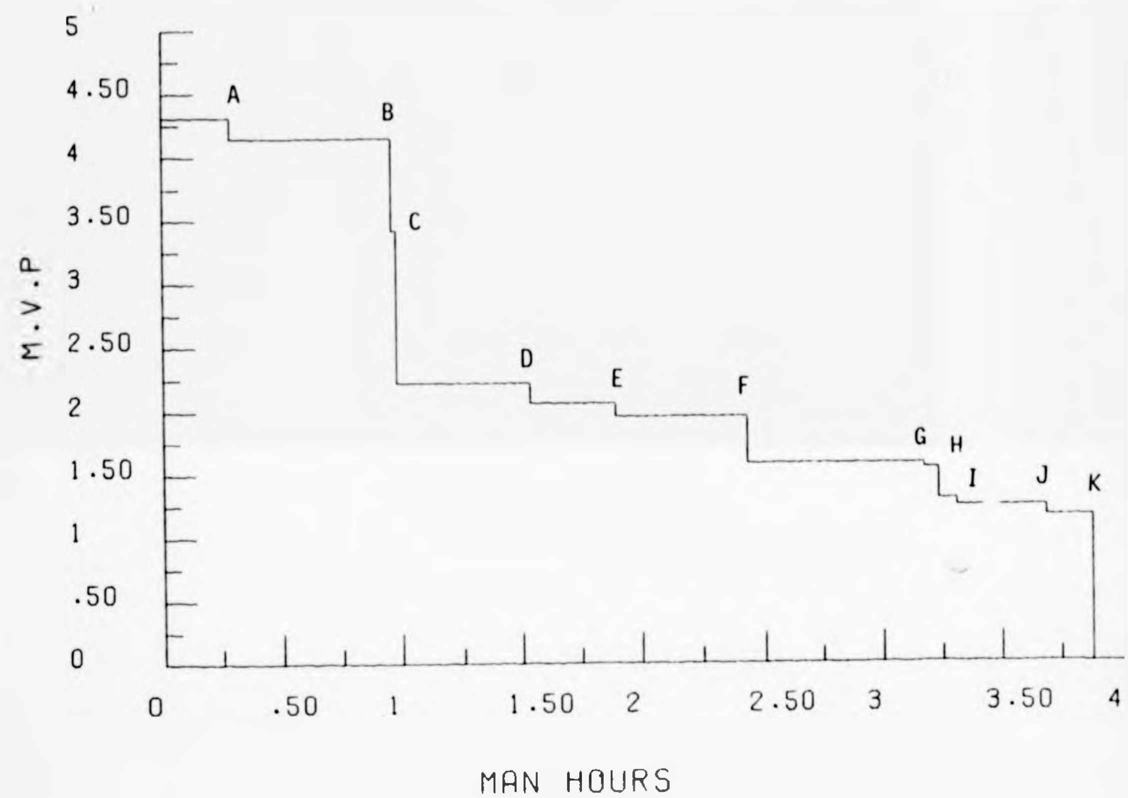
12.3. Demand Curve for Labour

The Al-Nahrawan demand schedule for labour shows the different quantities which the farm can use at different marginal value products, as listed in Table 12.2. More quantities of man/hours up to 387,650 hours would be worthwhile for the farm since the MVP, within this range, exceeds the cost per unit of labour. Exceeding 387,650 hours, the farm profits decrease by the cost of the additional hours used, since the MVP of an hour becomes equal to zero.

Table 12.2. Demand Schedule for Labour

Range of Bi Man/hour		M. V. P I.D.	Resource Price I.D.
zero to	28800	4.308	0.300
28800	95960	4.138	0.300
95960	97898	3.410	0.300
97898	153530	2.220	0.300
153530	189380	2.060	0.300
189380	242790	1.954	0.300
242790	317100	1.574	0.300
317100	323210	1.536	0.300
323210	331020	1.292	0.300
331020	368680	1.236	0.300
368680	387640	1.158	0.300
387640	387650	.603	0.300
387650	Infinity	zero	0.300

Figure 12.2. Demand Curve for Labour



XAXIS:SCALE = X * (10 **-5)

YAXIS:SCALE AS PRINTED.

The solutions used for the above schedule and curve, involve additional details about the use of labour resource at the Al-Nahrawan state farm. By using these details the labour demand curve in Figure 12.2 can be explained as follows: - Up to 28,800 man/hours the MVP of an hour is I.D.4.308, where the only possible production is poultry. As the poultry building capacity becomes fully used (the corner at point A), the MVP of an hour falls to I.D.4.138 and larger quantities of labour will be used to grow malting barley. Here, the area of malting barley reaches 1825 hectares, so that the MVP has dropped to I.D.3.41 and the sheep rearing activity appears (that is beyond the corner at point B in Figure 12.2). At this stage, sheep nutrient requirements are to be provided from the malting barley straw. But because of the limitation confronting the availability of nutrient contents of malting barley, alfalfa will enter the solution when the MVP drops to I.D.2.22 (that is beyond the corner at point C). At the top of this step (at point D) the size of the sheep herd reaches 6707 units, and the area of alfalfa becomes 152 hectares.

- Beyond point D, the use of the labour force is to be transferred from sheep activity to the dairy cattle. The MVP of an hour of labour falls to I.D.2.06 (that is beyond the corner at point D); as a result, the area of alfalfa increases as the number of cows increases. From point E up to point F the MVP falls to I.D.1.954 and the clover/sorghum rotation enters the optimum solution. Exceeding 242,790 man/hours, the MVP will drop to I.D.1.574 and the mixed crop/rotation will enter the solution (that is beyond the corner at point F). Up to point G, the alfalfa area will decrease while cows, mixed crop/maize rotation and clover/sorghum rotation will increase. Beyond the latter point, the MVP falls to I.D.1.536 and sheep activity reappears against a small reduction in the size of the dairy cattle herd. At point H, the farm pattern of production becomes a combination of 480 units of laying hens, 1825 hectares of malting barley, 139 hectares of alfalfa, 471 hectares of mixed crop/maize rotation, 163 hectares of clover/sorghum rotation, 353 units of cow and, 1763 units of sheep.

- Beyond 323,210 man/hours up to 368,680 hours the sheep rearing activity disappears from the optimal solution (the corner at point I). Alfalfa has a small decrease in its area, while the other including activities have expanded remarkably. At point at J the MVP of a man/hour is I.D.1.236 and the pattern of production is as follows: 480 units of poultry, 500 units of cow, 1780 tonnes of concentrate feed, 139 hectares of alfalfa, 471 hectares of mixed crop/maize rotation and 163 hectares of clover/sorghum rotation.

- The last stage of the labour demand curve involves the reappearence of the sheep rearing activity and the extension in the use of buying concentrate feed. The latter causes some decreases in the area of forage crops. The pattern of production at point K includes the use of the optimum capacity of the cow and poultry accommodation, the raising of 5929 units of sheep, the purchasing of 3919 tonnes of concentrate feed and the growing of 237 hectares of alfalfa, 333 hectares of mixed crop/maize rotation and, 39 hectares of clover/sorghum rotation. Beyond this point no more labour can be used, since the MVP of a man/hour becomes equal to zero.

12.4. Demand Curve for March Water for Irrigation

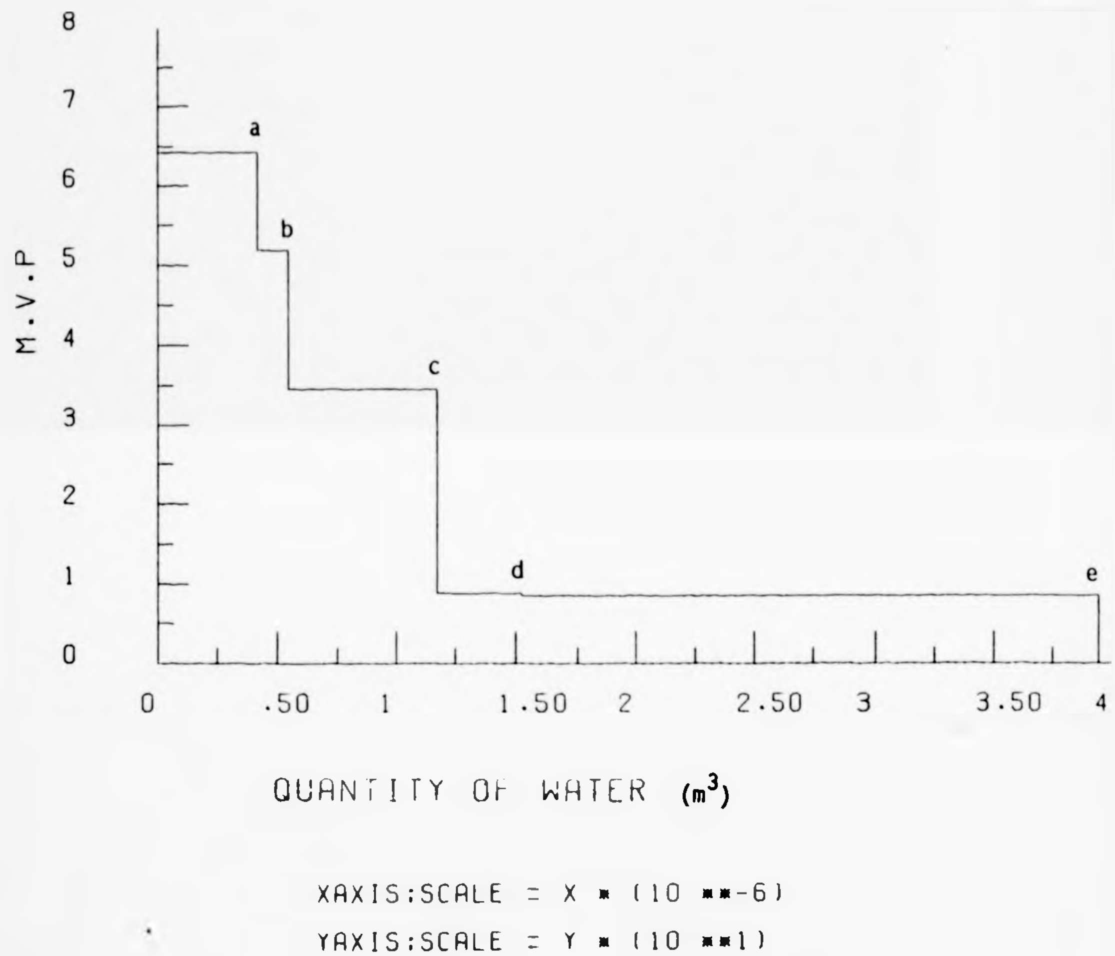
Table 12.3 is the demand schedule for March water for irrigation. It shows that more water up to 3,942,700 m^3 adds more profits to the farm total receipts since the MVP of a m^3 of water is positive (assuming that the marginal cost of a m^3 of water for irrigation is very small). Beyond 3,942,700 m^3, the marginal value product of a m^3 of water is zero, and consequently does not add any more to the farm output.

Table 12.3. Demand Schedule for March Water for Irrigation

Range of Bi m^3	M. V. P I.D.
zero TO 446.4	277.957
446.4- 418890	.642
418890 - 545930	.518
545930 - 1173200	.345
1173200 - 1523300	.088
1523300 - 3942700	.085
3942700 - Infinity	zero

Up to 446 m^3 of water, the marginal value product of a unit of March water is I.D.277.957 and the only possible activity to enter into the optimal solution is the poultry. Beyond this level of water use, the demand curve from the above schedule was plotted as shown in Figure 12.3.

Figure 12.3. Demand Curve for March Water for Irrigation



As the poultry building capacity becomes fully used, additional quantities of March water for irrigation, up to 418,890 m^3 (that is the corner at a) is required as a result of the entry into the solution of the cow rearing activity and the clover/sorghum rotation. At point a, the cow building capacity also becomes fully used and the dairy nutrient requirements are to be provided from an area of 255 hectares of clover/sorghum rotation and, of 6,565 tonnes of concentrate feed.

Beyond point a, the entry of mixed crop/maize rotation with smaller quantities of concentrate feed and a smaller area of clover/sorghum production are obtained. The pattern of production at the end of this stage (that is point at b) reaches 500 units of cows, 480 units of poultry, 120 hectares of mixed crop/maize rotation, 234 hectares of clover/sorgum rotation. The quantity of concentrate feed required for this solution is 5186 tons. At this stage, the MVP of one m^3 of water is I.D.0.518.

Beyond corner b, the entry of the sheep rearing activity, up to 11409 units (that is point at c), is the main change to be considered. The MVP of one m^3 of March water for irrigation has dropped to I.D.0.345 as shown in Table 12.3, and the farm activities became a combination of 472 hectares of mixed crop/maize, 326 hectares of clover/sorghum rotation, 11409 units of sheep and 4829 tons of concentrate feed. The units of cows and poultry remain unchanged.

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At the beginning of the next stage of the Al-Nahrawan demand curve for March water for irrigation, the entry of alfalfa appears to be profitable, since the MVP of a m^3 of water has dropped to I.D.0.088. As shown in Figure 12.3, this stage has a smooth decline. Up to point d, alfalfa and mixed crop/maize rotation takes 110 and 35 hectares respectively, from the clover/sorghum area. Sheep units and the quantity of bought-in concentrate feed becomes less than they were before.

Beyond point d, the entry of malting barley makes the largest changes in the size of some activities. At the end of this stage (that is corner e), the pattern of production becomes 1825 hectares of malting barley, 237 hectares of alfalfa, 333 hectares of mixed crop/maize rotation, 39 hectares of clover/sorghum rotation, 5933 units of sheep, 500 units of cow and 480 units of poultry. According to this solution, the quantity of concentrate feed is about 3920 tons. Beyond this point larger quantities of water for irrigation add zero MVP to the farm output. However, the optimum solution of the original problem can be seen at point O (see Fig. 12.3) of this stage.

12.5. Demand Curve for November Water for Irrigation

Along with the discussion above, a similar interpretation applies to November water for irrigation. Therefore the quantities range of this resource which the farm can use at different marginal value products, are shown in Table 12.4.

It can be seen from Table 12.4 that the marginal value product of a m^3 of water is very high (I.D.287.222) within a range between zero and $432m^3$, where poultry dominates all the farm demand curve for this resource. By using 432 m^3 of November water, the poultry building capacity becomes fully used, therefore more quantities of the resource cause the value of the marginal product to drop sharply and new enterprises will enter the optimum solution as illustrated in Figure 12.4 and explained in Table 12.5.

Table 12.4. Demand Schedule for November Water for Irrigation

Range of Bi m^3			M.V.P I.D.
Zero	to	432	287.222
432	-	201410	1.336
201410	-	251230	1.031
251230	-	572130	.645
572130	-	653300	.166
653300	-	859860	.103
859860	-	2517200	.098
2527200	-	2531400	.092
2531400	-	2546000	.079
2546000	-	3343400	.075
3343400	-	3638700	.017
3638700	-	3738200	.002
3738200	-	Infinity	zero

Figure 12.4. Demand Curve for November Water for Irrigation

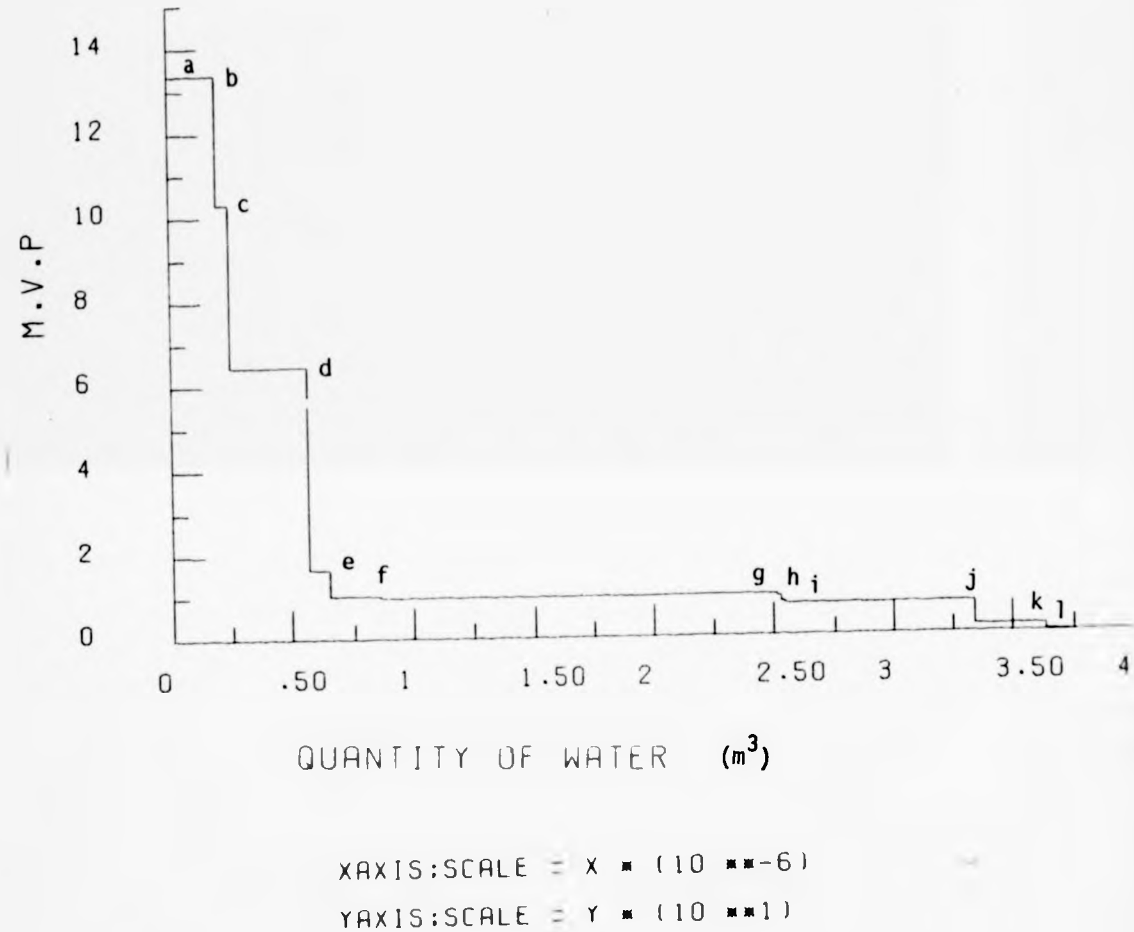


Table 12.5. The Use of November Water by the Farm Activities at Different MVP

	Poultry Unit	Clover/ Sorghum Hectare	Cow Unit	Bought-in Foodstuffs Tonnes	Sheep Unit	Malting Barley Hectare	M.Crop/ Maize Hectare	Alfalfa Hectare
Patterns of production at the following points of Figure 1.4.*								
a.	480	zero	zero	zero	zero	zero	zero	zero
b.	480	255.2	500	6566	"	"	"	"
c.	480	319	500	5494	.094	"	"	"
d.	480	720	500	6136	13512	.005	"	"
e.	480	715	500	6200	13671	87.6	.00065	"
f.	480	661.7	500	6116	13710	194	60.7	"
g.	480	232	500	6524	9571	1812	237.5	"
h.	480	230	500	6511	9502	1825	239	.008
I.	480	228	500	6487	9490	1825	238	4.421
j.	480	185	500	4442	7049	1825	173	231
k.	480	39.5	500	3922	5935	1825	333	237
l.	480	17	500	3453	5512	1727	360	271

* The patterns of production were taken at the corner points.

12.6. Conclusion

It can be seen from the above discussion that two points are considered in making a rational decision for the best allocation of the available resources of the Al-Nahrawan state farm.

Firstly, additional units of a resource used with constant quantities of fixed resources cause the MVP of each to decrease. Therefore, larger units of the resource will be employed to expand the farm output up to the point at which the farm's marginal cost equals its marginal revenue or product price. Accordingly, the farm will be using its variable resources in the correct combination and in the correct absolute amounts.

Secondly, resources are mobile among different uses. As units of the resource are transferred among the farm activities, its value of marginal product decreases in the uses to which it is transferred and increases in the uses from which it is transferred. Theoretically, the transfer continues until its value of marginal production is equalised in all its uses and all enterprises use the resource at a price per unit equal to its value of marginal product. Again, at this point, the resource is correctly allocated and makes its maximum contribution to the farm's net revenue.

When the farm employs each of its variable resources in the correct amount for profit maximisation, it necessarily will be using them in the correct combination and must use the absolute amounts necessary to produce those quantities of products which maximise profits, as LEFTWICH [1955] stated:

> "The same set of conditions for employing the correct amounts and the correct combination of resources to maximise profits can be reached by considering resources individually." (p.288)

However, when resources are combined in the correct ratios they are equally efficient at the margin and the farm will maximise its net revenue. e.g, an additional Dinar's worth of product (per unit of time) can be obtained from the same additional outlay on any one or on all of the resources. To summarise, the farm should employ those amounts of resources and produce that amount of product at which the profit maximising conditions take the usual form:

$$\frac{MPPa}{Pa} = \frac{MPPb}{Pb} = \cdots = \frac{MPPn}{Pn} = \frac{1}{MCx} = \frac{1}{Px}$$

where:

- MPPa, MPPb, ..., and MPPn represent the marginal physical product of resources a, b, ..., and n, respectively.
- Pa, Pb, ..., and Pn are the respective price per unit of resources a, b, ..., and n.
- MCx is the marginal cost of product x
- Px is the product price.

Otherwise, when resources are not correctly allocated, the farm revenue is below its potential maximum.

CHAPTER 13

LIMITATIONS OF THE MODELS AND DATA

13.1. Introduction

Limitations of the models used were dictated mainly by a number of simplifying assumptions that enable us to construct a linear programming analysis and hence make specific calculations. These simplified models have been in some sense justified by the fact that they have led to propositions that are consistent with expectations. However, simplifying assumptions are only some of the factors limiting development of more detailed models. The scarcity of uniform and current input-output data, especially for production costs, and seasonal labour available and required, is currently a greater obstacle than simplifying assumptions.

Interpretation of the results must be conditioned by certain characteristics of the basic model, as well as by certain characteristics of the coefficients. In the following discussion, the effects of certain of these characteristics on the results are presented.

13.2. General Model Limitations

The models are designed for a specific large Iraqi state farm. Certainly the objective function is misspecified for farms with different goals. The models do not explicitly consider yield, price or the weather risk; they use average yield over a six year period and alternative world prices. Also, the models are single year models which exclude investment and do not treat within-year adaptive management (prices are assumed fixed and constant throughout the year, as is weather).

Whether the patterns of production designated by the solutions are optimal in relation to specified output requirements depends on the structure of the models and the accuracy of the input-output coefficients. No claims are made that the results from these models (taking the farm capacity into account, especially for buildings), or even much more detailed models, would show strictly optimal crop and livestock patterns of production for other objective functions. The study focuses on the results for a particular state farm which represents production possibilities for dairy cattle, sheep, laying hens, fodder crop, wheat and malting barley. In addition the possibility of bought-in foodstuffs is represented. The production of each of these activities takes place within the yearly availability of resources. However, conclusions from such models would be made more accurate with regard to improvements in the technical efficiency of production, adjustments in the annual labour requirements, etc., by introducing risk into the objective function, and also changes in price expectations. The method for variable price programming developed by CANDLER [1957] is particularly useful in this context.

13.3. Cost Coefficients

The suggested possible improvement in the financial position of the Al-Nahrawan state farm is all the more remarkable in that input-output relationships and the level of managerial skill as experienced in the past have been incorporated and reflect the existing level of performance (taken as given); i.e. no improvement in the technical efficiency of production has been assumed. Programming is of little help in estimating input-product relationships; however, the method can specify the type and quantity of data needed. The planner must supply estimates of the amount and distribution of labour, feed, land, and capital needed to produce crops and livestock [BENEKE and WINTERBOER, 1973; p.8]. If estimates of this type are difficult to make, especially in cases where record keeping has been neglected, all we can hope to know is the "normal" or expected level of technical efficiency. For this we might turn to the information published by experimental farms, or the results of surveys of farm enterprises operated under similar conditions and methods of production. Moreover, some production coefficients can be built on knowledge transferred from another situation and adapted as best one can to the farm under study. In this regard, BENEKE and WINTERBOER [1973] stated that:

> "two likely sources of data which may be transferred are (1) experimental data and (2) cost accounting data." [p.105]

Therefore, a "comparative analysis" of this sort should enable one to show up the degree of technical inefficiency with which any enterprise on the farm is being operated and lead to an exploration of the reasons for this. However, even if a reason for technical inefficiency is found, it is still difficult to assess to what degree the farm may be able to correct it or, if it does, what effect it will have on the situation. For example, can we assume that milk yield can be raised in the future and, if so, by how much? There would, at first sight, appear to be a further problem. For each set of assumptions that we make concerning input-output relationships in the future, are we not going to have to work out a different optimum plan?

However, cost coefficients present the greatest difficulty of all estimates. In the case with errors in the ratios of yield and or costs between all the farm activities, rather large errors in the cost coefficients may affect the allocation of resources among activities and therefore the resulting farm patterns of production. While errors in cost ratios could distort the optimum combinations of production, their effect on the resulting total quantity of any surplus resource is cumulative. Certainly, the errors for individual activities can be quite large. A situation might exist where two activities with identical ratios of yields/cost are competing for the marginal output requirements. Either could be selected to meet the marginal output requirements without affecting the resulting total surplus capacity.

As "profit" is a resultant of inputs, outputs and prices, and since we have already discussed in Chapter 10 the fact that we can measure to what extent technical efficiency must change before it becomes necessary to change the allocation of resources, by taking prices as constant we can therefore calculate for each enterprise how much output for given inputs can vary before a change is necessary in the optimum. Thus, referring to Table 10.5, wheat yield would have to rise by more than 267 percent per hectare before it would be profitable to include the wheat activity in the optimum solution.

13.4. Labour

In constructing planning models of an Iraqi state farm one can expect to encounter the greatest difficulty in forming labour coefficients. The pace at which the workers work, the manager's capacity to organise their work, the level of mechanisation, and the type of the farm are all important sources of variability. In the farm records as well as in previous work, I did not find accurate and sufficient details of either the labour rate of work or interseasonal operational labour requirements and supplies for the existing farm situation. Moreover, there is no academic group within the experimental farms which has a primary interest in farm labour. Therefore, the establishment of the labour coefficients was found to be the most troublesome feature of this research.

The per unit total annual labour requirements of the various activities were built up from previous studies and information gathered on the farm, and where necessary this was supplemented by other data, such as enterprise costing, where these seemed appropriate.

However, since the labour requirement per unit of output is typically a function of the scale at which an activity is conducted, it was assumed that the farm activities enter at a level commonly found on farms in the area. Therefore, the labour requirement per unit of activity does not decline markedly with scale.

Undoubtedly this approach suffers from some deficiencies. In the first place, the annual labour requirements may give a misleading answer due to the seasonal nature of the labour demand. Labour requirements have a time dimension. It may be as important to the outcome of the planning process to know when labour will be required as to know how much will be needed. In gathering labour coefficients no special attention has been given to those time periods where labour requirements should be known to peak on the type of farm under study. The demand which activities make on labour at peak periods during the year is more important than their total labour demand. However, at the moment the data for establishing a reliable "standard" for seasonal labour requirements are sadly limited, therefore the selection of appropriate labour planning periods of the seasonal nature of the labour needs of state farms complicates the farm planner's task. However, the first task which faces the planner of Iraqi farms is the question of how to divide the year into appropriate planning periods. Commonly twelve monthly periods can be taken as the basis for estimating the labour requirements of the activities, and corresponding labour profiles can be estimated on the basis of man-hours per unit of activity. However it could be better to divide the year into selected periods in relation to the timing of particular farm operations, particularly at what are likely to be labour bottlenecks. Due to the seasonality of certain farm operations, considerable peaks and troughs of labour requirements occur during the year. It is only during the former that labour is likely to be scarce, and if there is sufficient labour to carry through a programme in the peak periods, then there is sufficient labour throughout the rest of the year.

However, allocations of the labour force are understated by the models used because they do not include sufficient detail of interseasonal labour requirements and supplies. Also, they do not meet the possibility of the overlapping of work from one season to another. A more detailed labour programme would show some more additional and precise results on labour force during the peak seasons, where the solutions currently obtained do not show such details. Probably, its basic and general conclusions might not be changed substantially by this added detail. The way linear programming can handle this important problem when seasonality arises is explained by NIX [1967], HARDAKER [1971], BARNERD and NIX [1979]. They described a broader allocation of labour requirements and work days (or hours) available, using a method that featured a break-down of seasonal labour requirements, and also whether or not the farm's labour force can cope with the estimated work load. In other words, this method enables a comparison to be made month by month between the estimated labour requirements and the labour actually available on the farm to do the work.

However, the level of the manpower hiring activities in the solution of a model set up on the lines indicated in this research is a useful indication of the optimal size of labour force for the farm. Although a considerable surplus of man/hours were shown in all the solutions obtained, it is not easy to decide to which level the labour force should be reduced. In a socialist farm climate, manpower cannot be dealt with only according to economic principles, as is the case for commercial farms. Labour legislation, manual worker training programmes, social and political affairs, all play decisive roles in many respects. When labour is found to be scarce in a particular season, overtime working and transferring workers between farm activities, and supplying workers from outside (especially voluntary work) can often be used to meet any deficit which might otherwise arise. Moreover, in the specification of the models (while the main current tasks, such as animal care, crops seeding, harvesting and transporting are not usually performed by men), it was assumed that corresponding labour requirements for fodder crops and livestock did not exceed the labour supply schedule because their requirements were spread through the year. While extra labour requirements that would be necessary for seeding and harvesting the increased area of malting barley exactly coincided with time period of relative abundance of labour (as a result of the lowest calving in June and July), seasonality in labour force requirements could be encountered along the lines described above and by the intensive use of machinery.

As a result it can be observed that it should be possible for the farm to adopt a new labour programme for the obtained solutions, since the total existing labour supply would substantially exceed the total labour requirements.

13.5. Feed Programme

The animal class unit response to feed input is mainly a function of body weight and milk yield. Therefore, the rate of weight and milk yield increase at any given time affect the optimum feeding programme response in the future. The farm manager may need to adjust the level and mix of the nutrient requirement programme through a year in order to achieve the rate of milk yield and animal growth to feed input which maximises profit over the entire production cycle. The feed programme at any time of the year should satisfy the requirements for cow maintenance, lactating cows, replacement heifers, growing calves, sheep and sheep replacements at different stages of the production cycle.

A more accurate assessment of the optimum feeding programme could lead to examining the relationships between animal coefficient variables such as cow weight, culling rate, calf birth date, milk yield capacity, and production cycle through a series of discrete time periods etc.. In the specification of the models used, the replacements during the year periods were treated as a part of the "cow group unit". The number of replacements represented approximately 22% and 25% of the total dairy cattle and sheep numbers respectively over the year, and some allowance was made for their requirements by assuming constant replacement conditions. A more accurate assessment of the replacements' optimum feeding system could be embodied in a linear programming model. Perhaps more satisfactorily, the optimum sequence of replacement growth rates to a minimum weight by the end of one year could be selected. This would involve systematic changes of the RHS of the linear programme representing replacement weight at the end of a time period. But what is the optimum replacement weight at the end of a production cycle? This affects the replacement conception rate, the birth rate of the calves and the subsequent progeny death rate. More quantitative, empirical work is needed to establish suitable replacement growth and also yield increase rates. It probably is not sufficient to estimate average requirements of growing a heifer to an arbitrary weight at a given age, with no growth function to represent variations in weight gain.

However, I feel that insight into the nature of the feeding problem of the dairy cattle herd was gained in the construction of the models. The technique proved to be a flexible and a useful analytical tool for selecting dairy cattle feeding systems based on average standardised data. As shown above, many aspects of feeding systems could be investigated using the model, which could possibly be improved by a more detailed treatment of the optimum replacement growth rate feeding system.

Because of the positive correlation between nutrient contents and fodder crop yield, further information on the yield variations of fodder crops of different types is urgently needed to complement work on dairy cattle selection programmes. Extension of this work to consider different levels of fodder yields is of considerable interest in view of current development programmes for the Iraqi breeds of cattle. Identification of the production variables to which the linear programming solutions are most sensitive is important to indicate the priority crops for improvement at the farm level, and for further research.

Where bought-in concentrate feed activity is used (introduced into the model) it plays a valuable role in the feeding of the dairy cattle herd. Of course it was mentioned earlier in this study that the farm was located in a region suitable for the growing of fodder crops. If the farm situation were changed, or growing fodder crop more costly or risky, the model could be extended to include concentrate bought in feed sources for the farm feeding system.

However, the model exemplifies the necessity for accurate descriptive data. In particular, more accurate estimation of the average yearly weight for each animal class included in the animal unit.

13.6. Risk in the Objective Function

Since the working details of the model have been described in Chapter 8, it is worth noting some of the assumptions associated with the model which perhaps require alteration for refinement of the results. The essential, but often the limiting, assumption of conventional linear programming models is that all objective function, resource constraint and input-output coefficients are known with certainty. Relaxation of the assumption for just one of these groups of coefficients greatly increases the complexity of determining an optimal solution. In Chapter 11, it was found that substantial changes in the patterns of production can be obtained by using alternative prices (world prices) within a fully relaxed model. However, the basic and general conclusions of the constrained models were not changed substantialy by this added investigation. Further, it highlights the importance of including more than one aspect of risk within the farm planning context, particularly in situations involving livestock feeding based on weather-dependent fodder sources.

Introducing risk within the farm planning context was complicated by lack of empirical evidence concerning managers' attitudes to both the riskiness of the total gross margin and the riskiness of not being able to feed livestock.

13.7. Water for Irrigation and Machinery Availability

For each period of the year, the supplied water for irrigation and machinery availability at the Al-Nahrawan state farm were assumed to be rigidly fixed in the models used. If the quantities of water currently available in the peak months are increased by using an additional pump, the resulting solutions show some extension in crop areas, especially of malting barley. This outcome was identical to that obtained by increasing the number of tractor hours available in peak seasons. The reason for these results is that when the fodder crops and livestock achieved their maximum, the only profitable activity to compete for the increasing water and machinery hours is the malting barley crop.

13.8. Control of Farm Activities

The most important limitations of controlled and constrained activities which appear to offer opportunities for correction are listed here. The basic model contains controlled and constrained activities that represent direct government intervention in the form of hectareage and livestock controls. The primary concern is, of course, the government's programme that wheat and dairy products be two main parts of the farm's pattern of activities. When poultry and wheat activities are constrained by the availability of building capacity and government intervention in the form of hectareage controls respectively, the degree of dairy cattle and malting barley specialisation tends to be exaggerated in the models used. If the formulation of the models require the dairy cattle and the malting barley producing activities to compete on the same basis with all the other farm activities (e.g. within fully relaxed constraints), substantial changes within the farm activities are to be expected.

13.9. Prices Used

The lack of further details on miscellaneous variable costs, and accurate data of price subsidisation in both input costs and crop and livestock product prices, might be an important limiting factor for the actual levels of economic price effects on the resulting solutions. Current prices received for produced goods, or paid for purchased inputs, have been used as the average prices for (i) controlled and (ii) non-controlled activities and hence are the basis for the calculation of financial returns. (i) Limiting the capability of the farm to respond to domestic incentives further reduces financial returns, but may increase social benefits. While under (ii) circumstances, poultry was the only recommended activity for the farm plan. However, in using the world market prices as alternative price weights in the objective function, the optimum farm plan shifted radically in the fully relaxed model. Of course, these prices differ significantly for both outputs and inputs and, at least in the absence of farm building capacity and institutional constraints, can be expected to produce both different cropping and livestock patterns when net revenues are maximised.

13.10. Other Data Used

Only the most important limitations of a general character, and which appear to offer opportunities for correction, are listed here. With respect to input-output functions, available data do not cover a sufficient range of variables; interdependency among variables is seldom measured; and seldom do available technical data lend themselves to ready extrapolation to conditions other than those under which the observations were obtained. There is insufficient knowledge, both quantitative and qualitative, of the stock of resources and their distribution among decision making units.

As indicated earlier in this chapter, there is a considerable discrepancy between actual ratios of dairy cattle replacements and the replacement combinations in the programmed models. Replacement ratios of dairy cattle production for the models used should be nearly identical to the actual 1979-1983 average ratios. Comparison between the coefficients (in the input-output matrix) used to estimate the standard "animal group unit" consumption requirements and that obtained for the actual 1979-1983 average ratios of animal class combination, might reveal an inconsistency between the resulting requirements. If there is such an inconsistency, adjustments to the basic model would have been required to satisfy the actual levels of dairy cattle consumption specified.

In the data used five possible sources of bias exist for input coefficients. Two result from the estimating of the feed nutrient contents required per unit of livestock and supplied per various fodder crops. First, nutrient content requirements per unit of livestock were calculated in standard forms corresponding to each component of the animal group unit. Second, since nutrient contents supplied by fodder crops, feed grains and hay, were calculated on the basis of all producing areas in Iraq, the implied ratios of nutrient contents in fodders and grains produced in a given region would change as the composition of these crop aggregates differs from one region to another. If nutrient contents were calculated according to the actual positions of the farm, it might have resulted in certain changes in the optimum combination of the farm's pattern of production.

A third and fourth source of bias in input coefficients which may have slight effects on the optimum organisation of the farm, relate to the choice of the standard requirements of water for irrigation and labour, respectively. These requirements were quoted from previous studies and therefore adopted according to the farm circumstances. Unfortunately, the data for establishing a reliable "standard" for water for irrigation and labour requirements are sadly limited, at least at the moment. Finally, in estimating the input-output coefficients, most data used are calculated on the basis of a six years average, and this could be considered as a fifth source of bias.

13.11. Conclusions

The above limitations exist to some degree for any model of the type used in this study. The merit of a model of the type used in this research, compared with previous studies, is that it incorporates the optimal mix of livestock production activities and ration components simultaneously. Additionally, in contrast to previous studies, the present analysis considers the production of cash crops within the framework of producing livestock. The analysis takes full account of the interpretations of shadow prices, the use of alternative world price weights, and the introduction of crop rotation for the largest number of the farm crops activities.

In this study "organisation" is taken as being concerned with over-all policy decisions involving the size and combination of enterprises and the allocation of resources. "Management" is taken as being concerned with the execution of the plan, the supervision of labour, and the day-to-day technical decisions involved in the timing of operations in crop production and in the tending of livestock, etc.. However, the results have greater meaning with respect to farm production capacity and the adjustments made for the succeeding models (as indicated by activity levels and their shadow prices), than for exact specifications of adjustments for the individual farm activities.

Since the value of programming in practice will depend on the amount of accurate input-output data on the particular farm, the power of the present models is diminished by lack of certain accurate data, as discussed above. This is an indication of the need to devote more resources to the accumulation of such data, not of the futility of using the technique. Such data, furthermore, will be vital to any form of detailed farm planning. The greatest difficulties are likely to arise in the preparation of the activity data. The need for this to be consistent if valid results are to be obtained has already been stressed.

While corrections for some of the limitations and the biases mentioned might result in slightly higher shadow prices, other biases mentioned could result in lower shadow prices. Therefore, in further work, it is worthwhile including refinements significantly to reduce limitations of the data and of specific models.

CHAPTER 14

IMPLICATIONS

14.1. General

Although the results of this study are not novel with regards to the use of linear programming as a farm management tool, they do suggest something of practical value in the potential uses of the linear programming technique for the planning of an individual Iraqi state farm. While it is not likely that at present linear programming will be widely used in farm planning at the farm level in Iraq, it may be that it will have an important role to play in basic farm management work in the Agricultural Establishments and State Farms, particularly when electronic computing facilities become available and more resources are devoted to the collection of the necessary data.

With regard to the Al-Nahrawan state farm's situation and capacity, a fairly wide range of alternative farm organisations appears to be acceptable by the net return criterion. This could mean that a more detailed model might provide an optimum solution within this acceptable range of profitability, considering the planner's ability to construct the appropriate detailed model and accurately determine the structural coefficients of the detailed model.

Using this type of programming model, the farm planner could certainly determine at least an acceptable solution for the inherent farm situation. The programming procedure permits a number of variations in the solution to be determined within a very short period of time, which would provide the manager with a package of solutions for evaluation. This would permit him quantitatively to evaluate his preferences.

14.2. Necessary Changes in Agricultural Prices

The Iraqi government intervenes directly in the agricultural sector by having both administrative and business functions, setting hectareage targets, procuring commodities, selling subsidised inputs and announcing prices for agricultural products. The Iraqi price structure does not seem to be based on an in-depth cost analysis. Production prices are fixed according to social rather than economic requirements. In fact, added pressure has been exerted on the farm decision-maker in Iraq, especially at the individual farm level, since the major activities produced by the state farms are under governmental supply control regulations which are constantly revised. For example, two major crops (wheat and malting barley) are under rigid governmental supply control programmes. More recently chicken, a product of rapidly increasing importance to Iraqi agriculture, has been placed under the price support programme.

It is probably impossible to predict with certainty how the overall Iraqi state farms will actually respond to price changes. But where it can be assumed that state farms will tend to maximise their incomes then, by computing a series of maximum profit positions for a range of product and/or input prices, some light may be thrown on the possible magnitudes of output and/or factor changes which price changes will induce.

The constrained solutions of the models used suggest that the cropping patterns and animal stock mix observed during the past several years reflect roughly the government's plans, while they clearly depart substantially from those that would have obtained if a fully relaxed model had been the only guide to resource allocation. The assumption that government policy has pushed production patterns towards a socially desirable allocation of resources injects a note of caution into projections of agricultural growth that rely on improvements in static efficiency.

The results of the models also underline the complexity of Iraqi agriculture and the importance of indirect effects on resource allocation created by the existing price policy. Accordingly, Iraqi farms will not use resources at their peak potential efficiency. The scale of any farm and the output which maximises the farm profits are not necessarily the optimum scale of the farm or the optimum rate of output of the scale of the farm which can be built. Moreover, the results indicate that it may be possible to change the economic climate in which the Iraqi farms make their decisions, if the current prices can be adjusted to respond in the farms' favour and also satisfy the government requirements. Economic incentives and an increase in the required product prices, or lower-cost inputs, are needed. Undoubtedly, at the beginning due to a shortage of accurate data and research, there will be some difficulties in implementing such a policy in Iraq.

We are in a position now to discuss pricing and output under Iraqi conditions. In the following discussions, detailed comparisons of various runs with current and world price weights, with the possibility of introducing "bought-in concentrate feed" activity into the farm plan, are presented. Such comparisons are the primary methodology for examining the links between the Iraqi agricultural price policy and the allocation of the country's domestic resources. A measure of the effects of Iraqi agricultural price policy on the Al-Nahrawan State Farm income is presented in Table 14.1, where the net revenues and the activity levels under alternative price assumptions (alternative prices prevail in both input and output markets) are compared.

Table 14.1. Net Revenues and Activity Levels Compared

	Da I.D	Db U.S.$	Ba I.D	Bb U.S.$	Ca I.D	Cb U.S.$
Green feed barley	-	-	-	27	-	37
Malting barley	-	677	1825	773	1550	505
Grain barley	-	-	-	-	-	-
Winter alfalfa	-	530	238	513	244	519
Mixed crop	-	-	333	-	323	-
Clover	-	481	39	502	52	495
Wheat	-	-	-	-	250	250
Maize	-	-	333	-	323	-
Sorghum	-	481	39	502	52	495
Summer alfalfa	-	530	238	513	244	519
Dairy cattle	-	543	500	500	500	500
Laying hens	8039	2253	480	480	480	480
Sheep	-	-	5933	2989	5888	3115
Bought-in foodstuffs	-	-	3920	-	3844	-
Objective function	2078030	1490186	915324	1407599	894161	1395799

So far LP has been used as a method for indicating ways of testing the effects of using alternative prices and governmental control on some outputs. It remains now to give an indication of how the state farming system in general may respond to price change which could serve as a useful basis of policy formation. It is extremely useful for the government to know how state farms can react economically to change in the price of their inputs and products, by assuming the absence of constrained outputs.

As previously discussed in Chapter 11, Solutions Da and Db maximise net revenue on the farm where crop and livestock may be freely selected. The divergence between the "current" and the "world" weights of net revenues is large, as are the patterns of production. It can be seen from solution Da (Table 14.1) that laying hens dominates other enterprises, and therefore constitutes the whole income of the enterprise. Based on the interpretation of the resulting value of shadow prices and range analysis, poultry would have to drop about I.D.10.2 (or 30.9%) in price before other enterprises could compete. Alternatively, a rise of about I.D.378.2 (30.4%) in the price of dairy cattle would have also changed the picture. The absolute values and the percentage changes needed in the values stated in the objective function, per each unit of the marketing activities, are given in Table 14.2. However, with regard to world prices, solution Db alters the farm plan substantially, as shown in Table 14.1.

Table 14.2. **Opportunity Cost Value and Percentage Changes Needed for the Excluded Activity.**

Activity	Values in the Obj. Function	Opportunity Cost Values	% Changes
Malting Barley	152.288	6.260	4.1
Wheat	71.928	103.160	143.4
Dairy cattle	1259.000	378.200	30.4
Sheep	19.915	5.245	26.1

Based on the resulting solutions, and in the absence of studies of national shadow prices and a well developed income-subsidisation system in Iraq, the government should subsidise dairy cattle and cash-crops productions and remove its support for poultry production. Subsidisation policy on such activities is relatively easy to control, particularly when these products are grown, raised and marketed through a centrally planned system. The problem then facing the government is the most suitable rate of subsidisation to impose. It wants to increase agricultural output without affecting too much the provided level of agricultural commodities prices.

The value of shadow prices given in Table 14.2 opposite each activity can be used to approximate the rate of wage subsidy. As such, it is somewhat unrealistic, but it serves the purpose of highlighting the direction which must be followed. The rate of wage subsidies depends on the form of the wage subsidies and the structure of the economy. Undoubtedly, there will be some rate of subsidisation at which the size and output of the agricultural section being subsidised will be adversely affected.

The two runs Ba and Bb introduce additional constraints into the models, reflecting direct dairy and poultry product controls in the form of building capacities. Limiting the capability of the farm to respond to domestic incentives further reduces the farm returns, but also further diversifies the pattern of product mix. According to these two solutions, sheep rearing was recommended as a relatively important activity for the Al-Nahrawan State Farm. Unfortunately, this finding goes against government policy, which implies that sheep production should be excluded from state agricultural establishments. However, the primary reason for achieving such solutions is the present capacity of the farm buildings and parlours.

Solutions Ca and Cb introduces additional constraints into the models used; these simulate direct government intervention in the form of hectareage controls. Therefore, when wheat is part of the cropping pattern it results in I.D.21,163 losses and very small changes in the level of the farm activities as shown in Solution Ca (Table 14.1), since wheat net revenue should rise at least I.D.84.65 (or 117.7%) to enter the solution. Similarly, in Solution Cb wheat results in U.S.$4,953 losses and also very small changes in the level of the farm activities, since wheat net revenue should rise at least $19.81 (or 13.8%) to enter the solution.

Although the two pairs of constrained solutions (Ba:Bb and Ca:Cb) do not result in substantially different patterns of production, they show significant differences between the effect of using current and alternative world price weights. As shown in Table 14.1, the levels of the included crop activities in the "world price" solutions are different from those obtained from the use of the current prices. The first observation in this comparison is the reasonable level of malting barley area in the "world price" solutions as compared with the exaggerated level of this activity when using the current prices. The second observation is the exclusion of some fodder crop (mixed crop and maize) and concentrate bought-in feed. The third observation is that if the farm were allowed to raise such a size of sheep herd, at current prices the sheep herd would be about half the size it would be at world prices.

14.3. The Distributive Effects of Governmental Control Programmes and Price Policies

Bringing together and comparing the previously mentioned solutions emphasises the role that comprehensive government planning can play in minimising the static efficiency losses of price distortions. By comparing the fully relaxed models as shown in Table 14.1, solutions Da and Db show that the ignoring of building capacities and government acreage requirements results in an unexpected specialised poultry farm, while using world prices results in a reasonable farm organisation. By imposing constraint requirements on activities that have a low return, the farm is forced into a pattern of production which is detrimental to its own net revenue but might be favourable to the government. Hence, if the Iraqi state farms seek to maximise their profits competitively with respect to the given set of present prices for goods and factors of production, the resulting configuration of inputs and outputs will be socially inefficient. By imposing governmental control programmes one may establish the fundamental interrelationships between the welfare concept of efficiency and the planned system of the Iraqi economy. Social efficiency is assumed to be maintained under such a regime and agricultural surpluses/losses are transferred to the government. However, under a complete scheme of socialist sector management, individual investment of the surplus is not regarded as a significant source of growth since the latter is the responsibility of the socialist sector. Should the latter link fail to materialise, the ultimate stagnation of the sector is to be expected.

However, these solutions provide a rough approximation of the magnitude of the distributive effect of government price policies. Even if the farm manager were free to respond fully to domestic incentives, net revenues would still be less than they could be if the farm were producing under a regime of world market prices, or if it was able to respond to the implied allocation of domestic resources.

Thus the price level effects might even be as large as the planning technique effects. The implication of this is that adoption of efficient planning techniques will be highly sensitive to price levels. A comparison of the solutions obtained shows that the introduction of government hectareage and livestock requirements reduces the financial revenue of the farm, while the introduction of world prices in a fully relaxed model shifts the farm plan and increases revenue substantially.

Having presented the major aspects of the existing situation with the Iraqi price structure (subject to the constrained outputs), we now return to the conclusions regarding the overall situation. Although the analysis in this thesis can be used to give an indication of the problems of simultaneous control of prices and quantities for the overall state planning system in Iraq, it cannot yield the expected result since the Iraqi state farms are all undeveloped and insufficient time has elapsed and too few studies have been undertaken to allow the full exploitation of expansion opportunities. This may explain why the existing state farms exhibit a great deal of dissatisfaction and some disappointment. The most important implication for the overall state planning system in Iraq is that, as long as government control of prices and quantities programme applies, it will pay the farms to produce some outputs even though prices are not economically competitive. But as soon as the price system has become fully developed, then the response of existing farms will appear. However, the price policy should aim at stimulating agricultural production and help orient it towards stated objectives. The price policy of agricultural products would have to be part of a price policy package comprising and linking prices of agricultural products to the prices of goods purchased by the agricultural sectors. In order to reduce the country's imports of many agricultural commodities and ensure the required level of supply of certain agricultural products, the Iraqi authorities should first establish an effective set of agricultural prices which stimulate agricultural production and satisfy a competitive equilibrium in the agricultural sector.

14.4. Cropping Pattern

The cropping patterns in the solutions obtained highlight the economic interpretations of the models. In the first place they indicate that it does not pay to grow green feed and grain barley for feeding on the farm. The basic solutions includes a government wheat constraint. Had this been omitted, wheat would have disappeared from the cropping pattern entirely.

The relatively low cropping intensity of the solutions obtained illustrates again the role of indirect effects. Most models are oriented heavily towards malting barley. As shown in Table 14.1, if international prices determine the farm decisions (see solution Bb), malting barley area would be much less than it would be if current prices are used, but maize and mixed crop would be excluded from the solution. The malting barley area is achieved mainly at the expense of the grain and green fodder barley areas that shrink from 518.25 hectares in the present farm plan to 27 hectares in the optimum solutions. Moreover, the returns for malting barley virtually eliminate wheat.

However, in the solutions obtained the area in fodder crops is reduced from 2,978.50 hectares in the present farm plan to 1,220 hectares and 1,238 hectares in the Ba and Ca solutions, respectively.

In terms of maximising returns at current prices (in a constrained model), there are obviously a number of arguments that might be raised against the resulting cropping pattern. First, large areas of malting barley would upset agronomists who are inflexible about the need to maintain a rotation that would ensure soil replenishment after barley. The standard is a two-year rotation, on especially fertile land, that includes malting barley every second year. The 40.3 percent acreage in barley implies that about 50 per cent of barley areas would grow barley twice every three years. In a number of the less fertile areas, there are undoubtedly sound agro-economic reasons for not making that the norm.

14.5. Necessary Developments in Agricultural Data

A programming service utilising these type of models would require the services of professional farm management specialists who were quite familiar with the individual farms' situation, and this could become costly. The costs for such a service could be minimised by developing a set of structured models and establishing a data base of enterprise coefficients for typical farm resource situations, which could be tailored to the individual farm situations. The Committee for State Farm Development Programme could contribute materially to such a data base, if sufficient attention is directed to recording data as provided for within the programme. This would greatly reduce the specialist time requirement for structuring the planning model to be used. Used in this manner, this type of service could greatly enhance the effectiveness of the management specialist in assisting the farmer with his planning problems.

However, the solutions determined by this study (which were based on "average" performance data) suggest a potential direct use for this type of programming procedure in individual farm planning.

A well defined set of "reference point" resource situations could be established for different systems of farming, and used as a basis for developing a sound data base. However this would require considerable stratification on the basis of soil type, level of technology, and enterprise production opportunities. The reference point situations could be programmed individually and a range of alternative farm organisations determined from variations in the resource constraints and the production opportunities. This would provide the farm planner with increased knowledge regarding the factors that affect farm organisation and the kind of effects the factors have on a particular choice, and thereby increase his effectiveness in determining which alternatives to consider in a programming analysis for a particular farm situation.

Additionally, as price relationships, production technology, or governmental regulations change, these reference point solutions could be updated readily at relatively low cost, to provide the farm planner with a sound basis for making recommendations for farm re-organisation. These same reference points could also be used very effectively to determine a set of profitable adjustment paths that farms with similar resource situations could follow.

This type of programming service could prove to be very expensive to organise, as not only would a sound data base of technical coefficients need to be established initially, but these would need to be updated as new technology became known. However, the cost could be reduced if the data could be obtained readily from the results of an effective, on-going farm business records and analysis programme, such as the General Establishment for Agricultural Projects and The Committee for State Farm Development Programmes. This would require effective coordination between the farm management researcher and the farm management extension specialist, with the former having the role of determining what technical coefficients are needed, and in what form. The latter's role would be that of educating the farm managers to maintain appropriate farm business records and assisting them to make sound operational and organisational decisions. Although this endeavor might prove to have a high cost, even with a farm business records programme supplying most of the data for the "filing store", it could be justified if emphasis is to be placed on providing farmers with the most intensive assistance possible in making economically sound management decisions.

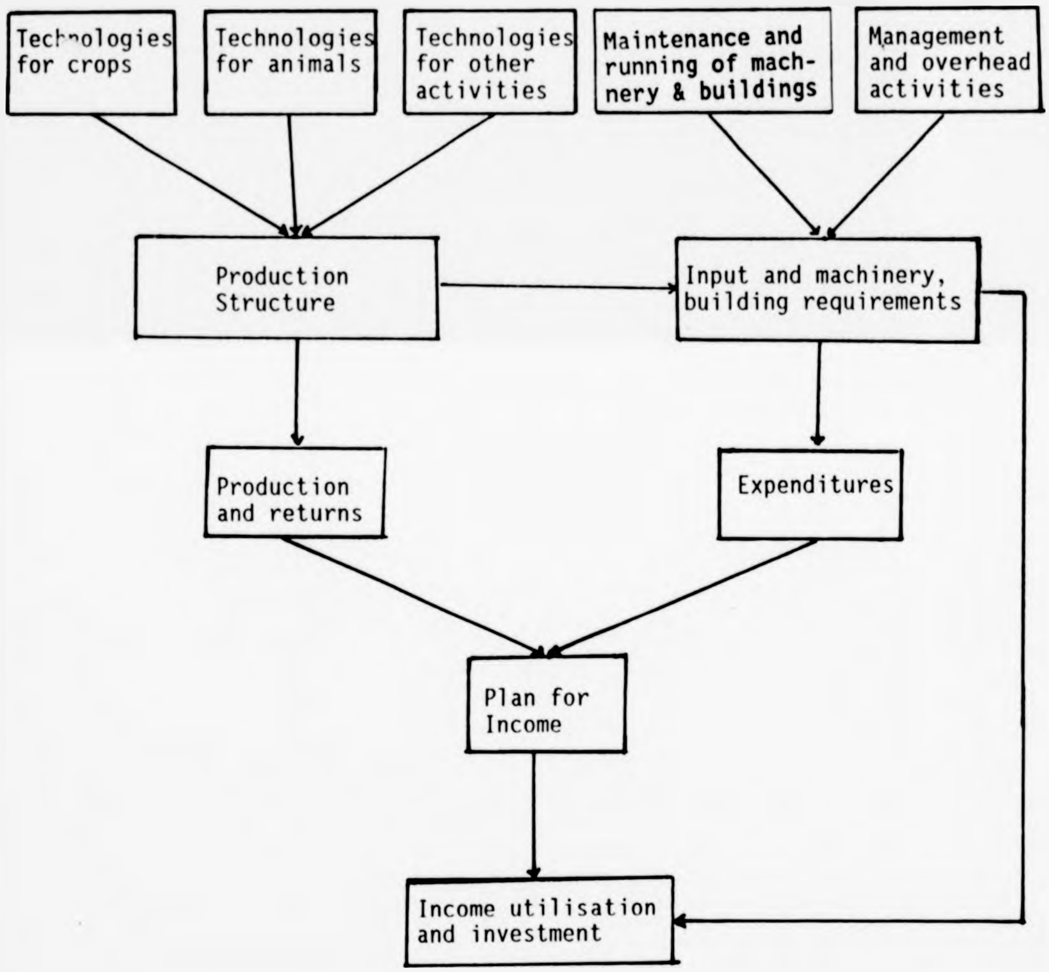
14.6. Necessary Development of the Planning Methods

Regarding the core of this study, a proposed development of the planning methods in the state farming sector in Iraq is devoted to more specific details of the major planning elements. Plans at the farm level constitute the means by which national and regional objectives are translated into directives. These objectives are therefore of crucial importance to the development of this sector and deserve much attention. There should be no more than four or five compulsory plan targets for one organisation. On the basis of these targets, the state farms should have full authority to develop their detailed farm plans. State farms need medium-term (e.g. five-year), annual and operating plans. The medium-term plans determine the major objectives and orientation of the state farming system and of the state farming sector. The annual plans set definite production targets and comprise total investment and input requirements, calculated on the basis of the production capacity of the state farms given the specific prevailing economic conditions within the state farms as well as outside. The realistic planning of annual operations is the only way to evaluate management efficiency and to operate a system of incentives for better management and higher achievement. It is evident that annual plans at the farm level should be more detailed and comprehensive than they are at present in Iraq. For a more accurate method of annual planning, the following improvements are required (see also Figure 14.1).

The formulation of detailed plans for production technologies: these should be prepared for every crop and animal type according to variety and species; soil conditions and building types; yield or output levels; patterns of product utilisation; major characteristics of production technologies.

The technology filing system for a unit of crop area or livestock should include: a description of the schedule of operations for the specific production process; methods used for implementing the operation within a time-table; physical input requirements for the operation; machinery and its combinations as planned for use in the various operations; indicative unit machinery requirements and outputs; manual labour requirements of the various operations; weekly or monthly total machinery and manual labour requirements; total expenditures and returns as well as planned unit costs of products excluding overhead and management expenditures.

Figure 14.1. Structure of a Proposed Annual Planning System for Iraqi State Farms



The availability of standards on expected machinery and labour performance in various operations is an essential condition for planning detailed technologies. For each product or crop, a continuous updating technology filing system should be developed depending on the differences among objectives and conditions. Irrigation operations should be planned partly in connection with crop production operations and as an independent set of activities (e.g. running and maintenance of major irrigation work). The determination of product mix is one of the most complex problems of decision-making, requiring an analysis of the production potential of the farm, the actual input-output relations in the various branches of production, together with a study of market and price conditions. Non-agricultural production and food processing and service activities should be planned in the same amount of detail as crop production and animal husbandry.

Physical and labour inputs as well as overhead expenditures must also be included in the plan, to cover expected machinery and labour requirements and cost.

Based on a detailed description of individual production and other activities, the collective input, machinery and labour requirements are summarised at farm level according to short periods (one week or a month). Total needs are then compared with available resources to determine the level of resource utilisation as well as new investment requirements. For this purpose, the use of balance sheets is required.

Cost projections should include all expenditures relating to farming activities in a given year. Cost calculations should be based on the unit direct cost projections spelled out on the technology filing system. When totalling expenditures, the depreciation of fixed assets should be taken into account. It is suggested that expenditures be grouped by major category (e.g. total materials, fertilisers, labour).

The planning of returns requires the projection of the total amount of outputs in physical measurements (yields, service). This step may also be completed using the information on the technology filing system. By using the expected price, returns in value terms may be calculated. The total value of production and services should be calculated considering not only cash returns but also inventories and intermediate products used at the farm.

The planning of farm income is an easy task if detailed projections of production value and expenditures are available. The allocation of earned income will present decision-making problems at the farms if the present system of financing is revised, i.e. when the allocation of earned income (at least in part) comes under the authority of the farm manager.

Major investment decisions have to be made on the basis of annual plans. Investment and replacement decisions, and the financial responsibility for these decisions, should come under the authority of the state farm managers. Annual planning should include a methodology for preparing such decisions and for undertaking the detailed calculations of both investment needs and financing possibilities.

State farm organisation also requires the elaboration of operation plans. These should consist of detailed organisational schedules for each operation having primary importance on the farm and for peak periods of work, when the scheduling of machinery use and the organisation of manual labour require special attention for the execution of all operations within an optimal period. Operation plans are extremely useful in many respects, such as organising the harvest of the main crops; utilisation of irrigation facilities (especially in the main irrigation season); and the organisation of the major ploughing and planting operations.

The quality of the operation plans drawn up at farm level will depend critically on the skills and knowledge of the people who formulate them, and on available data. Therefore, any improvement of the planning system should be combined with the intensive training of agricultural planners as a high priority. It is also necessary to develop a solid data base (as mentioned earlier in this chapter); i.e. a system of performance standards. In addition, information on the impact of new technologies on input requirements, prices, new inputs and machinery, et cetera, should be made available.

To be effective, plans at the farm level must be reliable and acceptable to both managers and farm workers. Moreover, flexibility in the preparation of farm plans should be considered.

Finally, it should be emphasised here that these proposed planning methods are extremely important (by far the most important limitation to farm planning at present is the inadequacy of the basic input-output data). It does not contain anything very new but it may be of practical value and will have an important role to play in basic farm management work in the state farming sector in Iraq, particularly when the expected electronic computing facilities become available.

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Appendix 1

H01AFF - NAG FORTRAN Library Routine Document

1. Introduction

This appendix describes the FORTRAN programme used to solve the original linear programming problem via the simplex method. The routine uses integer arithmetic throughout. The NAG Library subroutine (H01AFF) handles linear inequality constraints. The method used by the routine is described in GILL,P.E.and MURRAY,W., Numerical Methods for Constrained Optimisation, Accademic Press, 1974 (Chapter 4). The method is described in the NAG FORTRAN Library Manual, Mark 11, volume 6 (H01AFF):

> "It proceeds iteratively by minimising a series of objective functions formed from the coefficients of the violated constraints. Each iteration defines a search direction vector by projecting the steepest-descent vector along the active constraint, which is then added to the active set. Once the active set has its full complement of N active constraints, the sequence of points generated is the same as that obtained using the revised simplex method; each iteration begins with the testing of the Lagrangean multipliers for all the active inequality constraints, and moves off from the constraint with the negative multiplier of largest modulus. The objective function is redefined at the end of each iteration, and the algorithm terminates as soon as feasibility has been achieved." [p.1]

Since the problem of maximising F(x) is equivalent to the problem of minimising -F(x), I multiplied the values stated in the objective function by -1 to obtain the required maximisation solutions.

As we shall see in this appendix, the routine outputs information about the course of computation, and also the final results.

2. The Programme Used:

The following programme is applicable to problems of finding a vertex $X = (X_1, X_2, \ldots, X_{13})$ which satisfies 13 simple lower and upper bounds and 27 general linear constraints. Explanatory interpretations about the computational procedure are provided bellow. The programme outputs the value of the objective function, the activity levels, the constraints currently in the active set, the residuals of all the constraints and the Lagrange multiplier for excluded activities and exhausted resources as we shall see in section 4.

```
      DOUBLE PRECISION F,UMIN,YMOD
      INTEGER I,IBOUND,IFAIL,INITPT,J,LAGC,LB,LCON,LEL,
     1LIW,LNGC,LQT,LW,MAXIT,MSGLVL,N,NA,NGC1,NGC,NGCN
      LOGICAL VERTEX
      DOUBLE PRECISION AGC(16,27),BL(40),BU(40),C(13),
     1EL(91),QT(16,13),R(80),U(13),W(306),X(13)
      INTEGER INDEX(80),ISTATE(27),IW(53)
      N=13
      NGC=27
      LAGC=16
      IBOUND=0
      DO 20 I=1,NGC
      READ(5,*)ISTATE(I),BL(I),(AGC(J,I),J=1,N),BU(I)
      WRITE(2,*)I
   20 CONTINUE
      NGC1=NGC+1
      NGCN=NGC+N
      DO 40 J=NGC1,NGCN
      READ(5,*)BL(J),BU(J)
      WRITE(2,*)J
   40 CONTINUE
      LB=40
      LNGC=27
      INITPT=3
      MSGLVL=5002
      MAXIT=20*N
      READ(5,*)(C(J),J=1,N)
      VERTEX=.TRUE.
      LCON=80
      LEL=91
      LQT=16
      LIW=53
      LW=306
      (continued)
```

(continued)

```
      CALL X04ABF(1,4)
      IFAIL=110
      CALL H01BAF(N,NGC,AGC,LAGC,IBOUND,BL,BU,LB,ISTATE,
     1LNGC,INITPT,MSGLVL,MAXIT,C,VERTEX,X,F,YMOD,NA,
     2UMIN,R,U,INDEX,LCON,EL,LEL,QT,LQT,IW,LIW,W,LW,IFAIL)
      STOP
      END
```

Where:

2.1. Input (and associated dimension) Parameters

N specifies the number of independent variables.

NGC specifies the number of general linear constraints.

AGC is a real array of DIMENSION (LAGC, P)

where P ≥ max (NGC, 1); LAGC > N.

IBOUND = 0 specifies that the variables are bounded and the user will be supplying all the lower and upper bounds variables individually in BL and BU.

BL is a real array of DIMENSION at least (NGC+N). It holds the lower bounds of first the general constraints and then the simple bounds.

BU is a real array of DIMENSION at least (NGC+N). It holds the upper bounds of first the general constraints and then the simple bounds.

LB specifies the actual dimension of BL and BU as declared in the calling (sub)programme. LB≥ NGC+N.

ISTATE is an integer array of DIMENSION at least (NGC).

NGC specifies the second dimension of AGC and the dimension of ISTATE as declared in the calling (sub)programme. LNGC ≥max(NGC, 1).

INITPT specifies the point X from which the user would like to start. If he wishes H01AFF to find a feasible vertex with exactly N constraints active, INITPT should be set to 3 and VERTEX set to .TRUE..

MSGLVL specifies the amount of output required. The output will be sent to the unit determined by the NAG Library routine X04ABF. The users who wants a brief summary every other iteration but full details at the final printing should set MSGLVL to 5002.

MAXIT specifies the maximum number of iterations to be performed by H01AFF. 20 x N is a reasonable setting for MAXIT for most problems.

VERTEX specifies that the user wishes H01AFF to find a vertex with exactly N constraint active (VERTEX =.TRUE.).

2.2. Input/output Parameters

X is a real array of DIMENSION at least (N). On exit, X contains the final point X determined by H01AFF. Thus X(j) contains the j(th) component of the computed feasible point.

2.3. Output (and associated dimension) Parameters

This programme data represents the original Matrix (Table 8.2) as presented to the above programe (Explanatory comments in brackets () or **bold**).

NA gives the number of constraints currently in the active set.

R is a real array of DIMENSION at least (2 x (N+NGC)). On exit, R contains the residuals of all the constraints.

INDEX is an integer array of DIMENSION at least (2 x (N+NGC)). On exit, INDEX contains the ordering first of the NAG constraints in the active set and then of the rest.

LCON specifies the actual dimension of EL as declared in the calling (sub)programme. LEL$\geq$ N x (N+1)/2.

QT is a real array of DIMENSION (LQT, r), where r$\geq$ N. LQT$\geq$ N.

2.4. Workspace (and associated dimension) Parameters

IW is an integer array of DIMENSION (LIW). LIW $\geq$ 2 x N+NGC

W is a real array of DIMENSION (LW). LW $\geq$ 10 x N+7 x NGC.

2.5. Diagnostic Parameters

IFAIL controls the printing of error messages and monitoring information as well as specifying hard or soft failure.

3. Programme Data (HO1AFF ORIGINAL PROGRAMME DATA)

This programme data represents the original Matrix (Table 8.2) as presented to the above programme (Explanatory comments in brackets () or in **bold**).

Section I: General Linear Constraints (27 Constraints)

```
0,0,0,0,0,1,0,0,0,0,0,-1,0,0,0,0
1,0,3078,862.4,1773.252,4098.56,4215,3320,711.4,5730.32,8330,3073.92,
                                                       -15019,0,-379,100000
1,0,417.6,7,105.088,921.6,741,838.4,3.4,408.36,190.4,691.2,-2491,0,
                                                               -38.5,100000
1,0,5.4,7.8,2.928,38.4,24,41.6,2,13.28,81.2,28.8,-80.8,0,-2.1,100000
1,0,3.6,4.4,6.84,5.12,4.5,3.2,6.6,8.632,50.4,3.84,-61.6,0,-1.4,100000
2,0,1,1,1,1,1,1,1,0,0,0,0,0,0,3844
2,0,0,0,0,0,0,0,0,1,1,1,0,0,0,1687.5
2,0,900,828,828,900,592,520,828,0,0,0,1.86,0.93,0.465,3335904
2,0,1012,1220,1220,1012,852,764,1120,0,0,0,1.68,0.84,0.42,3942432
2,0,1352,1364,1364,3952,1340,1636,1364,0,0,0,1.86,0.93,0.465,3942432
2,0,1900,0,0,1900,1772,1976,1166,0,0,0,1.8,0.9,0.45,3942432
2,0,0,0,0,0,0,0,0,0,3220,3252,1.86,0.93,0.465,5054400
2,0,0,0,0,0,0,0,0,0,3840,4432,1.8,0.9,0.45,5256576
2,0,0,0,0,0,0,0,0,3180,4360,5580,1.86,0.93,0.465,5054400
2,0,0,0,0,0,0,0,0,1900,3900,5020,1.86,0.93,0.465,4650048
2,0,0,0,0,0,0,0,0,1764,2600,3700,1.8,0.9,0.45,5256576
2,0,0,0,0,0,0,794,0,1548,2600,2440,1.86,0.93,0.465,4447872
2,0,1452,972,972,4352,1152,784,1012,1240,0,0,1.8,0.9,0.45,3639168
2,0,1052,820,820,1052,420,1084,820,0,0,0,1.86,0.93,0.465,4094064
2,0,29.44,36.8,36.8,78.6,39.36,39.36,40.64,63,68.2,42.28,380,60,5.84,482328
2,0,2.428,2.428,2.428,2.428,2.428,2.428,2.428,2.428,2.428,0,0,0,0,8850
2,0,6.1,0,0,9.6,13.2,7,0,0,8.36,0,6,1,0.5,21300
2,0,6.1,2,2,0,6.6,7,2,0,7,9.6,6,1,0.5,23100
2,0,3.5,3.5,3.5,3.5,3.5,8.35,3.5,13.46,7,9.6,6,1,0.5,22200
2,0,4.89,4.89,4.89,4.89,4.85,7,4.89,0,8.6,4.8,6,1,0.5,21900
2,0,1.776,0,0,3.552,2.664,2.664,0,1.776,2.664,2.664,0,0,0,7080
2,0,0,1.28,1.28,0,0,0,1.28,0,0,0,0,0,0,2336
```

Section II: Simple Constraints (lower bounds and then upper bounds)

```
0,3219
375,3594
0,3219
0,1687.5
0,3219
0,3219
250,250
0,1687.5
0,1687.5
0,1687.5
0,500
0,480
0,758
```

Section III: Objective Function

```
78.5,-110.25,56,110,118.7,131,-29.46,106.7,115.3,77.3,-1158.7,-265,-16.5
```

Where:

(1) Column 1 (Section I) specifies that: 0= Equality Constraint; 1= Upper Bound Constraints; 2= Lower Bound Constraints.

(2) Column 2 (Section I) contains the Left-Hand-Side Constaints.

(3) Column 16 (Section I) contains the Right-Hand-Side Constraints.

(4) The other values in the body of section I specify the coefficients as stated in the original Matrix (Table 8.2).

4. Programme Results (final results only)

When running the above example, H01AFF has found a feasible vertex and the following typical results are obtained (constraint numbers are renumbered to coincide with their positions as presented in the programme data (section 1). (Explanatory comments in brackets () or in **bold**).

```
          OUTPUT FROM NAG LIBRARY ROUTINE H01BAF
          ------ ---- --- ------- ------- ------
PHASE 2, ITERATION     9


   13 CONSTRAINT(S) ACTIVE
      OBJECTIVE FUNCTION
     6.16528568695681D+05
VARIABLE        CURRENT SOLUTION
     1        0.00000000000000D+01
     2        1.23776247106840D+03
     3        0.00000000000000D+01
     4        7.71978572875096D+01
     5        1.05259944331083D+03
     6        1.19913449526866D+02
     7        2.50000000000000D+02       (Activity Level)
     8        4.34805725873495D+02
     9        2.80525570771393D+02
    10        7.71978572875096D+01
    11        5.00000000000000D+02
    12        4.80000000000000D+02
    13        5.68434188608080D-14
```

CONSTRAINT	RESIDUAL	TYPE	STATUS
1	-1.06581410364015D-14	EQUALITY	ACTIVE
2	3.95266970008437D+06	GENERAL L	INACTIVE
3	-2.35019115280011D-10	GENERAL L	ACTIVE
4	3.37459258100689D+04	GENERAL L	INACTIVE
5	-1.19030119094532D-11	GENERAL L	ACTIVE
6	1.10652677880640D+03	GENERAL U	INACTIVE
7	8.94970846067603D+02	GENERAL U	INACTIVE
8	1.34768833820263D+06	GENERAL U	INACTIVE
9	1.08456575258224D+06	GENERAL U	INACTIVE
10	1.39698386192322D-09	GENERAL U	ACTIVE
11	1.40076888134185D+06	GENERAL U	INACTIVE
12	3.89868383021713D+06	GENERAL U	INACTIVE
13	3.83588490473961D+06	GENERAL U	INACTIVE
14	2.01648585949471D+06	GENERAL U	INACTIVE
15	2.34095775124863D+06	GENERAL U	INACTIVE
16	3.47324814358975D+06	GENERAL U	INACTIVE
17	2.76047580163635D+06	GENERAL U	INACTIVE
18	2.32830643653870D-09	GENERAL U	ACTIVE
19	2.21943228237978D+06	GENERAL U	INACTIVE
20	1.05811951957038D+05	GENERAL U	INACTIVE
21	4.66590630688143D+02	GENERAL U	INACTIVE
22	1.09139364212751D-11	GENERAL U	ACTIVE
23	6.15314615996381D+03	GENERAL U	INACTIVE
24	7.27595761418343D-12	GENERAL U	ACTIVE
25	2.03977292398000D+03	GENERAL U	INACTIVE
26	1.95702868289489D+03	GENERAL U	INACTIVE
27	4.31664037032453D+02	GENERAL U	INACTIVE

LAGRANGE MULTIPLIERS HAVE BEEN COMPUTED

MINIMUM MULTIPLIER	MAXIMUM MULTIPLIER
1.91499589712948D+00	1.05855099687435D+03

ACTIVE CONSTRAINT	LAGRANGE MULTIPLIER	TYPE
M.O.C. for excluded activities		
1	6.31152094720743D+01	SIMPLE L B
3	1.27768679768950D+02	SIMPLE L B
13	1.91499589712948D+00	SIMPLE L B
M.V.P. for exhausted resources		
39*	2.59901215614515D+02	SIMPLE U B
3	1.05855099687435D+03	GENERAL L B
5	1.39930887376188D+02	GENERAL L B
38**	1.51790361273251D+02	SIMPLE U B
10	3.88044584591436D+02	GENERAL U B
18	4.92726372903203D+01	GENERAL U B
24	6.53279380600939D+01	GENERAL U B
22	4.52015114673512D+01	GENERAL U B

NORMAL EXIT.

------ END OF OUTPUT FROM H01BAF ------

* Poultry Accommodation capacity; ** Cow Buildings capacity.

Appendix 2

MULTI-PURPOSE OPTIMISATION SYSTEM (MPOS)

Post Optimality Analysis

This Appendix is based on the MPOS (Version 4) user's guide of the University of Manchester Regional Computer Center (UMRCC). MPOS is an integrated system of computer programmes to solve optimisation problems. The system has been collected together for running on a CDC 6000 series computer by the Vogelback Computing Center of the Northwestern University, Illinois. The system has been converted to run on the CDC 7600 by the UMRCC staff. MPOS problems are solved by specifying the appropriate objective function, constraints, and bounds. As many problems as desired may be input during a given run. Each problem is solved independently of the others. In this appendix a description of the standard input and the form of the output are provided.

The linear programming structure of the MPOS input can be illustrated with Model A (Chapter 10) as follows:

```
REGULAR
TITLE
LP DEMONSTRATION PROBLEM FOR MPOS V3
VARIABLES
X1 TO X14
MAXIMIZE
-78.5X1+110.25X2-56X3-110X4-118.7X5-131X6+29.46X7-106.7X8-115.3X9-
77.3X10+1158.7X11+265X12+16.5X13-52.2X14
CONSTRAINTS
X4-X10 .EQ. 0
X5-X8 .EQ. 0
X6-X9 .EQ. 0
3078X1+862.4X2+1773.25X3+4098.56X4+4215X5+3320X6+711.4X7+5730.3X8+8330X9
+3073.92X10-15019X11-379X13+690.9X14 .GT. 0
417.6X1+7X2+105.1X3+921.6X4+741X5+838.4X6+3.4X7+408.3X8+190.4X9+691.2X10
-2491X11-38.5X13+167X14 .GT. 0
```

(continued)

(continued)

```
5.4X1+7.8X2+2.93X3+38.4X4+24X5+41.6X6+2X7+13.28X8+81.2X9+28.8X10-80.8X11
-2.1X13+1.38X14 .GT. 0
3.6X1+4.4X2+6.84X3+5.1X4+4.5X5+3.2X6+6.6X7+8.63X8+50.4X9+3.84X10-61.6X11
-1.4X13+6.62X14 .GT. 0
X1+X2+X3+X4+X5+X6+X7 .LE. 3844
X8+X9+X10 .LE. 1687.5
900X1+828X2+828X3+900X4+592X5+520X6+828X7+1.86X11+0.93X12+0.465X13
.LE. 3335904
1012X1+1220X2+1220X3+1012X4+852X5+764X6+1120X7+1.68X11+0.84X12+0.42X13
 .LE. 3942432
1352X1+1364X2+1364X3+3952X4+1340X5+1636X6+1364X7+1.86X11+0.93X12+0.46X13
 .LE. 3942432
1900X1+1900X4+1772X5+1976X6+1166X7+1.8X11+0.9X12+0.45X13 .LE. 3942432
3220X9+3252X10+1.86X11+0.93X12+0.465X13 .LE. 5054400
3840X9+4432X10+1.8X11+0.9X12+0.45X13 .LE. 5256576
3180X8+4360X9+5580X10+1.86X11+0.93X12+0.465X13 .LE. 5054400
1900X8+3900X9+5020X10+1.86X11+0.93X12+0.465X13 .LE. 4650048
1764X8+2600X9+3700X10+1.8X11+0.9X12+0.45X13 .LE. 5256576
794X6+1548X8+2600X9+2440X10+1.86X11+0.93X12+0.465X13 .LE. 4447872
1452X1+972X2+972X3+4352X4+1152X5+784X6+1012X7+1240X8+1.8X11+0.9X12+0.45X13
 .LE. 3639168
1052X1+820X2+820X3+1052X4+420X5+1084X6+820X7+1.86X11+0.93X12+0.465X13
 .LE. 4094064
29.44X1+36.8X2+36.8X3+78.6X4+39.36X5+39.36X6+40.64X7+63X8+68.2X9+42.3X10
+380X11+60X12+5.84X13 .LE. 482328
2.428X1+2.428X2+2.428X3+2.428X4+2.428X5+2.428X6+2.428X7+2.428X8+2.428X9
 .LE. 8850
6.1X1+9.6X4+13.2X5+7X6+8.36X9+6X11+X12+0.5X13 .LE. 21300
6.1X1+2X2+2X3+6.6X5+7X6+2X7+7X9+9.6X10+6X11+X12+0.5X13 .LE. 23100
3.5X1+3.5X2+3.5X3+3.5X4+3.5X5+8.35X6+3.5X7+13.46X8+7X9+9.6X10+6X11+X12
+0.5X13 .LE. 22200
4.89X1+4.89X2+4.89X3+4.89X4+4.85X5+7X6+4.89X7+8.6X9+4.8X10+6X11+X12
+0.5X13 .LE. 21900
1.776X1+3.552X4+2.664X5+2.664X6+1.776X8+2.664X9+2.664X10 .LE. 7080
1.28X2+1.28X3+1.28X7 .LE. 2336
BOUNDS
X2 .GT. 375
X7 .GT. 250
X11 .LE. 500
X12 .LE. 480
PRINT
OPTIMIZE
GETFILE
MAXIMIZE
RNGRHS
RNGOBJ
OPTIMIZE
```

where:

.LE., $<$, or $\leq$ for less than or equal to,

.EQ. or $=$ for equality,

.GT., $>$, or $\geq$ for greater than or equal to.

REGULAR - regular simplex method.

VARIABLES - This keyword specifies that a variable list is to follow. It is used to name variables used in the problem. Variables are placed in the variable table in the order in which they are named.

MAXIMIZE - This command specifies that the objective function is to be maximised. The objective function specification follows this statement. This statement must precede the CONSTRAINTS statement. The objective function is input in the same format that one would write the equation algebraically. The coefficients of X1, X2, X3, X4, X5, X6, X7, X8, X9, X10, X11, X12, X13 and X14 are -78.5, +110.25, -56, -110, -118.7, -131, +29.46, 106.7, -115.3, +77.3, +1158.7, +265, +16.5 and -52.2 respectively.

CONSTRAINTS - This control phrase indicates that the constraint specifications are to follow. When GETFILE is used the CONSTRAINT statement is not required. The constraint specifications are used to specify the constraints for the problem. Like the objective function the constraints are written in the same format that one would write them algebraically. For example, in the last constraint, the coefficients of the variables X2, X3 and X7 are 1.28, 1.28 and 1.28 respectively. The Right-Hand-Side is 2336 The absence of a variable implies a coefficient of zero (blanks are ignored). Each constraint is terminated by a right-hand-side.

BOUNDS - The control phrase BOUNDS is used to indicate that the statements following define upper or lower bounds on the variables. This follow the CONSTRAINTS specifications. The bounds are specified with a variable name or variable list followed by an inequality relational (.LE., .GE., <, or >) and then a number.

PRINT - This command is used to indicate that only the initial and final tableaus are to be printed when the problem is being solved.

OPTIMIZE - The command OPTIMIZE is used to indicate the end of a problem and instructs MPOS to terminate the language processing and begin execution.

RNGOBJ - presence of the RNGOBJ command indicates that the objective function is to be ranged by the linear programming algorithms. RNGOBJ permits ranging the coefficients c_j of the objective function. Each coefficient corresponding to a <u>basic</u> decision variable is ranged, all other things being equal, while maintaining the same optimal basis.

RNGRHS - Presence of the command RNGRHS indicates that the right hand sides are to be ranged by the linear programming algorithms. RNGRHS permits ranging the coefficients b_i of the right-hand-side vector. Each coefficient corresponding to a <u>binding</u> constraint is ranged, all other things being equal, while maintaining the same optimal basis.

SUMMARY OF RESULTS

VAR NO	VAR NAME	ROW NO	STATUS	ACTIVITY LEVEL	OPPORTUNITY COST	LOWER BOUND	UPPER BOUND
1	X1	--	LB	0.0000000	59.5587537	0.0	INF
2	X2	--	B	1575.0000000	0.0000000	375.0	INF
3	X3	--	LB	0.0000000	137.7528700	0.0	INF
4	X4	--	B	235.4792052	0.0000000	0.0	INF
5	X5	--	B	315.9026664	0.0000000	0.0	INF
6	X6	--	B	58.1137396	0.0000000	0.0	INF
7	X7	--	LB	250.0000000	86.8193561	250.0	INF
8	X8	--	B	315.9026664	0.0000000	0.0	INF
9	X9	--	B	58.1137396	0.0000000	0.0	INF
10	X10	--	B	235.4792052	0.0000000	0.0	INF
11	X11	--	UB	500.0000000	288.9266846	0.0	500
12	X12	--	UB	480.0000000	260.5764730	0.0	480
13	X13	--	B	5995.9345725	0.0000000	0.0	INF
14	X14	--	B	3963.0734672	0.0000000	0.0	INF
15	ARTIF-- D-	1	LB	0.0000000	-115.2159597	0.0	INF
16	ARTIF-- D-	2	LB	0.0000000	13.3810647	0.0	INF
17	ARTIF-- D-	3	LB	0.0000000	-5.0132348	0.0	INF
18	SLACK-- D-	4	LB	0.0000000	-.0041651	0.0	INF
19	SLACK-- D-	5	LB	0.0000000	-.2891320	0.0	INF
20	SLACK-- D-	6	LB	0.0000000	-.7516463	0.0	INF
21	SLACK-- D-	7	B	4989.1204981	0.0000000	0.0	INF
22	SLACK-- D-	8	B	1409.5043888	0.0000000	0.0	INF
23	SLACK-- D-	9	B	1078.0043888	0.0000000	0.0	INF
24	SLACK-- D-	10	B	1391474.6825997	0.0000000	0.0	INF
25	SLACK-- D-	11	B	1185317.5829419	0.0000000	0.0	INF
26	SLACK-- D-	12	LB	0.0000000	.0765134	0.0	INF
27	SLACK-- D-	13	B	2524879.0651681	0.0000000	0.0	INF
28	SLACK-- D-	14	B	4097330.8734910	0.0000000	0.0	INF
29	SLACK-- D-	15	B	3985745.2317731	0.0000000	0.0	INF
30	SLACK-- D-	16	B	2478315.1413553	0.0000000	0.0	INF
31	SLACK-- D-	17	B	2636919.2295108	0.0000000	0.0	INF
32	SLACK-- D-	18	B	3672924.7435502	0.0000000	0.0	INF
33	SLACK-- D-	19	B	3182882.8698601	0.0000000	0.0	INF
34	SLACK-- D-	20	B	25231.9783071	0.0000000	0.0	INF
35	SLACK-- D-	21	B	2150000.9528989	0.0000000	0.0	INF
36	SLACK-- D-	22	B	93335.7954181	0.0000000	0.0	INF
37	SLACK-- D-	23	B	2030.9328221	0.0000000	0.0	INF
38	SLACK-- D-	24	B	7498.8901067	0.0000000	0.0	INF
39	SLACK-- D-	25	B	7812.8823908	0.0000000	0.0	INF
40	SLACK-- D-	26	LB	0.0000000	4.3523695	0.0	INF
41	SLACK-- D-	27	B	1777.2869452	0.0000000	0.0	INF
42	SLACK-- D-	28	B	3904.0234168	0.0000000	0.0	INF
43	SLACK-- D-	29	LB	0.0000000	1.6649952	0.0	INF

MAXIMUM VALUE OF THE OBJECTIVE FUNCTION = 649996.105240

RNGOBJ

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(OPTIMALITY RANGE FOR COST COEFFICIENTS)
BASIC VARIABLES ONLY

CJ	XIN	MIN CJ ------- Z-LOWER	ORIGINAL CJ ----------- Z	MAX CJ ------- Z-UPPER	XIN
4	18	-255.47 .61574E+06	-110.00 .65000E+06	-103.88 .65144E+06	43
5	20	-165.22 .63530E+06	-118.70 .65000E+06	-110.87 .65247E+06	43
6	43	-140.28 .64946E+06	-131.00 .65000E+06	-79.962 .65296E+06	20
9	43	-124.58 .64946E+06	-115.30 .65000E+06	-64.262 .65296E+06	20
13	43	16.005 .64703E+06	16.500 .65000E+06	23.184 .69007E+06	20
10	18	-222.77 .61574E+06	-77.300 .65000E+06	-71.185 .65144E+06	43
2	43	108.12 .64664E+06	110.25 .65000E+06	*INF*	
14	43	-52.646 .64823E+06	-52.200 .65000E+06	-37.880 .70675E+06	20
8	20	-153.22 .63530E+06	-106.70 .65000E+06	-98.866 .65247E+06	43

RNGRHS

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(OPTIMALITY RANGE FOR RIGHT-HAND-SIDE CONSTANTS)
NON-SLACK RESOURCES ONLY

BI	XOUT	MIN BI ------- Z-LOWER	ORIGINAL BI ----------- Z	MAX BI ------- Z-UPPER	XOUT
12	41	.32852E+07 .59971E+06	.39424E+07 .65000E+06	.39595E+07 .65130E+06	34
26	6	19189. .63689E+06	222200. .65000E+06	24404. .65959E+06	41
29	34	2304.1 .64994E+06	2336.0 .65000E+06	2719.6 .65063E+06	41