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WHOLE FARM PLANNING
FOR A LARGE SCALE SHEEP AND BEEF CATTLE FARM
"A CASE STUDY"

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ABSTRACT

The use of pasture by grazing animals is the basis of New Zealand pastoral agriculture. Therefore, a major part of the management of pastoral-based farms concerns decisions about the allocation of feed to livestock.

The aims of this study were first, to develop a linear programming (LP) model for the case study farm. Secondly, to use this model to determine optimal farm plans and associated information. Thirdly, to evaluate the technique as to its suitability as an aid to farm planning.

The LP model developed in this study was built to investigate alternative means of increasing farm profitability for Limestone Downs, a large sheep and beef cattle property situated on Raglan County. The model allows pasture to be used by grazing animals in 12 periods throughout the year, subject to maximum and minimum constraints on pasture cover which have the effect of limiting the amount of feed that can be transferred from one period to the next. Supplementary feed activities within the model include hay and nitrogen.

The animal production activities considered by the model were: (1) a breeding sheep system producing meat and wool; (2) a beef cattle system comprising breeding and finishing stock; and (3) a bull beef system.

The model was used to optimise farm surplus (\$/farm).

The results demonstrated that farm profitability could be substantially increased in direct proportion to the rate at which bull beef substitutes for, firstly sheep, and secondly breeding and finishing cattle.

However, to attain higher profits, current management constraints, in particular the maximum number of Friesian bulls and/or the minimum number of breeding ewes on the property will have to be overcome. Investigation of these issues as well as the effect of climatic variability on the various plans derived are clearly identified as areas requiring further study and consideration.

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Chapter One

INTRODUCTION

1.1 INTRODUCTION

In this section, an overview of some aspects of sheep and beef farms in New Zealand is presented. The objectives and motivation for the study are described. Finally, an outline of this dissertation is provided.

1.2 PASTORAL FARMING IN NEW ZEALAND

The use of pasture by grazing animals is the basis of New Zealand pastoral agriculture. New Zealand sheep and beef cattle graze pasture all year round, i.e., are not housed over the winter. Hay, silage and feed crops may be used to supplement pasture during winter, particularly in colder regions, but the basic objective is to exploit a generally favourable climate for pastoral production. Thus, stock are finished to prime condition on pasture with slaughter peaks following periods of high pasture growth rate.

In the New Zealand context, sheep and beef cattle complement each other in pastoral management systems, and for this reason most pastoral farms, other than dairy, are sheep and beef farms.

One of the features of the New Zealand pastoral farming sector is its dependence on export markets. For this reason world prices dominate and domestic prices reflect these.

Even though farm profitability has remained low for 6 years, agriculture has consistently provided 55 to 60 percent of New Zealand's export receipts from merchandise trade (NZMWBES, 1991).

As Table 1.1 shows, the sheep and beef sector contributes with 30% of New Zealand's total export receipts.

Table 1.1: New Zealand's Sheep and Beef Production Exported

	Production Exported	Export Receipts (\$M) 1989-90
Wool	90%	1,316
Lamb	95%	1,367
Mutton	55%	295
Beef	75%	1,369

		\$4,347
Percentage of Total Export Receipts:		30%

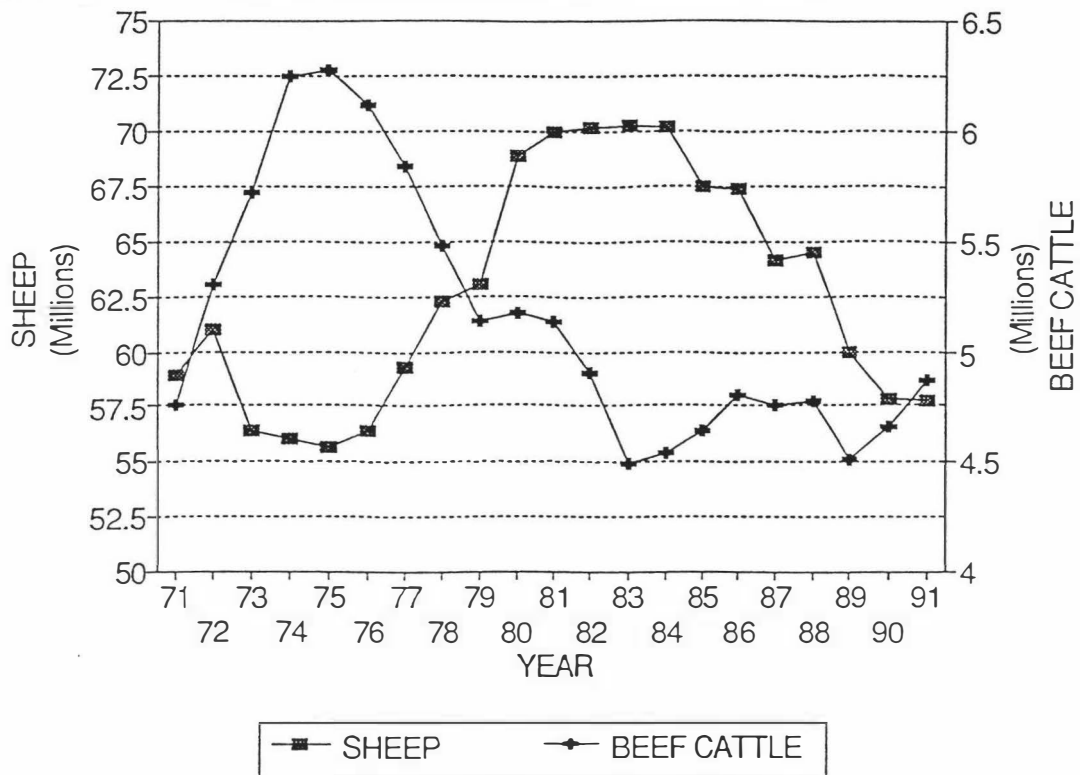
Source: New Zealand Meat and Wool Board's Economic Service
Department of Statistics

Furthermore, Table 1.1 shows that sheep products equate to 68.5% of total sheep and beef export receipts compared with 31% for beef.

Sheep have consistently provided 65 to 70% of the revenue on sheep and beef farms over the last 20 years. Beef cattle have increased in importance to reach 20% of sheep and beef farm revenue in the early 70's, but in the period mid 70's to mid 80's the beef contribution fell as low as 13%. Crop income has contributed 9 to 13% to the "all classes average" sheep and beef farms revenue over this period. (Davison, 1991).

With the current down turn in wool prices, the importance of beef cattle contribution to sheep and beef farm revenue is likely to increase quite markedly. For the 1990-91 season its contribution is estimated to reach 23% (NZMWBES, 1991).

In Figure 1.1, the trend for sheep and beef cattle numbers since 1971 is shown.

Figure 1.1: Trend for Sheep and Beef Cattle Numbers since 1971

The growth in sheep numbers in the late 1970s was due to a sustained improvement in sheep product prices until the reverse situation occurred in the 1980s where the reduction in sheep numbers reflected profitability relative to cattle.

An increase in beef cattle numbers has developed since 1983 but there was a significant set back in 1989 due to a severe drought in East Coast regions and the forced slaughter of capital stock at that time.

Therefore, sheep and beef cattle have been substituted at the margin depending on their relative profitability.

In 1984 and 1985, major changes in the New Zealand economic environment were introduced. These included the removal of subsidies and support measures to agriculture, deregulation of the financial markets and the floating of the New Zealand dollar. Since then, sheep and beef farm profitability has been less than half that of the 1970s and early 1980s, in inflation adjusted terms (SONZA, 1989). This continual low on-farm profitability has been reflected in low on-farm spending on key inputs such as fertiliser. These factors have been the major cause, apart from the 1989 drought, for the continuous rundown in stock carried on sheep and beef farms. Basically, lower inputs to farming have resulted in lower pasture production redeemed by the slaughter of capital stock.

At June 1991, sheep and beef livestock units (= 1 breeding ewe) are estimated to total 75.6 million, 10% less than at June 1985. However, sheep stock units have declined 16% during this period and were offset by a 6% increase in beef cattle stock units (NZMWBES, 1991). Cattle numbers are increasing particularly rapidly in 1990-91 with an additional 140,000 dairy calves retained for beef production in the spring of 1990 (Davison, 1991).

Unless a sustained improvement in farm profitability is realised, livestock numbers are unlikely to be rebuilt. The reality of the economic environment is that, since 1984-85, there has been great exposure to risk from interest rate changes, exchange rate changes and the uncertainty of overseas prices.

Therefore, growth from the current situation will only be driven by profit. This in turn is a function of market prices received at the farm gate, management and stock performance. The relative profitability of sheep versus beef production will continue to be a major determinant of profit on any one farm. Reassessing these relative profitabilities and designing systems with an optimum mix of sheep and beef is an important task for management.

1.3 MOTIVATION FOR THE STUDY

Large sheep and beef properties, like Limestone Downs, have the scope to change profitability quite markedly by altering the ratio of sheep to beef. In the current economic situation, this farm was particularly interested in investigating the full range of alternative sheep/beef production systems. This coincided with the author's interests in developing knowledge on New Zealand's pastoral sheep and beef industry, and in developing analytical farm management skills.

1.4 OBJECTIVES OF THE STUDY

The objectives of this study are:

- 1) To develop a linear programming model for the case study farm.
- 2) To use this model to determine optimal farm plans and associated information.
- 3) To evaluate the technique as to its suitability as an aid to farm management analysis.

1.5 THESIS OUTLINE

This study consists of eight chapters.

In Chapter One, an overview of some aspects of sheep and beef farms in New Zealand is presented. Also the objectives of the study are specified.

A description of the case study farm is presented in Chapter Two.

In Chapter Three, the use of models in agricultural research is considered.

The methodology used to investigate the case study farm is analysed in Chapter Four. The approach chosen for the study is discussed and the procedure for the analysis is described.

In Chapter Five, the linear programming (LP) model developed for the study is presented and its structure is described.

Chapter Six reports the optimal plan derived from the model described in Chapter Five. The key elements of this plan are analysed, discussed and compared with the current farm plan.

The Sensitivity Analysis is provided in Chapter Seven, in which optimal plans for five new situations are introduced and discussed.

Finally, the evaluation of the study in relation to its objectives is presented in Chapter Eight, which also discusses the value of LP to this study and highlights the areas in which the lack of information available limited further conclusions.

Chapter Two

LIMESTONE DOWNS

In this chapter, the case study farm is described. Further information on the farm can be gathered from annual publications of the C. Alma Baker Trust Series for Limestone Downs, which report the physical and financial characteristics of each season. While some performance data is presented in this chapter, the bulk of this information is provided in Chapter Five.

2.1 INTRODUCTION

Limestone Downs is a large sheep and beef cattle property situated on the coast 15 kilometres south of Port Waikato. The 3,219 hectares (2,530 ha effective) are characterised by a good balance between hills and flats, a wide range of soils varying from peat to volcanic origin and a favourable climate.

The property was part of the estate of the late Charles Alma Baker, CBE, who died in 1941. The English Trustees to Mr Baker's Will have been able to retain Limestone Downs by setting up the "C. Alma Baker Trust" which aims to further the science of agriculture. In July 1981 the Trustees appointed a New Zealand Committee which now administers the farm according to the terms of the Trust. Much of the farm has since been transformed into an intensive farm system where new ideas in agriculture can be fully explored.

2.2 PHYSICAL CHARACTERISTICS

2.2.1 Climate

Pasture growth at Limestone Downs is largely controlled by soil moisture almost regardless of season.

Since 1983, rainfall has been recorded on the farm. This information is summarized in Table 2.1 for the seasons 1985 to 1990. These records indicate an annual rainfall of 1090 to 1254mm, with the monthly average varying between 76mm in April (lowest) and 119mm in July (highest).

Table 2.1: Monthly rainfall (mm)

	1985	1986	1987	1988	1989	1990	Mean
January	82	147	98	20	173	48	95
February	181	120	43	105	60	15	87
March	68	65	148	141	52	124	100
April	60	59	78	21	73	118	76
May	112	151	102	108	148	137	115
June	112	107	98	86	124	103	106
July	160	211	83	115	112	141	119
August	126	121	54	148	93	237	113
September	70	62	116	126	58	91	86
October	61	100	72	118	171	97	100
November	120	40	102	102	101	111	90
December	102	46	96	106	70	27	84
Total	1254	1229	1090	1195	1235	1249	1171

2.2.2 Soils

A comprehensive survey of soils carried out by staff and students of the Department of Soil Science at Massey University commenced in March 1983. Part of this ongoing survey has been the production of a reconnaissance soil map adapted and modified from a soil survey of Raglan County. According to this, the soils of Limestone Downs are classified as follows:

1) Soils of the Flood Plains

This group contain soils formed from recent alluvial deposits and those formed from accumulations of peat in swampy depressions. These soils are young in age and show little horizon differentiation.

2) **Soils of the Terraces**

The soils on the river terraces are developed from material of alluvial origin. The drainage of these soils is imperfect and poaching usually occurs in winter months.

3) **Soils of the Rolling and Hilly Land**

These soils have developed on a wide variety of parent materials, including greywacke, argillite, calcareous sandstone and siltstone, non-marine siltstone, andesitic basalt, tephra, wind-blown sands, and pumiceous alluvium. This group contains the majority of the farm soils.

4) **Soils of the Steepland**

These are shallow soils with a very wide range of profile expression.

Tillman (Pers. comm.) provided the results of a soil test analysis taken in May 1989. This is shown in Table 2.2.

The values presented in Table 2.2 indicate that, on average, the pH level is slightly below the optimum 5.8 to 6.0 range. Although the Olsen P figure is in the optimum range of 15 to 30 (Tillman, Pers. comm.), the correct interpretation of this information will depend on phosphate retention levels.

Table 2.2: Soil Test Analysis Results

Sample	pH	Olsen P	Exch. K	SO4
6	5.6	21	1.21	11.5
7	5.7	21	0.55	6.5
21	6.8	8	0.91	5.5
22	5.9	15	1.04	9.0
38/39	5.8	13	1.15	9.0
41/37	6.2	15	0.52	4.5
44	5.9	13	1.63	12.0
76	5.6	19	0.87	4.5
82	5.6	30	0.73	5.0
85	5.1	28	0.72	29.5
87	5.5	29	1.16	7.5
95	5.5	14	1.13	10.0
97	5.4	16	0.53	9.0
107	5.2	19	0.26	45.5
115	5.7	12	0.80	8.0
121	5.2	14	0.74	42.0
126	5.4	20	0.38	7.5
132	5.3	26	0.95	6.0
150	5.6	12	0.96	11.5
156	5.9	27	1.00	5.5
MEAN	5.7	19	0.86	12.4

2.2.3 Fertiliser

Prior to 1984 Limestone Downs received 600 tonnes of superphosphate (235Kg/ha). Since then, 400kg/ha of reactive phosphate rock has been applied to half of the farm each year.

Lime was applied on the flats (400ha) in 1990 at 2.5 t/ha. The results will be monitored.

An area of 150ha responsive to molybdenum was detected and received molybdenum in 1986. This area will be monitored to see if further applications are necessary.

A nitrogen trial in six paired paddocks started in 1989 on the flats. For three pairs, the average response rate was 10:1, i.e., 10 Kg of dry matter per Kg of nitrogen applied. On the remainder three pairs there was no pasture growth response detected. The reasons for this are not clear.

2.2.4 Pastures

Following original development out of bush in the 1930's, English grasses and clovers were sown. New species have not been introduced in 10 years. These pastures are now characterised by a strong ryegrass (Lolium perenne) white clover (Trifolium repens) association. The presence of the summer grass Kikuyu (Pennisetum clandestinum), particularly on the coastal area of the property, is quite considerable.

2.2.5 Subdivision and Facilities

Limestone Downs is subdivided into 168 main paddocks of 15-20 ha, on average, with conventional and electric fences. Trough water is reticulated to 95% of paddocks. Three major gravelled tracks and a central lane allow access to all areas of the property all year.

The farm has a comprehensive stock of handling facilities, including covered sheep yards, two sets of cattle yards and scales for both sheep and cattle weighing.

2.2.6 Livestock Management

Breeding Ewes:

In 1981, the present management of Limestone Downs took over a flock of 12000 "old style" Romneys, i.e., short stature, woolly heads and low growth rates. A ram source was needed to meet Limestone Downs improvement requirements and to provide an opportunity to select for facial eczema tolerance. To this end, a ram-breeding programme was developed. Twinning two-tooth and four-tooth ewes were screened by ultrasound for entry into a fully recorded Romney flock at Tuapaka, a hill country sheep and beef farm operated by Massey University. These ewes are run under strict commercial conditions and are excluded on failure to rear twins. This flock has been closed at about 700 ewes from which all ram lambs are moved to Limestone Downs at weaning. Hogget growth rate, fleece weight and facial eczema tolerance are then recorded to complete the selection index. Rams with very high index are used for one year over the recorded flock and then are returned to Limestone Downs. The value of this scheme to the farm has now become apparent through increased animal performance.

At Limestone Downs, lambing starts in mid-August and weaning is in December. The shearing months are: ewes, December and May; lambs, January; hoggets, September; and two-tooths in February.

Ewes are rotationally grazed post-weaning, cleaning up paddocks. The length of rotations is determined by ewe feed demand and feed availability. In December, cull ewes are drafted on the basis of age, poor mouths, bad feed and low condition.

Over the flushing-tupping period, the ewes are on a faster rotation to build up pasture for lambing. Crayons are used with the rams in order to determine early, mid and late lambing ewes. As lambing approaches the rotation is shortened and, on the basis of the information obtained at tupping, mobs are set stocked just prior to lambing according to their pregnancy status (early, mid or late-lambing). This system is used to improve rationing of feed to ewes at lambing. The ewes remain set stocked until weaning.

Lambs:

After weaning (December), the lambs are grazed over several paddocks at low stocking rates. Lamb selling is dictated by feed supply. Usually, most lambs have been sold by February.

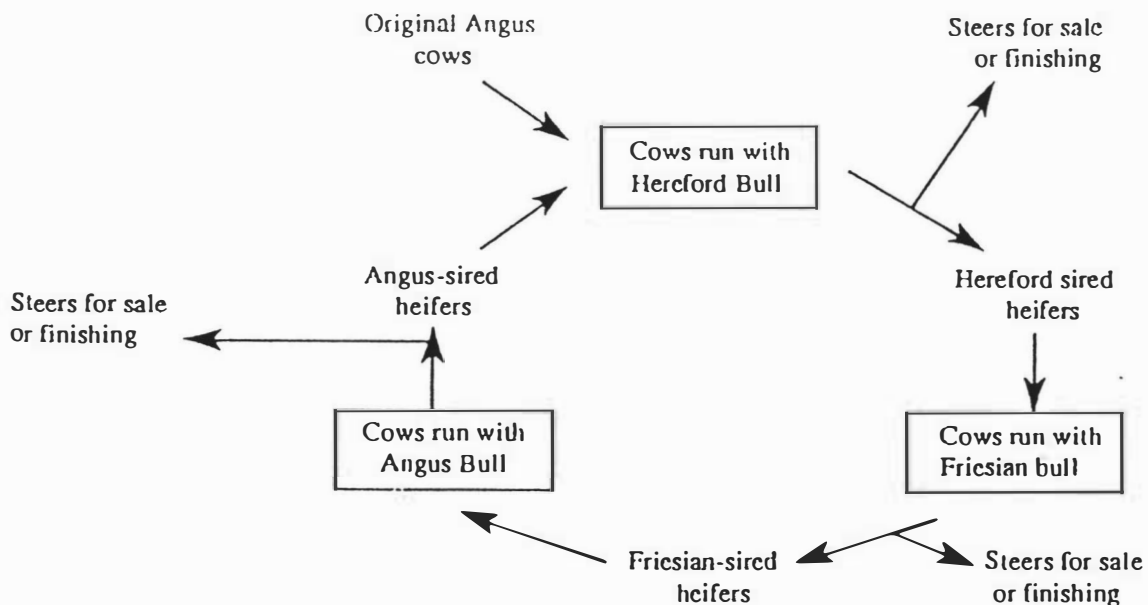
Replacements Ewes:

After weaning, the replacement ewe lambs are shuffle grazed until the end of May when the rotation is slowed down for the winter. In August, the hoggets are placed on a faster rotation to increase their liveweight. Following shearing in September they are set stocked until January to help maintain pasture quality. In January the hoggets (now two-tooths) are placed on a rotation again. They are shorn in February and join the mixed age ewes at the start of flushing in March.

Breeding Cow:

A three-breed rotational crossbreeding programme was initiated in 1982. This programme started with the base herd Angus cows being mated to Hereford bulls. To improve milk production and therefore calf weaning weight, the Friesian was used as the third breed in the rotation (Morris and Lowe, 1990). The heifer progeny from each cross are mated at 15 months to the next breed of bull in the rotation sequence (see Figure 2.1). The male progeny are either sold as weaners or finished on the farm at 18 to 24 months of age. The Charolais bull is used as a terminal sire over aged cows.

Figure 2.1: Rotational crossbreeding programme at Limestone Downs



This crossbreeding programme has performed up to expectations, and is now at a stage where cows of all sire breeds are in the herd which has averaged 90% calving (calves marked) over the last 4 seasons. Mating starts in late October and weaning is in April. After weaning, the breeding cows are rotationally grazed, cleaning up paddocks. As the calving period approaches, the breeding cows are moved onto the coastal area of the property, approximately 548 ha, where feed is set aside for calving. They are break-fed behind electric fences and shedded out as they calve. Cows and calves remain set-stocked in this area until weaning.

Steers and Heifers

After weaning, steers and heifers are placed on good quality pastures until May, when they are separated. At that time, the steers are moved onto the flats where they are set-stocked mixed with Friesian bulls until slaughtering. The heifers are wintered on rotation with the ewe hoggets.

Bull Beef

The bull beef enterprise has been located on the flats adjacent to the Kaawa Stream, in part because this area is subject to sudden flooding and running sheep there could result in high losses. In addition, this area which is well subdivided has been relatively easy to electrify fences to control bulls.

Friesian bulls are purchased from saleyards or directly from dairy farmers in November, at 10-12 weeks of age. Their weight at that time is about 90 kg liveweight.

The general management strategy is to run the bull calves in mobs of about 100-150, shifting them as necessary to ensure that they have good quality feed in front of them. This usually continues until the autumn, when they are set-stocked on paddocks with about two-thirds bulls and one-third steers. This has the major advantage that stocking rates can be adjusted by moving steers in or out depending on levels of pasture cover without causing behaviour problems. In general, they are slaughtered at about 16-20 months of age at about 250 kg carcass weight. However, some bulls can be taken through a second winter and slaughtered at heavier weights if feed supply permit.

2.2.7 Physical Performance

Pasture improvement through subdivision and rotational grazing has allowed a greater number of the progeny to be taken through to slaughter. Table 2.3 shows the changes in stock numbers for the last six seasons.

Table 2.3 Stock Numbers

	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90
Sheep:						
Ewe Hoggets	7,488	5,964	6,130	6,803	5,800	6,836
2th Ewes	6,453	5,895	4,932	4,456	4,850	3,432
Older Ewes	15,537	13,326	11,781	9,993	10,500	10,838
Rams	168	203	190	227	270	217
Other Sheep	591	551	530	651	66	457
	-----	-----	-----	-----	-----	-----
Total Sheep	30,219	25,939	24,663	23,270	22,866	21,330
Cattle:						
Cows	1,202	992	1,023	1,115	925	1,067
R1yr Heifers	353	480	402	507	513	427
R2yr Heifers			58	7	4	
R1yr Steers		127	117	303	434	357
R2yr Steers	2				7	102
Breeding Bull	25	33	24	17	23	25
R1yr Beef Bulls	454	571	580	655	680	814
Other Cattle		44	117	8		118
	-----	-----	-----	-----	-----	-----
Total Cattle	2,036	2,247	2,321	2,612	2,586	2,910
Sheep s.u.	27,745	23,923	21,508	22,100	21,911	19,212
Cattle s.u.	10,236	10,761	11,151	12,380	11,956	13,955
Total s.u.	37,981	34,684	32,659	34,485	33,867	33,167
s.u./ha	15.01	13.71	12.91	13.63	13.39	13.20

As Table 2.3 shows, cattle numbers have increased over that period, particularly Friesian bulls. Since the 1988/89 season, a decision was made to retain all calves for finishing rather than sell weaners. By contrast, sheep numbers have decreased.

The breeding programme for both sheep and cows has shown benefits which are most easily measured by the improved growth rate of young stock and improved production. For example, the cut-off mating weights for 15 month heifers was 215kg in 1982, raised to 230kg in 1985 and 250kg in 1987. The wool production per sheep stock unit wintered was 4.3kg in 1985, increased to 4.8kg in 1986 and 1987 and 5.2kg in 1988.

Indices such as lambing percentage have also increased. In the 1989/90 season this figure exceeded 100% for the first time. This achievement was repeated in the 1990/91 season which experienced 108% lambing.

2.2.8 Financial Performance

The farm working accounts for the seasons since 1985/86 are presented in Table 2.4.

As shown in Table 2.4, some costs such as animal health rose significantly. However, these reflected the increased proportion of young stock carried.

The big increase in farm surplus in 1988/89 reflected the results of improved performance, a relatively good wool price and the increased contribution from bull beef.

Table 2.4: Farm Working Account

	1985/86	1986/87	1987/88	1988/89	1989/90
Income:					
Sheep	192,470	147,419	223,887	153,512	329,187
Cattle	208,879	299,680	342,750	551,034	466,395
Wool and Skins	364,052	440,679	412,939	475,499	373,105
Other	3,737	2,550	2,850	3,663	554
	-----	-----	-----	-----	-----
Total Farm Income	769,938	890,328	982,426	1,183,708	1,169,238
Expenses:					
Wages	174,656	174,716	186,643	209,052	207,714
Animal Health	34,754	43,528	34,803	45,070	65,324
Breeding Expenses	7,305	4,492	4,195	3,105	6,054
Electricity	7,956	9,301	10,940	11,220	10,655
Fertiliser	123,712	26,632	96,308	103,202	120,113
Freight	37,924	*	*	*	*
Horses, dogs, etc	5,836	5,270	3,095	3,632	1,949
Shearing	82,534	79,483	85,516	91,864	93,081
Sundry	1,777	2,141	3,597	2,013	2,656
Weed and Pest	4,575	5,215	15,299	20,294	11,450
Cookhouse	5,599	7,646	8,044	**	**
Travel	7,936	8,186	7,379	10,376	10,861
Vehicle Running	20,147	15,742	17,932	18,978	15,365
Telephones	3,755	5,114	4,453	5,188	4,896
Buildings R & M	8,407	14,973	15,343	7,695	20,797
Improvements R & M	6,483	12,138	13,634	17,884	20,411
Plant & Machinery	4,621	2,714	3,753	6,246	5,021
Rates	17,741	26,872	31,586	30,700	31,145
Insurances	4,591	4,263	6,147	4,761	3,051
Administration	23,942	26,019	25,483	28,908	25,809
Accounting & Audit	17,620	14,835	18,000	18,300	9,500
Depreciation	54,688	57,655	60,810	69,403	***
	-----	-----	-----	-----	-----
Total Farm Expenses	661,559	546,935	652,960	707,888	665,862
Farm Surplus	107,579	343,393	329,466	475,820	503,376

Notes:

- * An accounting change was introduced from the 1986/87 season onwards with freight cost debited against particular items e.g. stock, wool, fertiliser, to give a clearer picture of real costs and prices.
 - ** The cook-house was closed when self-contained unmarried staff quarters were completed.
 - *** Depreciation is not included as farm expenditure from 1989/90.
- 1) Lack of killing space or market changes can lead to sales being held over after June 30th which can exaggerate differences in results between seasons.
 - 2) Care must be taken in drawing conclusions from the figures above as some items are distorted by major policy changes implemented over this period. For example, the increase of some 2,000 stock units in beef cattle in 1989/90 represented a forgone income of about \$150,000. This, in effect, was the price paid to increase beef and reduce sheep numbers. Taking this into account, the 1989/90 season was financially very successful, despite a big reduction in wool price.

2.3 CONCLUSION

With diminishing returns from sheep forecast, a decision to increase cattle numbers was made back in 1984/85. The gradual increase in beef has been made by means of carrying more stock through to slaughter, in particular bull beef. This has proved to be financially successful as well as fitting in well in terms of labour requirements. Although the bull beef operation continued to provide excellent returns, this is in part due to the fact that they are given highest priority for feed.

Since redevelopment is now largely completed, there is scope to further increase financial performance at Limestone Downs.

This will need to come from further increases in animal performance and perceptive management decisions.

Chapter Three

SYSTEMS MODELLING

3.1 INTRODUCTION

Scientific research has been traditionally based on the two concepts of reductionism and mechanism (Dillon, 1976; Menz, 1980). More recently, however, scientists have used a systems approach to assist their understanding. In this section both principles and the use of models in agricultural research are discussed.

3.2 THE REDUCTIONISM RESEARCH CONCEPT

According to Dillon (1976), the concept of reductionism implies reducing the systems being studied to their components; analysing these components as independent entities to explain their behaviour; and then explaining total system behaviour in terms of the sums of the behaviour of the components. The idea of reductionism relies on the concept of mechanism which implies that phenomena can be explained in terms of mechanical-like cause and effect relationships.

In recent years some researchers have expressed some dissatisfaction with that scientific approach. Dillon (1976) states that as phenomena are ordered into smaller and smaller categories, the concerns of the disciplines associated with each category move further away from the problems of the real world. Dillon also emphasizes that following that approach it is difficult to consider concepts such as objectives, goals or choices, and as such, researchers spent little time addressing those aspects.

Research conducted under the concepts of reductionism and mechanism provides precise answers for component relationships. However, when applied to the larger phenomena the answers tend to be inaccurate (Menz, 1980). Menz (1980) suggests two reasons why this happens. Firstly, reductionist research is conducted with all but one or two factors held constant, whereas in reality many factors are constantly changing. Secondly, most phenomena occur on a large scale and under the reductionist approach they are studied on a small scale.

Concern with these problems has increasingly led science today to gain an understanding of the structure of the parts from an understanding of the functioning of the whole (Dillon, 1976), therefore

indicating a 'systems approach' whereby the parts or phenomena under study are seen as parts of a larger system or systems.

3.3 THE SYSTEMS RESEARCH CONCEPT

The term 'systems research' was used by Wright (1971) to "encompass all activities involving the study of large complex systems." A definition of what is meant by 'system' becomes crucial. Spedding (1988) stated that "a system consists of a group of interrelated components that interact for a common purpose and react as a whole to external or internal stimuli. It is unaffected directly by its own outputs and has a specified boundary based on the inclusion of all significant feedbacks". Spedding's definition highlights the importance of the external environment in which the system performs and the ability of the system to react to this environment. Brockington (1979) stated that the main characteristic distinguishing systems from non-systems is the existence of links between constituents parts.

A system is thus characterised by complexity, interaction and feedback. A sheep and beef farming system composed of an area of land occupied by pasture and animals, and affected by climatic and market factors as well as all the interrelationships that may exist between these factors clearly fits these criteria. According to Wright (1971), a farming system is an attempt to control biological systems in an uncertain environment in order to achieve some goal which is predominantly economic in nature. It encompasses both a production system and a management system. Wright (undated) states that information is an output from the production system and, in turn, an input to the management system.

The systems approach provides a framework for the description and analysis of agricultural production. All agricultural production systems can be described in terms of their purpose, components, inputs, interactions, resources, products and constraints. A systems approach to agricultural research is particularly useful because of the complexity of agricultural systems and the imperfect knowledge associated with decision-making on farms.

3.4 THE PRINCIPLES OF FARM MANAGEMENT

The principles of managing a farm are no different from the principles of managing any other complex business firm. To be successful farmers must be 'efficient' in allocating the limited supply of physical, financial and human resources so as to best achieve their objectives. Determining these objectives and then achieving them as efficiently as possible is known as the management problem.

Farm management is quite different from plant, soil and animal sciences, accountancy, finance, economics and sociology. Efficient farm management usually requires at least a basic knowledge of all these disciplines, for these are the manager's tools (Dent et al., 1986).

Management is a separate discipline concerned with the efficient attainment of objectives. Dillon (1980) defines farm management as "the process by which resources and situations are manipulated by the farm manager in trying, with less than full information, to achieve goals."

Farm management is commonly acknowledged as having three major components: planning, implementation and control. Plans which will best achieve the farmer's objectives are formulated, then put into effect and constantly monitored to assure that the farm business remains on target in terms of the specified plans and objectives.

Although relatively simple planning techniques are available, farmers undertake a fundamental replanning of their business "no more than once or twice in their working lifetime" (Longbottom, 1980; Hardaker and Anderson, 1981). This apparent lack of planning by farmers can be associated with the amount of time required and the lack of empathy that farmers show towards office tasks (Lockhart, 1990).

Hardaker and Anderson (1981) suspect that for most farmers "management is a matter of routine". Major changes to this routine are seldom considered and many of the changes that are made occur more by a process of constant adaptation rather than by a decision to change.

Farmers operate in a dynamic and uncertain environment in which physical and economic variables are constantly suffering alteration. Successful farmers are almost continually involved in the process of assessment and adjustment of their farming systems. Planning is therefore an ongoing process. This does not mean that farmers are constantly making major modifications to their system. It means that they regularly have their program under review making marginal changes on a day-to-day basis and occasionally making more substantial policy changes. The extent to which later stages of a plan must

be reformulated is determined not only by external factors such as weather, diseases, pests and product prices, but also by the skill with which the first stages of the plan are implemented and the quality of the control that is exercised.

Some variation in relation to the planned outcome is expected and can be accepted. Establishing the causes for differences between target and actual performances may not be simple as often several factors are involved. If that is the case, a re-evaluation of the objectives might be necessary.

3.5 FARM PLANNING MODELS

The modelling process begins by carefully observing and formulating the problem and then constructing a scientific model that attempts to abstract the essence of the real problem. It is then hypothesized that this model is a sufficiently precise representation of the essential features of the situation, so that conclusions obtained from the model are also valid for the real problem.

Many farm decisions originate from informal planning procedures whereby farmers initially make assessments, weigh alternatives and finally decide on a particular course of action. There is a whole range of procedures that may be used to put planning on a more systematic basis. Irrespective of the technique used, the same basic idea is being applied:

- a model of the farm business is created; and
- this model is used to assess what courses of action can be undertaken and their likely outcomes.

The use of models in systems research is becoming more widespread for several reasons:

- 1) Computers make modelling faster and easier than modelling systems by hand as was done in the past. Modern computers are faster, more user-friendly and have considerably increased capacity.
- 2) Experimentation using models can be conducted more quickly and at lower cost than experimentation on the real system.
- 3) Modelling enables research priorities to be more clearly established.

Nevertheless, it is important to remember that a modelling approach should complement the study of real systems since a model must ultimately generate solutions that are biologically valid and also concerned with the practical management in terms of providing understandable conclusions to the decision maker.

3.6 MODEL DEFINITION

Models have been widely used to analyse and design farming systems (Jeffers, 1978; Miller, 1983; McCall, 1984; Ridler et al., 1987).

Spedding (1988) defined a model as "an abstraction and simplification of the real world, specified so as to capture the principal interactions and behaviour of the system under study, and capable of experimental manipulation in order to project the consequences of changes in the determinants of the system's behaviour." While this definition may seem rather long, it highlights important features of models:

- 1) Models are a simplification of the real world. This implies that certain assumptions must be made in order to allow the model to be used.
- 2) The model should capture the principal interactions and behaviour of the system which are relevant to the research.
- 3) Since the main objective of the research is usually to improve the understanding of the particular system, the model must be capable of predicting changes in behaviour caused by alterations on the system.

Models provide an important means of understanding livestock production systems since they are constructed on the basis of existing knowledge. Gaps in the current knowledge are therefore readily identified. By this means research priorities can be established (McCall, 1984).

3.7 NATURE OF MODELS

Models can be classified by their properties as being qualitative or quantitative. Qualitative models are classified as iconic or analogue. Some agricultural research stations use small scale farmlets to

investigate farming systems. Such farmlets can be thought of as iconic models of normal sized farms where alternative managements can be imposed and the outcomes evaluated. The idea is to gain confidence that the real system will react in the same way as the iconic model.

Analogue models are also physical representations of the real system. However, they are not simply miniaturisations. They represent the entire system. A farm map is an analogue model. These models assist planning by defining and indicating the availability of resources.

Mihram (1972) classifies quantitative models as:

a) Static or dynamic

Static models are independent of time.

Dynamic models are time-dependent and may be either continuous or discrete depending on whether they use continuous or discrete variables.

b) Deterministic or stochastic

Deterministic or "normative" models do not account for risk or variability. Therefore they assume that the outcome from any set of initial conditions is known with certainty.

Stochastic models are better suited to biological systems because they contain the intrinsic variability associated with biological phenomena. However, data indicating the variability of component behaviour is often not available or cannot be readily expressed as a mathematical relationship. In practice, most models are therefore deterministic because they are easier to build and the output is generally simpler to interpret. The effect of uncertainty can be estimated in deterministic models by parametrizing input variables.

Models are also optimising or non-optimising. Non-optimising models require the user to make some informal judgement outside of the model when selecting from among alternative systems. Simulation models are non-optimising models primarily concerned with describing the behaviour of the system under a given set of assumptions (Wright, 1971). They can, through experimentation, approximate solutions to problems, although their primary role is not problem-solving.

Optimising models require an objective function (e.g. profit maximisation or cost minimisation) to evaluate different decision rules. They find the optimal combination of inputs required to best attain the objective function specified. Linear programming is a classic example of such models.

3.8 PURPOSE OF MODELLING

The type of model chosen is dependent on the nature of the system, the objectives of the research, and the purposes for which the model is to be used.

The purposes of modelling can be summarized as:

- to improve the understanding of how a complex system functions (Wright, 1976).
- to generate a quantitative hypothesis about the described system (Spedding, 1977; Baldwin and Koong, 1980) and possibly an 'optimal' combination of inputs.
- to evaluate the output from a proposed system in relation to existing systems (Wright, 1973).
- to determine the required economic conditions (e.g., input/output prices) for sub-optimal systems to become relevant (Wright, 1973).
- to predict how a system will respond to natural or induced disturbance (Wright, 1976) and thus, provide an aid to the design of 'improved' systems (McCall, 1984).
- to generate practical management decisions, i.e., to provide understandable conclusions to the decision maker(s) (Hillier and Lieberman, 1990)
- as a focus for communicating or coordinating basic research needs in relation to current and future objectives (McCall, 1984) and to solve problems related to manipulation of the system to achieve given ends (Wright, 1976).
- for extrapolation of system effects over longer time/climate sequences and to other sites (Seligman & Arnold, 1980).

Whatever the purpose, the model building exercise must be justified. Such justification can be that experimentation with the model is more feasible than experimentation and observation of the real system. Model construction and use may also be justified in relation to time-consumption, physical resource requirements, accuracy and cost (Dent & Anderson, 1971).

3.9 PROBLEMS IN APPLYING PLANNING MODELS

Modelling use in farm planning assumes that the model is a realistic representation of the farm system. As all farm models are acknowledged as being 'simplifications of the real world', the information obtained from using a model can only be viewed as a guide to what the farmer might expect to happen on the property. Therefore, important issues must be considered. These are:

Reliability of Data

The ideal source of data for any farm planning model is the farmer's own records. Where records are not available or data are required for activities not previously or recently carried out on the property, district data should be used. Historical data on prices and costs may be of little value, but some market outlook information will always be valuable.

Risk

Single-value estimates of input and output data fail to reflect the unpredictability of results. Thus, some form of sensitivity analysis should be performed to verify the stability of the selected plan. This would involve reworking the analysis using alternative estimates for key parameters such as yields and prices.

All models suffer from limitations. This does not mean that they are not useful. Modelling, to some degree, is an inevitable necessity. The creation of an abstract representation of a particular system which incorporates a number of assumptions should not raise concern. What is important is to recognise that these assumptions have been made, and to check their reasonableness in the particular decision situation.

3.10 CONCLUSION

As a means of overcoming some of the problems associated with reductionist research, scientists have undertaken a systems approach to research. The principle of the systems approach is that understanding is achieved from studying the system as a whole rather than its individual components.

A farm is essentially a business undertaking, and plans for the future organisation and progress of the farm business need to be developed along systematic lines. Given the complexity of the decision-making problem, farm managers have been concerned to devise techniques which will aid in the planning process.

Modelling is an important tool in agricultural research. The representation of both whole systems and the individual relationships within systems allows an investigation of the likely effects of change on existing systems, or evaluation of new systems. The model should be used in a thoughtful and creative manner.

The results from the planning analysis do not replace the existing information. Rather, they augment the present knowledge so that fuller and more certain information upon which to base a decision can be used.

If the model is well formulated and tested the resulting solution should tend to be a good approximation to the ideal course of action for the real problem. Therefore, the test of the practical relevance of research is whether it provides a better guide for action that can be obtained by other means.

Chapter Four

METHODOLOGY

4.1 INTRODUCTION

This study required a modelling method which could:

- 1) accurately simulate the production system on the case farm;
- 2) represent the physical and financial characteristics of several production options; and
- 3) allow the effects of market price variation on the physical and financial performance of the case farm to be investigated.

In this section the methodology used to investigate these issues for Limestone Downs is reviewed. The main features of the model are discussed and the procedure for the analysis is described.

4.2 CHOICE OF MODEL

Farm planning may be viewed as the process of selecting an appropriate set of activities for the farm, and the optimum level at which each activity is to be conducted. This choice is made in order to attain a stipulated objective (e.g. profit maximisation) knowing the supply of each of the available resources to carry out these activities and the stipulated payoff for each activity.

For some planning problems, it is not feasible to determine the optimal activity levels by whole farm budgeting, partial budgeting or gross margin analysis (Rickards and McConnel, 1967; Dent et al., 1986; Ridler and Hurley, 1988). These methods involve a large number of repetitive calculations if several alternative farm plans are to be investigated. Even if carried out with the aid of a computer, they enable neither a thorough search of all combinations of activity levels nor a methodic approach towards the determination of the optimal combination.

In addition, a major part of the management of pastoral-based farms concerns decisions about allocating feed to livestock. The quantity and quality of feed likely to be available for grazing at any time is dependent on factors that can be controlled (e.g. soil fertility and plant species) and those that cannot be controlled (e.g. climatic factors). The efficiency with which livestock will utilise available feed is also dependent on a series of factors (e.g. genetic and physiological). A crucial task of livestock and pasture research is to quantify the relationships between inputs and outputs with the objective of increasing the confidence with which managers can estimate outcomes from alternative strategies. Assuming that some information on these relationships exist, the dilemma is still how to process this information to greatest advantage.

Feed budgeting and analogous simple computer models have shown to be useful aids to short-term grazing decision making (McRae, 1987; Ridler and Hurley, 1988; Lockart, 1989). However, more complex management decisions demand the use of different types of models which allow investigation of longer-term decisions and which incorporate financial as well as physical relationships.

Linear Programming (as discussed in section 4.3) is a mathematical technique suitable for solving problems where an objective function is to be maximised or minimised for a number of variables which are subject to a number of constraints is well suited for such applications, and for this reason was chosen for this study.

4.3 THEORETICAL ASPECTS OF LP MODEL BUILDING

4.3.1 Introduction

Linear programming (LP) was originally developed for use during World War II as a method for the evaluation of alternative routes for shipping supplies to the Allied troops, with the objective of minimising travel distance for the limited shipping facilities available, and for determining the best method of allocating scarce labour and capital resources to produce war materials. Since then it has been used as a research tool in agriculture to define the optimum organisation of resources and enterprises on farms; to suggest desirable farm adjustments; to specify profit maximizing mixes of commodities produced by marketing firms; to specify cost minimizing methods of processing products such as fertilizer or mixed feeds; to indicate optimum patterns of resource use and product specialization in agriculture; and related types of problems.

In fact, it has application opportunities in any type of problem for which an objective can be determined in quantitative terms. As a rule, the objective will be one of maximizing or minimizing quantities. The quantity to be maximized can be profits of a farm, feed units of an agricultural area, or calories and other food components of an agricultural sector. The quantity to be minimized may be the cost of a feed, the cost of transportation between the origins and destinations of a product, or the amount of labour required to provide the food needs of a particular population.

4.3.2 Definition

Linear programming (LP) is a planning technique which given suitably formulated data is capable of producing optimal mathematical solution in terms of either maximising or minimising some stated objective. According to Yang (1958), LP as applied to farm planning and budgeting represents a systematic method of determining mathematically the optimum plan for the choice and combination of farm enterprises (technically known as activities) so as to maximise the income (or to minimise the cost) within the limits of the available resources (technically also known as constraints) on an individual farm.

Linear programming is a mathematical technique for solving a problem that has the following characteristics:

- 1) a function or objective to be maximised or minimised:
- 2) limited resources to be used in the attainment of this objective; and
- 3) alternate means of exploiting the available resources.

The Objective

The objective of a linear programming study may be expressed in physical, monetary, or other terms, depending upon the problem being analysed.

For the typical farm management problem the objective will be maximum income or minimum cost. However, in practice, there is no reason why the objective should be so restricted. For instance, the farmer may be interested in the maximum farm income, subject to the inclusion of an Autumn-lambing plan or may be willing to maintain a pedigree herd even if it involves a financial sacrifice.

Limited Resources

A linear programming problem does not exist unless resources are restricted or limited. Although physical resources represent the main types of restrictions, e.g. land, machinery, capital and labour, again there also can be subjective or other types of restrictions, e.g. the manager himself may place restrictions on the minimum or maximum size of certain enterprises.

Alternate Methods or Processes

Unless the specified objective can be attained in more than one way there is no problem to be analysed. Given several methods or processes (different activities and different methods or techniques of producing these activities) by which the objective can be attained, the methods or processes (activities) which are most efficient in transforming resources into the objective are chosen.

On many farms it may appear initially that the activity options are very limited. On a sheep and beef property, for instance, the options would seem to be limited to sheep and cattle production. On close inspection, however, it can be seen that these activities are aggregates of a much larger set of activities. That is, within the broadly defined livestock activity, many alternative arrangements of production are open to the farmer (e.g. cattle finishing options, sheep shearing policies) each using a unique combinations of inputs to produce a particular output. Indeed the number of possible combinations is enormous and one of the first problems in farm planning is to limit the number of alternatives to be evaluated to a realistic set.

The Characteristics of LP Problems

The requirements for constructing an LP model for a given farm situation as described by Hazell and Norton (1986) are:

- (a) the alternative farm activities, their unit of measurement, their resource requirements, and any specific constraints on their production;
- (b) the fixed resource constraints of the farm;
- (c) the forecast return (or cost) for each activity.

4.3.3 Assumptions of Linear Programming

Implicit in an LP model are a number of important assumptions. These are:

1) Additivity

It is assumed that the resource demands and net profit (gross margin) per unit of an activity are independent of the level of that activity, and of any other activity. This assumption implies that there are no interaction effects between activities. Therefore, complementary and/or antagonistic interactions between activities are compromised. In order to handle this situation a new activity that includes the relationship between other activities must be specified.

2) Linearity

The assumption of linearity is directly related to that of additivity. A constant gross margin per unit of activity used is assumed, i.e., the gross margin and resource requirements per unit of activity are assumed to be constant regardless of the level of the activity used, leading to a linear relationship. Hence, no adjustment for economies of scale is made. To represent non-linear production relationships requires that these be approximated by linear segments where each segment is represented by an activity.

3) Finiteness

It is assumed that there are a limited number of alternative activities and resource constraints which need to be considered so that a solution may be sought.

4) Non-negativity

It is assumed that none of the activities can be carried out at negative levels.

5) Divisibility

Activities and resources are assumed to be capable of utilization at any positive fraction and that any proportion of each resource can be used in the production. Because the mathematical procedure requires complete divisibility of inputs and outputs, a practical interpretation of the results requires the judgement of the analyst. For example, a solution that includes the purchase of 0.5 of a tractor does not make sense since this would not be possible. In this case the problem would have to be set up differently or integer programming used.

6) Determinism

It is assumed that the resource supply, input-output coefficients and prices used are known constants.

In fact, the same assumptions are made in almost all other analysis procedures, including budgeting and gross margin analysis. However, in the linear programming procedure prices and production coefficients can easily be varied and the resulting sensitivity analysis can illustrate the effect of variation on resource allocation and returns.

4.3.4 Algebraic Formulation of an LP Problem

In a situation where the maximisation of the objective function is to be attained the problem is to find the optimal values for the variables $X_1, \dots, X_j, \dots, X_n$ which include all the possible activities that can be undertaken and all the various ways of producing them. This can be algebraically expressed as follows:

$$1) \quad \text{Maximise } Z = \sum_{j=1}^n C_j X_j \text{ for } j = 1, 2, \dots, n.$$

Where: Z is the objective function, e.g. farm income;
 C_j is the return or cost per unit of the j th activity;
 X_j is the level of the j th activity.

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

$$2) \quad \sum_{j=1}^n a_{ij} X_j \geq, \leq \text{ or } = b_i \text{ for } i = 1, 2, \dots, m.$$

Where: only one of the signs holds for each constraint;
 a_{ij} is the input-output coefficient which specifies the amount of the i th resource required to produce one unit of the j th activity;
 b_i is the amount available of the i th resource.

$$3) \quad X_j \geq 0, \text{ i.e., each activity must be carried out at a non-negative level.}$$

Any selection of values for X to X_{n+m} is called a "solution" to the problem.

If the solution satisfies all the constraints of the problem it is said to be a "feasible solution" and if it is also the solution which gives the highest objective function value (for a maximisation problem) or the lowest objective function value (for a minimisation problem) it is said to be an "optimal solution".

If it is impossible to solve an LP problem then it is said to be either an "infeasible" or an "unbounded" problem.

A problem is said to be infeasible when it is impossible to satisfy all the constraints simultaneously. The simplest type of infeasibility would be the one where one constraint specified that an activity had to exceed a certain level while another constraint limited that same activity to less than that value. These two constraints cannot be satisfied at the same time, therefore any problem containing both of them would be infeasible.

A problem is said to be unbounded when there is no limit in the supply of an activity which contributes favourably to the objective function, i.e., it is possible to select an infinite number of units of that activity. This is generally due to a matrix construction error.

4.3.5 Solving an LP Problem

The general procedure for solving LP problems is called the Simplex method and was developed by George Dantzig in 1947. Although this procedure has since been revised and extended to improve its computational efficiency for modern computers, the principles of the solution procedure remain unchanged. (Hazell and Norton, 1986)

The mathematics and computational procedures of the simplex method are extensively reviewed in such texts as Hillier and Lieberman (1990), Hazell and Norton (1986), Hadley (1962) and Heady and Candler (1958), and, in practice, it is not imperative to understand the mathematical details of the Simplex method since LP problems are invariably solved with the aid of a computer.

In this section a brief description of the Simplex method is presented.

The SIMPLEX Method

The Simplex method is based on the economic concept of opportunity cost.

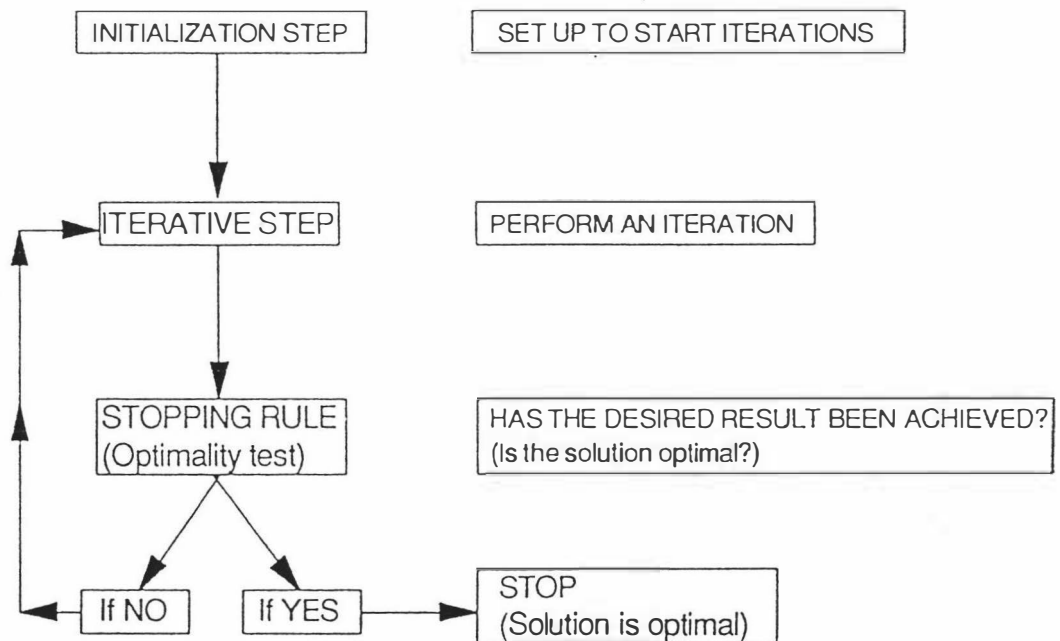
As stated by Dent et al. (1986) "expressed simply, the opportunity cost of undertaking an action is the value of the best alternative action that has to be forgone." The concept of opportunity cost applies to resources as well as activities. The opportunity cost of a resource is the value that the resource would

generate if used in the best alternative way. Indeed the opportunity cost of an activity is the sum of the opportunity costs of the resources required by that activity. If a resource is not fully utilised it has zero opportunity cost.

The Simplex method is an algorithm, i.e., a process in which a systematic procedure is repeated (iterated) over and over again until a desired result is achieved.

In Figure 4.1 the general structure of an algorithm is presented.

Figure 4.1: Structure of Algorithms (Adapted from Hillier and Lieberman, 1990)



The Simplex method is a mathematical procedure that examines the "corner points" of the production possibility boundary as a means to detect the optimal plan. The starting point is the origin where all the activities are at zero level and all the resources are completely in surplus. Since all resources are in surplus they will initially have zero opportunity cost. Due to the fact that the activities require resources which initially are not scarce, they will also have zero opportunity cost.

The next step is to introduce one of the activities (usually but not necessarily the one with the highest return per unit) to a level at which one of the resources becomes scarce. Subsequently, the introduction of any other activity that requires the same resource will involve an opportunity cost since the level of that first activity will have to be reduced. A second activity is introduced into the plan only if the return from this activity exceeds the opportunity cost of including it in the plan. The level of this activity increases until a second resource becomes scarce. Activities are then progressively introduced until a stage where no activities remain for which the returns exceed the opportunity costs. At this point the optimal plan is found.

4.3.6 Information Provided by the Optimal Solution

The optimal solution's output for an LP problem provides several pieces of information. These are:

- 1) The optimal objective function value which represents the maximum profit or the minimum cost plan;
- 2) The activity's level, i.e., the level at which each activity is present in the optimal plan;
- 3) The activity's status, as follows:
 - (a) A "basic" activity represents an activity that is part of the optimal plan at a level greater than zero;
 - (b) A "non-basic" activity represents an activity that is not part of the optimal plan;
 - (c) A "degenerate" activity represents an activity that is included in the optimal plan but at zero level. This suggests that there is a redundant constraint in the problem limiting the activity to a zero level.
 - (d) A "multiple" activity indicates that although the activity is not present in the optimal plan there is an equally profitable plan which does include it.
- 4) The activity's shadow cost, i.e., the increase in the objective function value that would be necessary to make a "non-basic" activity become a "basic" activity. Basic activities have a shadow cost of zero since they are already included in the optimal plan.

- 5) The constraint's slack, i.e., the difference between the use of a resource or constraint and its limit value. For example, if there are 5 tractors available for use but the optimal plan only uses 3, the tractor constraint row will have a slack of 2 tractors. Alternatively, if the problem specifies that there must be at least 1000 sheep and the optimal plan includes 1500 the slack for the sheep minimum row will be 500 sheep. "Equals" constraints must have, by definition, zero slack.
- 6) The constraint's shadow price, i.e., the amount by which the objective function value would increase if an extra unit of the constraint was available. For example, a shadow price of \$2000 for land indicates that an extra hectare of land would increase the value of the plan by \$2000. Therefore it is worth leasing at any price less than \$2000.

For "less than" constraints, shadow prices may be positive or zero if the constraint is "slack". A positive shadow price indicates that an increase in the constraint limit would increase profit.

"Greater than" constraints may have negative or zero shadow prices. A negative shadow price indicates that a decrease in the constraint limit would increase profit. "Equals" constraints may have positive, negative or, very rarely, zero shadow prices. If an equals constraint has zero shadow price it means that the constraint would have been met even if it had not been specified in the matrix. Positive or negative shadow prices are interpreted as for "less than" or "greater than" constraints, respectively.

- 7) The range analysis specifies the upper and lower limits within which the objective function or constraint limits could be varied without affecting the mix of activities selected. However, the level of the selected activities is likely to change in response to changes within those ranges.

4.3.7 Sensitivity Analysis

An optimal solution to an LP problem cannot be taken as the final plan for implementation without carrying out further tests on the stability of the plan. This testing of the stability of the optimal solution by making small changes in the costs, prices, resources supply and input-output coefficients in order to determine whether or not it depends critically on the exact values of particular data is called sensitivity analysis or post-optimality analysis.

The general rule is to vary one parameter at a time, otherwise there is a possibility of obtaining an unclear result with no indication of the relative importance of each parameter changed. The exception to this rule is where there is a correlation between two or more parameters.

The sensitivity analysis provides answers to many questions which contribute to a more comprehensive understanding of the planning situation. Beneke and Winterboer (1973) list some of these questions as follows:

- How great is the advantage of the activities which entered the plan over those which did not?
- How would increasing or decreasing one or more resources affect the optimum mix of activities and the value of the plan?
- How would changes in price relationships affect the solution?

Answers to questions such as these allow the decision-maker to appropriately decide on the final plan to be implemented. According to Hillier and Lieberman (1990) finding an optimal solution is the "fun part" whilst the "real work" comes with the sensitivity or post-optimality analysis. In fact, in many real applications of LP models, these observations are even more important than finding the optimal plan.

The ability to quickly vary returns, costs, resource levels and input-output coefficients in LP models allows for a wide-range analysis of the sensitivity of the optimal solution. This is very convenient in risky situations or in situations where the accuracy of some input data could be questioned.

When LP is used as planning tool for decision making, risk can sometimes be assessed outside the framework of the model, and the farm plan indicated as optimal may be adjusted in a subjective way as in this study. However, it is also possible to incorporate risk formally into the planning framework using linear (e.g. MOTAD¹) or quadratic risk programming.

1 MOTAD = minimum of total absolute deviations method. For risk programming reference see Hazell and Norton (1986).

4.3.8 Steps for LP Model-building

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

1) Define the objective function

In LP models the objective is either profit maximisation or cost minimisation.

The first step is to define the objective function and to determine the values for the objective function row which correspond to the return or cost values for each of the activities. The signs of the coefficients are determined as explained in step (4).

2) Define the activities

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

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

- Producing or growing crops.
- Raising and/or feeding livestock.
- Selling products.
- Buying or hiring inputs or services including labour and capital.
- Harvesting crops.
- Transferring inputs or intermediate products from one activity or time period to another.
- Paying fixed costs and/or family living expenses.

The unit chosen for measuring the level of each activity should be practical and must be used consistently all through the model when defining each of the coefficients for the activities.

3) Define the constraints

In this step constraints are defined.

There are two major types of constraints which may limit the level of the activities that may enter the optimum plan. These are:

- (a) Resource constraints, i.e. the total amount of land, capital, labour and machinery available per period of time;
- (b) Activity constraints, i.e. the maximum or minimum amount allowable for some activities.

Each resource or activity constraint is identified as a maximum, minimum or an equality constraint, depending on the purpose of the restriction. For example, the restriction could be due to the maximum amount of resource (such as land, capital, etc.) available to the farm; or there could be external restrictions such as government programs; or the farmer could impose subjective restrictions forcing in activities which he/she requires for other than economic reasons; or designed for risk aversion reasons.

4) Define the input/output coefficients

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

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

5) Construction of the LP matrix

Having determined the objective, all the possible activities, the resources (or constraints) and the input/output coefficients, the next step is to elaborate the model layout. The model takes the form of a matrix of coefficients which show the relationship between the production activities and the resources in the problem. Within the matrix, columns represent the production activities and rows represent the resources (constraints) as well as the objective function.

The values of the resources (or constraints) are generally placed on the right-hand side of the matrix and hence referred to as the "right-hand sides" or "RHS".

By convention, this way of presenting an LP model is referred to as a "tableau". The layout of the LP matrix may generally look as shown in Table 4.1.

Table 4.1: An LP Tableau

Row Name Resource Constraints	Activities				Amount of Resource Available
	X1	X2	...	Xn	
OBJECTIVE FUNCTION	C_1	C_2	...	C_n	
1	a_{11}	a_{12}	...	a_{1n}	b_1
2	a_{21}	a_{22}	...	a_{2n}	b_2
.
.
.
m	a_{m1}	a_{m2}	...	a_{mn}	b_m

4.4 CONCLUSION

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

The use of pasture by grazing animals is the basis of New Zealand pastoral agriculture where farmers have learned, generally through experience, to integrate their animal and pasture resources. The decisions they have to make include choice of stocking rate, time of lambing and calving, how much supplements to make and how long mobs of stock should stay in a paddock. The skills required to balance the feed supply and demand of grazing livestock include a knowledge of the seasonal feed requirements of grazing animals and the ways in which these can be met from pasture.

The model created for this study is an attempt to investigate some of these issues for the case farm.

Chapter Five

THE MODEL

In this section the linear programming (LP) model developed for this study is described. The structure of the model is presented. The objective function is specified in terms of production alternatives (activities) and constraints.

5.1 INTRODUCTION

The model allows farm surplus (gross income less fixed and variable costs) to be maximised for 75 activities (production alternatives) and subject to 62 constraints. A complete presentation of the LP matrix is included in Appendix 1.

The basic production data used in this study was obtained from farm records and/or provided by the farm manager.

5.2 ACTIVITIES

The activities included in the model encompass all the production possibilities analysed in this study. Within the matrix, each column represents an activity.

5.2.1 Pasture Production

The pasture production activity included in the model (PASPRO) represents the monthly supply of pasture expressed in kilograms of dry matter per hectare (Kg DM/ha) of land in pasture.

Pasture production is a function of pasture growth rate (Kg DM/ha/day) and pasture quality (MJ ME/Kg DM), and can be specified for a particular farm locality. The pasture growth rates used in this study are presented in Table 5.1 and represent the net accumulation in pasture mass (cover) expected

in each period, i.e., the amount of pasture which can be harvested per unit of time either by grazing stock or by cutting. It was derived from the analysis of pasture cover measurements using the rising plate technique (Earle and McGowan, 1979) and the level of livestock performance achieved on the case farm. Table 5.1 also shows the pasture quality values which were derived by Walker (1984) for hill country and assumed to be relevant to this farm. Feed quality or feeding value is a function of both intake and nutritive value (Holmes and Wilson, 1984). Ulyatt et al. (1980) defined nutritive value as the nutrient concentration per unit of feed. This is commonly expressed as megajoules of metabolisable energy per kilogram of dry matter (MJME/KgDM).

The quality of pasture as a feed depends on its species composition and on the chemical and physical composition of the species present (Holmes and Wilson, 1984). The energy content of pasture will therefore vary over the season due to the type of species present and the stage of growth of these species.

Feed quality declines rapidly if the sward is allowed to seed (Korte, 1982). The low preference of livestock for pasture at reproductive stage means that most of it senesces and dies. This dead material then depresses both pasture digestibility and energy content (Ratray and Clark, 1984). Grazing management should therefore aim to maintain the sward in a leafy vegetative thus highly digestible state.

Table 5.1: Pasture Growth Rates and Pasture Quality

Month	Pasture Growth KgDM/ha/day	Pasture Quality KgDM/ha/month	MJ ME/Kg DM
January	27	837	10.3
February	22	616	9.3
March	17	527	10.0
April	15	450	10.8
May	13	403	10.8
June	10	300	11.0
July	17	527	11.2
August	22	682	11.2
September	25	750	11.3
October	30	930	11.0
November	40	1200	11.0
December	30	930	11.0

In the context of this model, pasture growth rate represents the net accumulation of pasture defined as kilograms of dry matter per hectare per month (KgDM/ha/month). While the components of net pasture accumulation (pasture growth less animal intake, less losses due to senescence and decay) may be expected to vary in relation to the level of dry matter of the pasture, the pasture growth rates used in this study are assumed to be fixed within the range of pasture cover allowed in the model. (See pasture cover constraints in section 5.3.2.)

The cost of the pasture production activity is \$200/ha. It represents the costs which are directly proportional to the level of that activity in the plan (e.g. fertiliser, weed and pest control) and the costs associated with running the farm (e.g. working expenses, repairs and maintenance, electricity) which are assumed to be constant over the range of production possibilities considered in this study. These costs were derived from the 1989/90 farm accounts and are presented in Appendix 2.

As a result, the objective function optimised represents farm surplus.

5.2.2 Pasture Cover

The pasture cover activities (PCJULY..PCJUNE) allow the model to choose the pasture cover at the start of each month as a function of feed supply, feed demand and the amount of feed transferred in and out of each period. According to the model, the pasture cover activities can be constrained within pre-determined limits. (See section 5.3.2)

There is no monetary value associated with these activities, i.e., there are no costs or returns incurred by the level of pasture cover in the optimal plan.

5.2.3 Feed Wasting

The feed wasting activities for each month (JULWST..JUNWST) represent feed that is neither consumed in that period nor transferred to the following period due to senescence and decay. These activities are also related to the range of pasture cover allowed in the model. (See section 5.3.2)

There is no monetary value associated with the feed wasting activities, i.e., there are no costs or returns incurred by the level of these activities in the optimal plan.

5.2.4 Hay Making

The hay making activities (HMAKDEC..HMAKFEB) allow hay to be made in December, January and February at a cost of \$2.50 per bale (25 KgDM) made. (See Appendix 3)

According to Barry et al. (1980) field dry matter losses in making pasture hay are expected to be in the order of 15-25%; dry matter losses for 5-7 months storage are about 4-8%; and feeding out losses are about 15-35%. Thus, overall losses are assumed to be 50% for this study. (See Section 5.2.5)

Within the model each bale of hay made requires 25 KgDM from the feed row in that month and supplies 1 bale to the hay pool row (HAYPOOL).

5.2.5 Hay Feeding

The hay feeding activities (HFEDMAY..HFEDSEP) allow hay to be fed out monthly from May through to September. Within the model, each bale of hay fed out uses 1 bale from the hay pool row (HAYPOOL) and supplies 12.5 KgDM to the feed row in that month. Therefore, losses between conservation and feeding are assumed to be 50%. (See section 5.2.4 above.)

5.2.6 Nitrogen

The nitrogen activities in the model (NJUN..NSEP) allow nitrogen (N) to be applied (as urea) from June through to September at a cost of \$1 per kilogram of nitrogen (see Appendix 4). A response of 10 Kg of dry matter per Kg of nitrogen applied is assumed to occur over a two-month period, 75% in the first month and 25% in the second month after the application.

Within the model, each kilogram of nitrogen applied uses 1 Kg of N from the nitrogen pool row (NPOOL) and supplies 7.5 and 2.5 KgDM to the feed rows in the two months subsequent to the application, respectively.

5.2.7 Animal Production Activities

The animal production activities included in the model are based on actual performance levels achieved in the case farm. The feed requirements for each activity were calculated using a series of computer spreadsheet models developed by Brookes (Pers. comm.). Liveweight profiles, calving and lambing periods and performances, shearing dates and wool clip are entered. Monthly feed requirements are calculated converting metabolisable energy requirements to kilograms of dry matter. As the model comprises twelve periods in which feed is on offer, for activities that continue for longer than 12 months the feed requirements in each month represent the sum of the requirements for the recurrent months.

Dressing out percentages were provided by Morris (Pers. comm.) and supported by on farm data.

A) Sheep Activities

Breeding Ewe

The breeding ewe activity (BRDEWE) included in the model represents one Romney ewe with the characteristics presented in Table 5.2:

Table 5.2: Breeding Ewe Activity - BRDEWE

Cost:	- \$9.75/ewe
Lambing date:	15th August
Lambing %:	100
Weaning:	mid-November
Shear 1:	December = 2.3 kg wool
Shear 2:	May = 2.6 kg wool
Losses:	6%

The cost value represents animal health, breeding and shearing expenses plus the opportunity cost of capital associated with a breeding ewe (see Appendix 5). The lambing percentage figure represents lamb survival to weaning.

The liveweight profile (ewe) and feed requirements (ewe and its lamb until weaning) are presented in Table 5.3.

Table 5.3: Breeding Ewe - Liveweight and Feed Requirements

Month	Liveweight (Kg)	Feed Requirement	
		(Kg DM/Day)	(Kg DM/Month)
July	54	1.1	37
August	56	1.2	38
September	51	2.0	60
October	54	2.5	77
November	52	1.2	35
December	53	1.5	46
January	54	1.1	36
February	54	1.3	36
March	55	1.4	42
April	55	1.1	34
May	55	1.0	30
June	54	1.3	40

Within the model, each breeding ewe supplies 0.50 ram lambs to the ram lamb row (MALAMB), 0.50 ewe lambs to the ewe lamb row (FELAMB), 0.19 cull ewes to the ewe cull row (EWECULL) and 4.9 Kg of wool to the wool pool row (WOOLPOOL). Each breeding ewe requires 0.25 replacement hoggets from the ewe replacement row (EWEREP) and 1 breeding ewe from the minimum sheep row (MINEWE).

Replacement Ewe

Within the model, 25% of the breeding ewes are replaced annually. The characteristics of the replacement hogget activity (REPHGT) are presented in Table 5.4.

Table 5.4: Replacement Hogget Activity - REPHGT

Cost:	-\$12.35		
Shearing:	Lamb	(January)	= 1.3 Kg Wool
	Hogget	(September)	= 3.3 Kg Wool
	2-Tooth	(February)	= 2.7 Kg Wool
Losses:	3.5%		

The cost figure is made up of animal health and shearing expenses plus the opportunity cost of capital of a replacement hogget (see Appendix 6).

The replacement hogget activity represents a ewe lamb reared for 15 months (from weaning to mating) when, in the context of this model, it becomes a breeding ewe.

The liveweight profile and feed requirements for a replacement hogget are presented in Table 5.5.

Table 5.5: Replacement Hogget - Liveweight and Feed Requirements

Month	Liveweight (Kg)	Feed Requirement	
		(Kg DM/Day)	(Kg DM/Month)
December	25	0.8	27
January	27	1.4	44
February	30	1.4	40
March	32	1.1	35
April	33	1.0	29
May	34	1.0	31
June	35	1.0	29
July	36	0.9	28
August	37	1.4	42
September	38	1.6	47
October	40	1.5	44
November	44	1.4	42
December	46	1.2	40
January	48	1.7	52
February	52	3.0	83
March	54	1.8	53

According to the model, each replacement hogget requires 1.035 ewe lambs from the ewe lamb row (FELAMB), therefore allowing for 3.5% losses, and supplies 7.3 Kg of wool to the wool pool (WOOLPOOL) row (which corresponds to the three shearings specified in Table 5.4) and 1 replacement hogget to the replacement ewe row (EWEREP).

Cull Ewe

The cull ewe activity (CULLEWE) allows 19% of the breeding ewes (25% replacements less 6% losses) to be sold for \$15.

Within the model each cull ewe to be sold requires 1 ewe from the ewe cull row (EWECULL).

Ram Lamb activities

Ram lambs can be sold store (STMALMB) at weaning for \$17.60 or can be finished (FATMALMB) and sold in February for \$29.90. The characteristics of this ram lamb finishing activity in which a ram lamb is reared for three months after weaning are presented in Table 5.6.

Table 5.6: Ram Lamb Selling Activity - FATMALMB

Return:	\$29.90	
Shearing:	January	= 1.3 Kg Wool
Final Weight:	35 Kg	
Carcass Wt:	14 Kg	
Losses:	3%	

The return figure represents the income from selling the lamb to the freezing-works less the animal health costs, shearing expenses and the opportunity cost of capital associated with that ram lamb. (See Appendix 7).

The liveweight profile and feed requirements for this ram lamb are presented in Table 5.7.

Table 5.7: Ram Lamb - Liveweight and Feed Requirements

Month	Liveweight (Kg)	Feed Requirement	
		(Kg DM/Day)	(Kg DM/Month)
December	25.0	1.3	42
January	29.5	1.9	58
February	32.0	2.4	35

Within the model each ram lamb to be sold store at weaning (STMALMB) requires 1 ram lamb from the ram lamb row (MALAMB), while each ram lamb to be finished requires 1.03 ram lambs (to cover losses of 3%) from the ram lamb row (MALAMB) and supplies 1.3 Kg of wool to the wool pool row (WOOLPOOL).

Ewe Lamb activities

Ewe lambs can be sold store (STFELMB) at weaning for \$15.60 or can be reared and sold as hoggets (HGTSELL) for \$24.65 in September. The characteristics of this ewe hogget selling activity are presented in Table 5.8.

Table 5.8: Ewe Hogget Selling Activity - HGTSELL

Return:	\$24.65		
Shearing:	Lamb	January	= 1.3 Kg Wool
	Hogget	September	= 3.3 Kg Wool
Losses:	3.5%		

The return figure represents the income from the selling of each ewe hogget less the animal health costs, shearing expenses and the opportunity cost of capital associated with this ewe hogget. (See Appendix 8).

The liveweight profile and feed requirements for this ewe hogget are presented in Table 5.9.

Table 5.9: Ewe Hogget Activity - Liveweight and Feed Requirements

Month	Liveweight (Kg)	Feed Requirement	
		(Kg DM/Day)	(Kg DM/Month)
December	25	0.8	27
January	27	1.4	44
February	30	1.4	40
March	32	1.1	35
April	33	1.0	29
May	34	1.0	31
June	35	1.0	29
July	36	0.9	28
August	37	1.4	42
September	38	1.6	47

Within the model each ewe lamb to be sold store at weaning (STFELMB) requires 1 ewe lamb from the ewe lamb row (FELAMB). Each hogget to be sold in September (HGTSELL) requires 1.035 ewe lambs (to cover for 3.5% losses) from the ewe lamb row (FELAMB) and supplies 4.6 Kg of wool to the wool pool row (WOOLPOOL) corresponding to the two shearings specified in Table 5.8.

Wool Selling

The wool selling activity (WOOLSELL) allows the wool produced from any of the sheep activities selected to be sold for \$3.55/Kg.

Within the model, each kilogram of wool to be sold uses 1 Kg of wool from the wool pool row (WOOLPOOL).

B) Beef Cattle Activities

Breeding Cow

The breeding cow (BRDCOW) included in the model represents one breeding cow with the characteristics presented in Table 5.10.

Table 5.10: Breeding Cow Activity - BRDCOW

Cost:	-\$67.55/Cow
Calving Date:	1st August
Calving %:	90
Weaning:	28th February
Calf Wt:	190 Kg
Losses:	3%

The cost figure represents animal health costs, breeding expenses and the opportunity cost of capital associated with a breeding cow (see Appendix 9). The calving percentage figure represents calf survival to weaning.

The liveweight profile (cow) and feed requirements (cow plus its calf until weaning) are presented in Table 5.11.

Within the model each breeding cow supplies 0.45 steer calves to the steer calf row (MACALF), 0.45 heifer calves to the heifer calf row (FECALF) and 0.20 cull cows (23% replaced less 3% losses) to the cull cow row (COWCULL); and requires 0.23 replacement heifers from the replacement cow row (COWREP).

Table 5.11: Breeding Cow - Liveweight and Feed Requirements

Month	Liveweight (Kg)	Feed Requirement	
		(Kg DM/Day)	(Kg DM/Month)
July	433	6.7	208
August	386	9.0	278
September	393	9.4	283
October	400	9.5	296
November	407	9.1	275
December	413	9.6	299
January	420	11.4	352
February	427	14.5	407
March	434	4.0	123
April	426	3.8	114
May	421	4.1	127
June	418	6.0	180

Cull Cow

The cull cow activity included in the model (CULLCOW) allows 20% of the breeding cows (23% replacement less 3% losses) to be sold for \$380.

Within the model each cull cow to be sold requires 1 cow from the cull cow row (COWCULL).

Replacement Heifer

Twenty-three percent of the breeding cows are replaced annually. The characteristics of the replacement heifer activity (REPHFR) are presented in Table 5.12.

Table 5.12: Replacement Heifer Activity - REPHFR

Cost:	-\$107.30/Heifer
Calving Date:	1st August
Calving %:	90
Weaning:	28th February
Calf Wt:	190 Kg
Losses:	2%

The cost figure is made up of animal health costs, breeding expenses and the opportunity cost of capital associated with a replacement heifer (see Appendix 10). The calving percentage figure equates to calf survival to weaning.

The replacement heifer activity represents a heifer calf reared for 23 months after weaning when, in the context of this model, it becomes a breeding cow. The liveweight profile (heifer) and feed requirements (heifer plus its calf until weaning) are presented in Table 5.13.

Within the model, each replacement heifer requires 1.02 heifer calves (to cover losses of 2%) from the heifer calf row (FECALF) and supplies 0.45 steer calves to the steer calf row (MACALF) and 0.45 heifer calves to the heifer heifer calf row (FECALF). Therefore, the net effect on the heifer calf row is the requirement of 0.57 (1.02-0.45) heifer calves.

Table 5.13: Replacement Heifer - Liveweight and Feed Requirements

Month	Liveweight (Kg)	Feed Requirement	
		(Kg DM/Day)	(Kg DM/Month)
March	190	4.0	126
April	195	3.9	117
May	201	4.1	128
June	208	4.0	121
July	217	3.8	119
August	227	3.9	119
September	238	4.5	135
October	256	6.0	188
November	279	6.4	191
December	304	5.9	182
January	322	6.2	193
February	335	6.8	190
March	346	6.2	191
April	355	4.9	148
May	362	5.1	158
June	369	5.2	155
July	377	5.5	171
August	327	8.6	267
September	339	9.0	271
October	351	9.3	287
November	361	8.3	249
December	365	9.0	278
January	369	10.7	331
February	374	13.8	387

Heifer Calves

Within the model each heifer calf can be sold store at weaning for \$320 (STOHFR), can be reared for 13 months after weaning and slaughtered in April (FATHFR) or can be reared, mated and slaughtered after calving (see Once-bred Heifer Activity on page n).

The characteristics of the heifer finishing activity (FATHFR) are presented in Table 5.14.

Table 5.14: Heifer Finishing Activity - FATHFR

Cost:	- \$58.00/Heifer
Losses:	2%
Final Wt:	429 Kg
D/O %:	51.5%
Carcass Wt:	221 Kg

The cost figure represents the animal health costs plus the opportunity cost of capital associated with this heifer. (See Appendix 11)

The liveweight profile and feed requirements for this heifer are presented in Table 5.15

Within the model, each heifer to be finished requires 1.02 heifer calves from the heifer calf row (FECALF) to cover losses of 2%, and supplies 221 Kg of beef to the beef pool row (BEEFS1).

**Table 5.15: Heifer Finishing Activity - FATHFR
Liveweight, Liveweight Gain and Feed Requirements**

Month	Liveweight (Kg)	LWG (Kg/Day)	Feed Requirement (Kg DM/Day) (Kg DM/Month)	
March	190	0.650	5.5	170
April	208	0.450	5.2	154
May	222	0.400	5.1	159
June	233	0.400	4.5	134
July	244	0.350	4.2	130
August	254	0.400	4.0	124
September	266	0.700	4.8	143
October	286	1.000	6.8	209
November	318	1.000	7.7	232
December	347	0.750	7.1	221
January	369	0.700	8.1	253
February	391	0.500	9.5	268
March	407	0.500	8.0	250
April	422	0.500	7.7	232

Steer Calves

Within the model each steer calf can either be sold store at weaning for \$340 (STOSTR) or can be reared and slaughtered in one of three periods: April (FATSTAPR), June (FATSTJUN) and November (FATSTNOV). The characteristics of these steer finishing activities are presented in Table 5.16.

Table 5.16: Steer Finishing Activities

	FATSTAPR	FATSTJUN	FATSTNOV
Cost:	-\$61.25	-\$69.75	-\$91.00
Losses:	2%	2%	2%
Final Wt:	429Kg	460Kg	582Kg
D/O %:	51.5%	52.5%	54.0%
Carcass Wt:	221 Kg	242 Kg	314 Kg

The cost figures represent animal health expenses plus the opportunity cost of capital associated with each steer finishing activity. (See Appendix 12).

The liveweight profile and feed requirements for these three activities are presented in Table 5.17.

Within the model each steer to be finished requires 1.02 steer calves from the steer calf row (MACALF) to cover for losses of 2%, and supplies the carcass weights (Kg of beef) specified for each activity in Table 5.16 to the beef pool rows BEEFS1, BEEFS1 and BEEFS2, respectively.

**Table 5.17: Steer Finishing Activities
FATSTAPR (1), FATSTJUN (2) and FATSTNOV (3)
Liveweight, Liveweight Gain and Feed Requirements**

Month	Liveweight (Kg)	LWG (Kg/Day)	Feed Requirements (Kg DM/DAY) (Kg DM/Month)	
March	190	0.600	5.5	170
April	208	0.450	5.2	154
May	222	0.400	5.1	159
June	233	0.400	4.5	134
July	244	0.350	4.2	130
August	254	0.400	4.0	124
September	266	0.700	4.8	143
October	286	1.000	6.8	209
November	318	1.000	7.7	232
December	347	0.750	7.1	221
January	369	0.700	8.1	253
February	391	0.500	9.5	268
March	407	0.500	8.0	250
April (1)	422	0.500	7.7	232
May	437	0.500	8.4	263
June (2)	452	0.500	8.0	242
July	467	0.500	7.3	228
August	482	0.500	7.2	226
September	497	0.700	8.4	250
October	520	1.000	9.2	285
November (3)	551	1.000	11.7	353

Once-Bred Heifer Activity

The once bred heifer system consists basically in rearing a heifer calf which is mated at 15 months of age and slaughtered after producing a calf.

The once-bred heifer activity included in the model (OBHFR) represents one heifer with the characteristics presented in Table 5.18.

Table 5.18: Once-bred Heifer Activity - OBHFR

Cost:	-\$90.00/Heifer
Calving Date:	1st August
Calving %:	90
Weaning:	31st December
Losses:	2%
Final Wt:	408 Kg
D/O %:	50%
Carcass Wt:	204 Kg

The cost figure is made up of animal health costs, breeding expenses and the opportunity cost of capital associated with this once-bred heifer (see Appendix 13). The calving percentage figure equates to calf survival to weaning.

The once-bred heifer activity represents a heifer calf being reared for 24 months after weaning when it is slaughtered. The liveweight profile (heifer) and feed requirements (heifer plus its calf until weaning) are presented in Table 5.19.

Within the model, each once-bred heifer requires 1.02 heifer calves (to cover losses of 2%) from the heifer calf row (FECALF) and supplies 0.45 steer calves to the once-bred heifer steer calf row (OBHMACA), 0.45 heifer calves to the once-bred heifer heifer calf row (OBHFECA) and 204 Kg of beef to the beef pool row (BEEFS3).

Table 5.19: Once-Bred Heifer - Liveweight and Feed Requirements

Month	Liveweight (Kg)	Feed Requirement	
		(Kg DM/DAy)	(Kg DM/Month)
March	190	4.0	126
April	195	3.9	117
May	201	4.1	128
June	208	4.0	121
July	217	3.8	119
August	227	3.9	119
September	238	4.5	135
October	256	6.0	188
November	279	6.4	191
December	304	5.9	182
January	322	6.2	193
February	335	6.8	190
March	346	6.2	191
April	355	4.9	148
May	362	5.1	158
June	369	5.2	155
July	377	5.5	171
August	327	8.6	267
September	339	9.0	271
October	351	9.3	287
November	361	8.3	249
December	365	9.0	277
January	369	8.4	261
February	388	10.5	294

Once-bred Heifer Calves

Within the model each OBH calf can either be sold store at weaning for \$270 (OBSTHFR) or can be reared for 16 months after weaning and slaughtered in April (OBFTHFR). The characteristics of this heifer finishing activity are presented in Table 5.20.

Table 5.20: OBH Heifer Finishing Activity - OBFTHFR

Cost:	- \$66.00/Heifer
Losses:	2%
Final Wt:	429 Kg
D/O %:	51.5%
Carcass Wt:	221 Kg

The cost figure represents the animal health costs plus the opportunity cost of capital associated with this OBH heifer. (See Appendix 14).

The liveweight profile and feed requirements for this OBH heifer are presented in Table 5.21.

Table 5.21: OBH Heifer Finishing activity - OBFTHFR Liveweight, Liveweight Gain and Feed Requirements

Month	Liveweight (Kg)	LWG (Kg/Day)	Feed Requirement	
			(Kg DM/Day)	(Kg DM/Month)
January	147	0.740	4.5	140
February	170	0.710	5.9	166
March	190	0.581	5.0	155
April	208	0.467	5.2	154
May	222	0.355	4.9	151
June	233	0.367	4.5	134
July	244	0.322	4.2	130
August	254	0.387	4.0	124
September	266	0.667	4.8	143
October	286	1.032	6.8	209
November	318	0.967	7.7	232
December	347	0.710	7.1	221
January	369	0.710	8.1	253
February	391	0.571	9.5	268
March	407	0.484	8.0	250
April	422	0.460	7.7	232

Within the model, each OBH heifer to be finished requires 1.02 heifer calves from the OBH heifer calf row (OBHFCA) to cover losses of 2%, and supplies 221 Kg of beef to the beef pool row (BEEFS1).

Once-bred Steer Calves

Within the model each OBH steer calf can either be sold store at weaning for \$290 (OBSTSTR) or can be reared and slaughtered in one of three periods: April (OBSTAPR), June (OBSTJUN) and November (OBSTNOV). The characteristics of these steer finishing activities are presented in Table 5.22.

Table 5.22: OBH Steer Finishing Activities

	OBSTAPR	OBSTJUN	OBSTNOV
Cost:	-\$69.75	-\$78.25	-\$99.50
Losses:	2%	2%	2%
Final Wt:	429Kg	460Kg	582Kg
D/O %:	51.5%	52.5%	54.0%
Carcass Wt:	221 Kg	242 Kg	314 Kg

The cost figures represent animal health expenses plus the opportunity cost of capital associated with each activity. (See Appendix 15).

The liveweight profile and feed requirements for these three activities are presented in Table 5.23.

Table 5.23: OBH Steer Finishing Activities
OBSTAPR (1), OBSTJUN (2) and OBSTNOV (3)
Liveweight, Liveweight Gain and Feed Requirements

Month	Liveweight (Kg)	LWG (Kg/Day)	Feed Requirements (Kg DM/Day) (Kg DM/Month)	
January	147	0.740	4.5	140
February	170	0.710	5.9	166
March	190	0.581	5.0	155
April	208	0.467	5.2	154
May	222	0.355	4.9	151
June	233	0.367	4.5	134
July	244	0.322	4.2	130
August	254	0.387	4.0	124
September	266	0.667	4.8	143
October	286	1.032	6.8	209
November	318	0.967	7.7	232
December	347	0.710	7.1	221
January	369	0.710	8.1	253
February	391	0.571	9.5	268
March	407	0.484	8.0	250
April (1)	422	0.500	7.7	232
May	437	0.484	8.4	263
June (2)	452	0.500	8.0	242
July	467	0.484	7.3	228
August	482	0.484	7.2	226
September	497	0.767	8.4	250
October	520	1.000	9.2	285
November (3)	551	1.033	11.7	353

Within the model each OBH steer to be finished requires 1.02 steer calves (to cover for losses of 2%) from the OBH steer calf row (OBMACA) and supplies the carcass weights (Kg of beef) specified for each activity in Table 5.22 to the beef pool rows BEEFS1, BEEFS1 and BEEFS2, respectively.

Bull Beef Activities

The bull beef system in the model comprises several activities: one buying in activity (FBCABUY) which represents the purchase of each Friesian bull calf in November for \$310; and five finishing activities representing five slaughtering options, four as yearlings either in December (FB1YDEC), February (FB1YFEB), April (FB1YAPR) or June (FB1YJUN), and one as two-year old bulls in December (FB2YDEC). The characteristics of these bull beef finishing activities are presented in Table 5.24.

Table 5.24: Friesian Bull Finishing Activities

	Cost (\$/bull)	Final Lwt (KG)	D/Out (%)	Carcass Wt (Kg)	Losses (%)
FB1YDEC	-57.40	455	50.0	228	3
FB1YFEB	-65.15	520	51.0	265	3
FB1YAPR	-72.90	575	51.5	296	3
FB1YJUN	-80.65	619	52.0	322	3
FB2YDEC	-103.90	651	52.5	342	3

The cost figures represent animal health expenses plus the opportunity cost of capital associated with each activity (see Appendix 16).

The liveweight profile and feed requirements for these bull beef activities are presented in Tables 5.25 and 5.26.

**Table 5.25: Friesian Bull Finishing Activities
FB1YDEC (1), FB1YFEB (2), FB1YAPR (3), FB1YJUN (4)
Liveweight, Liveweight Gain and Feed Requirements**

Month	Liveweight (Kg)	LWG (Kg/Day)	Feed Requirement	
			(Kg DM/Day)	(Kg DM/Month)
November	90	0.850	3.1	93
December	108	0.850	3.6	112
January	144	0.850	4.7	146
February	167	0.850	6.3	176
March	191	0.850	6.2	192
April	215	0.850	6.2	186
May	238	0.750	6.7	208
June	257	0.500	5.9	177
July	271	0.500	5.6	174
August	294	0.750	6.3	195
September	319	1.300	8.5	255
October	357	1.500	10.4	322
November	399	1.500	11.3	339
December (1)	439	1.200	10.6	329
January	488	1.000	11.6	360
February (2)	516	1.000	14.7	412
March	544	1.000	13.8	428
April (3)	570	0.700	11.3	339
May	589	0.700	12.3	381
June (4)	609	0.700	12.2	195

Table 5.26: Friesian Bull Finishing activity - FB2YDEC Liveweight and Feed Requirements

Month	Liveweight (Kg)	LWG (Kg/Day)	Feed Requirement (Kg DM/Day) (Kg DM/Month)	
November	90	0.85	3.1	93
December	108	0.85	3.6	112
January	144	0.85	4.7	146
February	167	0.85	6.3	176
March	191	0.85	6.2	192
April	215	0.85	6.2	186
May	236	0.50	5.7	177
June	249	0.25	4.9	147
July	256	0.25	4.6	143
August	266	0.25	4.5	140
September	275	0.50	5.2	156
October	296	1.50	9.2	285
November	338	1.50	9.8	294
December	378	1.20	9.6	298
January	425	0.75	9.2	285
February	446	0.75	11.5	322
March	467	0.75	10.9	338
April	488	0.75	10.4	312
May	507	0.50	9.8	304
June	519	0.25	8.4	252
July	526	0.25	7.8	242
August	537	0.25	7.5	233
September	546	0.50	8.4	252
October	567	1.50	14.3	443
November	609	1.50	15.1	453

A clearer picture of the liveweight profiles is provided in graph 5.1 which also shows the slaughtering options for these bull beef activities.

Figure 5.1: Friesian Bull Activities Liveweight Profiles and Slaughtering Options

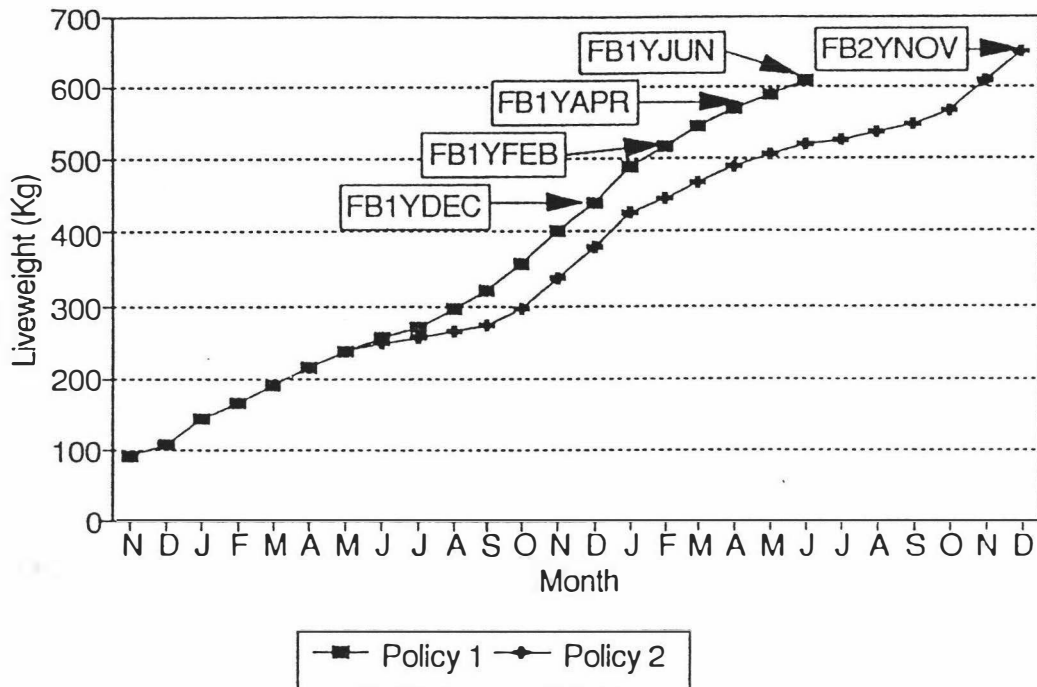


Figure 5.1 shows that the 'Policy 1' bulls require higher gains than the 'Policy 2' ones from May through to September in the first year and from January through to June in the second year. This equates to a difference in liveweight gain of 0.410 and 0.225 Kg/day, on average, during those two periods, respectively.

Within the model each Friesian bull to be finished requires 1.03 bull calves from the bull calf row (BULLCALF), thus covering losses of 3%, and supplies the carcass weights (Kg of beef) specified in Table 5.24 for each activity to the bull beef pool rows BBFSCH1, BBFSCH2, BBFSCH3, BBFSCH4 and BBFSCH5, respectively.

Beef Schedules

The beef cattle activities included in the model allow beef (as Kg of carcass) to be sold according to five bull beef schedules (BBSCH1..BBSCH5) and three beef schedules (BSCH1..BSCH3). The characteristics of these schedules are presented in Table 5.27.

Table 5.27: Beef Schedules

Schedule	Weight Range (Kg LW)	Schedule Price (\$/Kg C/C)
BBSCH1	220.5-245	2.40
BBSCH2	245.5-270	2.45
BBSCH3	295.5-320	2.50
BBSCH4	320.5-345	2.55
BBSCH5	Over 345	2.60
BSCH1	220.5-245	2.30
BSCH2	295.5-320	2.50
BSCH3	195.5-220	2.20

Source: Deighton, (Pers. comm.) December 1990

5.3 CONSTRAINTS

The constraints included in the model comprise the resource utilisation limits which must be satisfied by the activities selected in the optimal plan. Within the matrix each row represents a constraint.

5.3.1 Land

The land constraint (LAND) ensures that:

$$\text{LAND USED} \leq \text{LAND AVAILABLE}$$

The model can be used either in a farm basis or in a per hectare basis. Thus, within the model:

$$\text{LAND USED} \leq 1 \text{ HA or}$$

$$\text{LAND USED} \leq 2530 \text{ HA}$$

5.3.2 Feed Constraints

Twelve feed rows (JULYFD..JUNEFD) are used to constrain the model so that for each month of the year:

$$\text{FEED DEMAND} \leq \text{FEED SUPPLY}$$

Within the model:

$$\text{FEED DEMAND} - \text{FEED SUPPLY} \leq 0$$

The feed rows also ensure that the amount of feed that can be transferred from one period to the next is constrained according to some pre-determined pattern of grazing management (see Section 5.3.3).

In properties like Limestone Downs feed resources are often managed through the monitoring of the average pasture cover so that an evaluation of the feed status can be made.

The pasture cover at a time can be expressed as follows:

$$PC_{(t+1)} = PC_{(t)} + S_{(t)} - D_{(t)} - W_{(t)}$$

Where:

$PC_{(t+1)}$ is the pasture cover at the start of period (t + 1) or,
is the pasture cover at the end of period (t);

$PC_{(t)}$ is the pasture cover at the start of period (t);

$S_{(t)}$ is the feed supply during period (t);

$D_{(t)}$ is the feed demand during period (t), and

$W_{(t)}$ is the feed wastage during period (t).

In LP notation (see section 4.3.5) this is transposed to:

$$-PC_{(t+1)} = -PC_{(t)} - S_{(t)} + D_{(t)} + W_{(t)} \text{ or, rearranging,}$$

$$PC_{(t+1)} - PC_{(t)} - S_{(t)} + D_{(t)} + W_{(t)} = 0 \quad \dots\dots\dots (1)$$

Equation (1) represents the general form of the feed constraint row for each month (JULYFD..JUNEFD).

Thus, activities that 'supply' feed (feed supply and opening pasture cover) have negative coefficients, whilst activities that 'require' feed (feed demand, closing pasture cover and wastage) have positive coefficients. Similarly, supplementary feed making activities 'require' feed from the monthly feed supply rows and 'supply' it to the feed pool rows while activities that use supplementary feeding 'require' feed from the feed pool rows and 'supply' it to the monthly feed supply rows.

5.3.3 Pasture Cover Constraints

Twenty-four rows (JULMIN,JULMAX...JUNMIN,JUNMAX) are used in the model to constrain the pasture cover activities within pre-determined limits, so that:

$$\begin{aligned} \text{MONTHMIN} &\geq X \\ \text{MONTHMAX} &\leq Y \end{aligned}$$

Where:

"X" and "Y" represent pasture cover limits expressed in kilograms of dry matter per hectare (KgDM/ha).

Therefore, the pasture cover at the start of each period is chosen so that:

$$X \leq \text{PASTURE COVER} \leq Y$$

Bircham (1984) and Hodgson and Maxwell (1984) suggest that pasture growth rates are relatively constant over the range of pasture cover between 1000 and 2000 KgDM/ha. They found that for pasture covers below 1000 Kg DM/ha pasture growth rates are reduced due to below optimum leaf area. For pasture covers above 2000 Kg DM/ha pasture growth rates are reduced due to high levels of pasture senescence. Based on the above, the model selects a pattern of pasture cover within that range.

Within the model:

$$1000 \text{ KgDM/ha} \leq \text{PASTURE COVER} \leq 2000 \text{ KgDM/ha}$$

5.3.4 Hay Row

The hay constraint row (HAYPOOL) ensures that:

$$\text{HAY FED OUT} \leq \text{HAY MADE}$$

Within the model:

$$\text{HAY FED OUT} - \text{HAY MADE} \leq 0$$

5.3.5 Nitrogen Row

The nitrogen constraint row (NPOOL) specifies that nitrogen cannot be used at a rate greater than 25Kg per hectare.

Within the model:

$$\text{N USED} \leq 25 \text{ KgN/ha}$$

5.3.6 Sheep Constraints

5.3.6.1 Lamb

Two lamb constraints, one for ram lambs (MALAMB) and the other for ewe lambs (FELAMB), ensure that if the breeding ewe activity is selected the number of lambs used in the plan must be less than or equal to the number of lambs born.

Within the model:

$$\text{LAMBS USED} - \text{LAMBS BORN} \leq 0$$

5.3.6.2 *Wool Row*

The wool constraint row (WOOLPOOL) ensures that:

$$\text{TOTAL WOOL SOLD} \leq \text{TOTAL WOOL PRODUCED}$$

Within the model:

$$\text{TOTAL WOOL SOLD} - \text{TOTAL WOOL PRODUCED} \leq 0$$

5.3.6.3 *Replacement Ewe Row*

The replacement ewe constraint row (EWEREP) ensures that 25% of the breeding ewes are replaced each year.

Within the model, each breeding ewe (BRDEWE) requires 0.25 replacement hoggets (REPHGT).

5.3.6.4 *Cull Ewe Row*

The cull ewe constraint row (EWECULL) ensures that 19% of the breeding ewes (25% replaced less 6% losses) are sold each year.

Within the model each breeding ewe (BRDEWE) supplies 0.19 cull ewes (CULLEWE) to the cull ewe row (EWECULL).

5.3.6.5 *Minimum Sheep Row*

The minimum sheep constraint row (MINEWE) incorporates the farm manager's minimum requirement of ten thousand breeding ewes on the property (or 3.953 ewes/ha) as an essential part of the pasture-weed management control.

Within the model:

BREEDING EWE (head) \geq 3.953 (heads/ha) or,
 BREEDING EWE (head) \geq 10,000 (head)

5.3.7 Beef Cattle Constraints

5.3.7.1 Calf Row

Two calf constraint rows, one for steer calves (MACALF) and the other for heifer calves (FECALF), ensure that if the breeding cow activity is selected the number of calves used in the plan must be less than or equal to the number of calves born.

Within the model:

CALVES USED - CALVES BORN \leq 0

5.3.7.2 Replacement Cow Row

The replacement cow constraint row (COWREP) ensures that 23% of the breeding cows are replaced each year.

Within the model, each breeding cow (BRDCOW) requires 0.23 replacement heifers (REPHFR).

5.3.7.3 Cull Cow Row

The cull cow constraint row (COWCULL) ensures that 20% of the breeding cows (23% replaced less 3% losses) are sold each year.

Within the model, each breeding cow (BRDCOW) supplies 0.20 cull cows (CULLCOW) to the cull cow row (COWCULL).

5.3.8 Bull Beef Constraints

5.3.8.1 Bull Calf Row

The bull calf constraint row (BULLCALF) ensures that the number of Friesian bulls used must be less than or equal to the number of Friesian bull calves bought.

Within the model:

$$\text{BULLS USED} - \text{BULLS BOUGHT} \leq 0$$

5.3.8.2 Maximum Bull Row

Two maximum bull constraint rows stipulated by the farm manager ensure that the number of yearling bulls wintered (MAX1YBULL) cannot exceed one thousand (0.395/ha) and that the number of two-year old bulls wintered (MAX2YBULL) cannot exceed three hundred (0.119/ha).

5.3.8.3 Beef Schedule Rows

Within the model there are eight beef schedule rows: five bull beef schedule rows (BBFSCH1..BBFSCH5) and three beef schedule rows (BEEFS1..BEEFS3). These rows accumulate all beef produced from any of the cattle finishing activities included in the optimal plan and allow it to be sold, such as:

$$\text{BEEF SOLD} \leq \text{BEEF PRODUCED}$$

Within the model:

$$\text{BEEF SOLD} - \text{BEEF PRODUCED} \leq 0.$$

Chapter Six

DATA ANALYSIS, RESULTS AND DISCUSSION

In this chapter the optimal plan derived from the model described in Chapter Five is presented. The key elements of this plan are analysed, discussed and compared with the existing farm plan. However, before dealing with the results and their interpretation, an account of the deficiencies of the model will be given in order to provide an indication of what the results may lack.

6.1 LIMITATIONS OF THE MODEL

The model used in this study is a single year model which excludes investment and does not allow for within-year adaptive management. Prices and yields used are assumed fixed throughout the planning horizon (one year).

Labour, capital and cash management aspects of the farm businesses are not treated explicitly in the model. It is considered that this does not significantly diminish the utility of the model as a planning tool.

Although actual data from the farm was used in formulating the coefficients of the model, these may not represent realistic performances in future periods. As averages of past performances, they do not take into account possible technological improvements.

The LP model does not explicitly consider price, yield or weather variability. However, prices and yields for the more significant activities are tested by sensitivity analysis. While climatic variability is an important factor when analysing farming systems it has not been incorporated in the model because this aspect was judged to be outside the scope of this study.

6.2 RESULTS

In order to accept the model created for this study as a simulation of the real farm situation it was necessary to force the production activities currently run on the farm into the model. Therefore, this plan should provide similar financial returns and require similar levels of resource use as the existing farm plan. To be able to measure and compare the results of the "current" plan with those of the "optimal plan" the figures must be made comparable. A simple comparison of the computed farm surplus figure from the optimal solution with that actually revealed in the farm accounts would be misleading owing to differences between prices actually realized and those used as the basis for planning. Therefore, the prices used to achieve this comparison are taken as the prices paid/received in the 1990 season.

6.2.1 The Optimal Plan

The optimal plan presented here was derived from the model described in Chapter Five. The activities included in the optimal solution are presented in Table 6.1, along with those included in the current plan.

The main interest of the optimal plan is its effect on farm profitability. As shown in Table 6.1 the farm surplus associated with the optimal plan is \$171,939.00 (25.25%) higher than the current plan. Before giving any further comparison of the optimal with the current plan, a detailed analysis of the optimal solution will be presented.

Table 6.1: The Optimal and Current Plans

Activity	Optimal Plan		Level	Current Plan	
PASPRO	2530	Ha		2530	Ha
PCJULY	1000	Kg DM/Ha		1000	Kg DM/Ha
PC AUG	1048	Kg DM/Ha		1043	Kg DM/Ha
PCSEP	1190	Kg DM/Ha		1158	Kg DM/Ha
PCOCT	1269	Kg DM/Ha		1178	Kg DM/Ha
PCNOV	1364	Kg DM/Ha		1285	Kg DM/Ha
PCDEC	1835	Kg DM/Ha		1871	Kg DM/Ha
PCJAN	2000	Kg DM/Ha		2000	Kg DM/Ha
PCFEB	2000	Kg DM/Ha		1966	Kg DM/Ha
PCMAR	1736	Kg DM/Ha		1674	Kg DM/Ha
PCAPR	1556	Kg DM/Ha		1460	Kg DM/Ha
PCMAY	1438	Kg DM/Ha		1365	Kg DM/Ha
PCJUN	1253	Kg DM/Ha		1240	Kg DM/Ha
BRDEWE	10000	Head		13270	Head
STMALAMB	---	---		2635	Head
FATMALMB	4854	Head		3883	Head
STFELMB	2412	Head		---	---
REPHGT	2500	Head		3317	Head
HGTSELL	---	---		3108	Head
WOOLSELL	73560	Kg Wool		108586	Kg Wool
CULLEWE	1900	Head		2521	Head
BRDCOW	1049	Head		1032	Head
REPHFR	241	Head		237	Head
STOHFR	334	Head		---	---
FATHFR	---	---		322	Head
FATSTAPR	---	---		460	Head
FATSTNOV	569	Head		100	Head
CULLCOW	209	Head		206	Head
FB1YFEB	96	Head		266	Head
FB1YJUN	874	Head		523	Head
FB2YDEC	291	Head		---	---
FBCABUY	1300	Head		814	Head
BBSCH2	25480	Kg Beef		70570	Kg Beef
BBSCH4	281660	Kg Beef		168724	Kg Beef
BBSCH5	99611	Kg Beef		---	---
BSCH1	---	---		172998	Kg Beef
BSCH2	178792	Kg Beef		31400	Kg Beef
FARM SURPLUS	852839	Dollars		680900	Dollars

6.2.2 Sheep activities included in the optimal solution (basis)

The optimal solution (Optimal Plan) shown in Table 6.1 includes 10,000 breeding ewes (BRDEWE), 2,500 replacement hoggets (REPHGT), 2,412 ewe lambs sold store at weaning (STFELMB), 4,854 ram lambs sold as prime lambs (FATMALMB), 1,900 cull ewes (CULLEWE) and a total production of 73,560 Kg of wool (WOOLSELL).

Table 6.2 shows the price range over which these activities' level in the optimal plan remains constant.

Table 6.2: Price range over which the optimal plan remains constant.

Activity	Price range over which optimal plan remains constant		
	Lower	Current	Upper
BRDEWE	-Infinity	-9.75	9.06
FATMALMB	22.94	29.90	68.66
STFELMB	14.75	15.60	93.60
REPHGT	-Infinity	-12.35	38.77
WOOLSELL	0.00	3.55	3.73
CULLEWE	0.00	15.00	114.05

The breeding ewe activity was forced into the solution by the MINEWE row (see Section 5.3.6.5), which specifies that a minimum of 10,000 breeding ewes must be in the solution, i.e., must be on the property as an essential requirement of the pasture-weed management control, according to the farm manager's perception. Reducing the level of this activity by one unit (1 breeding ewe) would increase the farm surplus by \$18.82. This indicates that for the range between 0 and 10,014 breeding ewes, each unit (each ewe) has a shadow price of -\$18.82, i.e., a cost of \$18.82. Thus, withdrawing the minimum breeding ewes constraint the breeding ewe activity, and consequently sheep, do not enter the optimal solution. Further discussion of the implications of the minimum sheep constraint is provided in the next chapter in which other plans are introduced.

All ram lambs are finished and sold prime at 14 Kg carcass weight. Each lamb would have to be worth less than \$22.94 (decrease \$6.96) before it becomes more profitable to start selling any amount of

them store. On the other hand, the price received for each lamb would have to increase by \$38.77 (being \$68.67) to become more profitable to produce more prime lambs through increased ewe numbers.

Within the model the ewe lambs can be sold store at weaning or can be reared and sold as hoggets. The ewe lambs which are not used as replacements are all sold store at weaning. The price received per ewe lamb would have to decrease \$0.86 (from \$15.60 to \$14.74) before it becomes more profitable to sell any of them as hoggets. This topic is further discussed in the following section.

With regard to wool, the price received per kilogram of wool would have to exceed \$3.73 in order to make any changes in the optimal plan. In fact, when it reaches \$3.78, the best policy is to keep all ewe lambs and sell them as hoggets. This plan provides a farm surplus of \$869,810.00 which is \$16,971 more than the optimal plan. This policy requires a reduction in the number of breeding cows (from 1,049 to 953) and, consequently, a reduction in the amount of their progeny reared.

When the wool price reaches \$5.85/Kg, the best plan includes 18,000 breeding ewes rearing all the progeny and 1,300 Friesian bulls, which is the maximum amount allowed in the model. The breeding cattle system is omitted in favour of sheep production at this wool price.

6.2.3 Sheep activities not included in the optimal solution (non-basis)

The sheep activities which did not enter the optimal plan (non-basis) are valued in relation to those activities that did enter the optimal plan. Their shadow costs (negative shadow prices) are shown in Table 6.3. Forcing one unit of any of them into the optimal plan would reduce the total farm surplus of the plan by the amount specified in the table.

Table 6.3: Shadow Costs for non-basis sheep activities

Activities	Shadow Cost (\$)
STMALMB	6.75
HGTSELL	0.87

As Table 6.3 shows, forcing the ram lambs to be sold store at weaning (STMALMB) instead of as prime, would decrease the farm surplus by \$6.75 per lamb sold. Similarly, the price received per store lamb would have to increase by \$6.76, i.e., from \$17.60 to \$24.36, before it would be economically preferable to start selling any of them store.

With regard to the ewe lambs, forcing them to be reared and sold as hoggets (HGTSELL) instead of store would decrease farm surplus by \$0.87 per hogget sold. This equates to an increase of \$0.88 in the price received per hogget (from \$24.65 to \$25.53) as necessary to make it more profitable to start rearing some ewe lambs to sell as hoggets. In fact, when the price received per hogget reaches \$25.69, i.e., increases by \$1.04, the best policy is to rear all ewe lambs and sell them as hoggets. This would require a reduction in the number of breeding cattle (953 breeding cows plus progeny instead of 1,049). However, the farm surplus in this case is \$852,849.00 which is only \$10.00 higher than the the farm surplus when all the ewe lambs are sold at weaning. As the margin of \$1.04 is relatively small, a decision on whether or not to keep ewe lambs and how many, will depend on the market expectation for an increase in hogget and/or wool prices.

6.2.4 Beef Cattle activities in the optimal solution (basis)

The beef cattle activities included in the optimal solution (Optimal Plan) shown in Table 6.1 comprise 1,049 breeding cows (BRDCOW), 241 replacement heifers (REPHFR), 334 heifers sold store at weaning (STOHFR), 569 steers taken through two winters and sold as prime cattle at the end of November (FATSTNOV), 209 cows sold as culls (CULLCOW), 1,300 Friesian bull calves bought in November (FBCABUY), 96 Friesian bulls taken through one winter and slaughtered in February (FB1YFEB), 874 Friesian bulls taken through one winter and slaughtered in June (FB1YJUN), 291 Friesian bulls taken through two winters and slaughtered in December (FB2YDEC).

As described in Chapter Five, the replacement heifer activity comprises a heifer being reared from weaning until prior to second calving. Therefore, the number of calves born per year are referred to as from a total of 1,290 cows (1,049 cows plus 241 heifers).

Table 6.4 shows the price range over which this optimal plan remains constant.

Table 6.4: Range over which the activity's level in the optimal plan remains constant

Activity	Price range over which optimal plan remains constant		
	Lower	Current	Upper
BRDCOW	-87.33	-67.55	-32.60
REPHFR	-193.34	-107.30	44.62
STOHFR	303.92	320.00	429.57
FATSTNOV	-124.86	-91.00	-19.63
CULLCOW	281.05	380.00	554.71
FBCABUY	-342.45	-310.00	0.00
FB1YFEB	-90.36	-65.15	-48.05
FB1YJUN	-97.74	-80.65	30.07
FB2YDEC	-137.33	-103.90	Infinity

The number of breeding cows in the optimal plan was determined by the minimum breeding ewes constraint (see Section 5.3.6.5) and the two constraints on bull beef numbers MAX1YBULL and MAX2YBULL (see Section 5.3.8.2) which stipulate that (1) not more than 1,000 bulls can be taken through the first winter, and (2) not more than 300 bulls can be taken through the second winter, respectively. Thus, these constraints limit the number of bull calves to be purchased to a maximum of 1,300. As this is exactly the amount selected in the optimal plan for the bull calf buying activity (FBCABUY), it indicates that these two constraints are also limiting overall farm profitability such that (1) for every unit (one bull) increased (decreased) in the MAX1YBULL constraint within the range of 881 and 1,013 Friesian bulls, overall farm surplus increases (decreases) by \$47.45, and (2) for every unit increased (decreased) in the MAX2YBULL constraint within the range of 297 and 1,551 Friesian bulls, overall farm surplus increases (decreases) by \$32.45. The effects of releasing these constraints are discussed in more detail in the next chapter which reports the sensitivity analysis for other farm plans.

Table 6.4 shows that the price paid per bull calf can go up \$32.45 (from \$310.00 to \$342.45) before it becomes more profitable to start reducing the number of calves bought from 1,300. When the price paid per calf reaches \$371.31 the bull beef system is totally omitted in favour of breeding and finishing cattle.

The cost of rearing a bull would need to go up \$25.21 (\$90.36 less \$65.15) or down \$17.10 (\$65.15 less \$48.05) before the optimal level for the FB1YFEB activity decreases or increases, respectively. For the FB1YJUN activity, this cost will have to rise \$17.09 (\$97.74 less \$80.65) or diminish \$50.58 (\$80.65 less \$80.65) before that activity's level in the optimal solution is reduced or augmented, respectively. Similarly, the cost figure for the FB2YDEC activity will have to increase \$33.43 per bull (\$137.33 less \$103.90) before its level in the optimal solution is decreased.

The level of the replacement heifer (REPHFR) and cull cow (CULLCOW) activities in the optimal solution is directly related to that of the breeding cow activity, since, within the model, these activities are expressed as a percentage of breeding cow numbers. Therefore, a variation in the level of these activities will only occur if the level of the breeding cow activity changes. For the level of the breeding cow activity in the optimal solution to decrease (increase) it is necessary that its cost increases by \$19.78 (decreases by \$34.95).

The optimal solution specifies that all 569 steer calves be kept for two winters and be slaughtered in the following November. This is the optimal level for this steer finishing activity unless the cost of this activity increases by \$33.86 (\$124.86 less \$91.00) or decreases by \$71.37 (\$91.00 less \$19.63). The reason why this activity is the best steer finishing policy is related to the fact that the bull beef activities are more profitable than the steer ones. Therefore, keeping the steers for two winters at a lower liveweight gain rate allows higher gains to be achieved by the Friesian bulls, thus allowing 970 bulls (77% of them) to be slaughtered before their second winter on the farm, and consequently, allowing a higher number of bulls to be carried on the property.

6.2.5 Beef Cattle activities not included in the optimal solution (non-basis)

The beef cattle activities which did not enter the optimal plan (non-basis) are valued in relation to those in the solution. Forcing one unit of these activities in the optimal solution would reduce farm surplus by the amount shown in Table 6.5. This amount represents the shadow cost (negative shadow price) associated with each of the non-basis activities.

Table 6.5: Shadow Costs for non-basis beef cattle activities

Activity	Shadow Cost (\$)
FATHFR	62.13
STOSTR	21.75
FATSTAPR	107.98
FATSTJUN	109.18
OBHFR	21.53
OBSTHFR	47.85
OBFTHFR	41.93
OBSTSTR	41.07
OBSTAPR	107.98
OBSTJUN	109.18
OBSTNOV	48.81
FB1YDEC	73.30
FB1YAPR	11.60

As shown in table 6.5, there would have to be an increase of more than \$62.13 in the value of the FATHFR activity in order to make it more profitable to start finishing heifers instead of selling them all as store cattle. This increase in value can be either by a reduction in cost or by an increase in the beef schedule of \$0.28 (from \$2.30 to \$2.58/Kg carcass). Similarly, to become more profitable to start selling steers as store cattle it would require an increase of \$21.75 (\$361.75 instead of \$340.00) in the price received per weaner.

With regard to the once-bred heifer system, the level of these activities is directly related to that of the once-bred heifer (OBHFR) activity. Therefore, a variation in the level of these activities will only occur if the level of the OBHFR activity changes. The once-bred heifer activity (OBHFR) is the one that requires the smallest increase in value (\$21.53) as a means to start bringing that activity into the optimal solution. This in turn means a \$0.10 increase in the heifer schedule (from \$2.20 to \$2.30/Kg carcass).

6.2.6 Pasture Production activity

The pasture production activity (PASPRO) represents the monthly supply of pasture as described in Section 5.2.1. The optimal solution uses 2,530 ha of pasture which represents the maximum area available.

The shadow price for land is \$389.00 per hectare, which gives an indicative upper limit on annual rentals per hectare of additional land, if such land could be acquired and incorporated into the optimal farming plan. In other words it means that an extra hectare of pasture would increase the farm surplus by that value, i.e., it is worth leasing land paying up to \$389.00/ha.

6.2.7 Feed Wasting activities

The model allows feed to be wasted where, feed supply exceeds feed demand and where pasture cover is at the upper limit (see Section 5.3.2). However, these feed wasting activities are at zero level.

6.2.8 Hay activities

The hay activities comprise hay making and feeding out activities. The hay making activities are all non-basis activities, i.e., are not included in the optimal plan. As a result, none of the feeding out activities are in the optimal plan either. The inclusion of any of the hay making activities in the optimal solution would incur a reduction in total farm surplus. The cost value (shadow cost) for each of these activities is presented in Table 6.6.

Table 6.6: Shadow Cost for Hay Making Activities

Activity	Shadow Cost (\$/bale)
HMAKDEC	3.11
HMAKJAN	3.11
HMAKFEB	3.52

The shadow cost figure for making hay indicates that if, for instance, the decision to make hay in February (HMAKFEB) was made, it would cause a reduction in total farm surplus of \$3.52 per bale of hay made. This indicates that, in terms of animal products, the value of the amount of hay fed out is smaller than the value of the amount of pasture cut. This discussion is extended in Section 6.2.10.

6.2.9 Nitrogen activities

The nitrogen (N) activities are also non-basis activities, i.e., they did not enter the optimal solution. Table 6.7 shows that the cost per kilogram of nitrogen would have to decrease by \$0.35 in order to make N an economically viable option of producing more feed at critical times.

Table 6.7: Shadow Cost for Nitrogen

Activity	Shadow Cost (\$/Kg N)
NJUN	0.34
NJUL	0.34
NAUG	0.34
NSEP	0.34

Table 6.7 demonstrates that, assuming a response of 10 Kg of dry matter per kilogram of N applied (see Section 5.2.6), unless the cost of nitrogen goes down from \$1.00 (see Appendix 4) to \$0.65 per kilogram of N applied, it is not profitable to use it. If the N cost is reduced to \$0.65/Kg applied then the application of N in September enters the optimal solution.

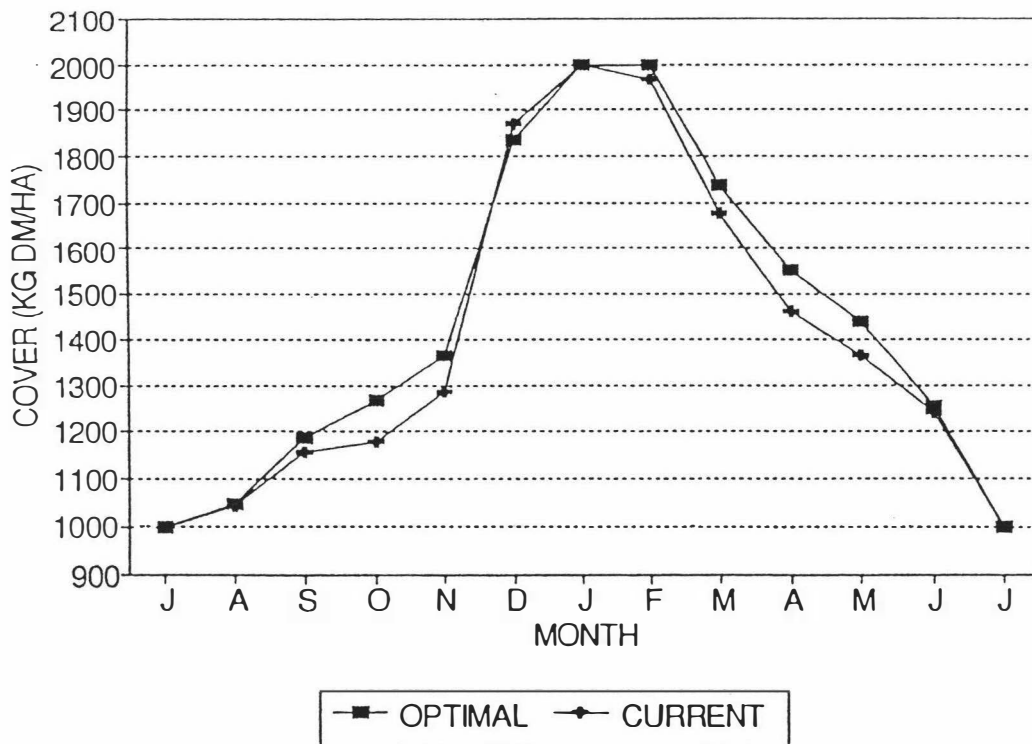
When the response rate is 15.5:1 (15.5 KgDM per Kg of nitrogen applied) it becomes profitable to apply nitrogen in June. Due to the fact that the most profitable activities (bull beef system) are already at the maximum level, the increase in pasture production results in an increase in breeding cattle numbers. For instance, when the response rate is 17:1, the increase in pasture production allows 1,355 cows plus progeny to be run on the farm instead of 1,049.

6.2.10 Pasture Cover activities

Pasture cover is a function of feed supply and demand throughout the year. The monthly supply of feed used in the model was calculated using average pasture growth rates, which were assumed to be fixed regardless of pasture cover, provided that pasture cover was within the bounds set in the model, i.e., between 1000 and 2000 KgDM/ha (see Section 5.3.2).

For the optimal plan, the pasture cover activities reflect the levels of pasture cover at the start of each month which best match animal requirements with the available supply of feed. The pasture cover levels for the optimal and current plans presented in Table 6.1 are shown in Figure 6.2.

Figure 6.1: Pasture Cover Levels for the Optimal and Current plans



As Figure 6.1 shows, both plans follow the same trend of pasture use. From July to January the supply of feed exceeds animal demand. Therefore, there is an accumulation of pasture during this period demonstrated by the increase in pasture cover. Conversely, from January/February to July, animal demand exceeds the supply of feed. As a result, a decrease in pasture cover occurs.

The value of feed available in each period follows the same trend. This is demonstrated in Table 6.8 which shows the value (shadow prices) for each extra unit of feed (kilogram of dry matter) in each month, if such feed was available.

Table 6.8: Shadow prices for feed in each month

Month	Feed Shadow Price (\$)
JULY	0.066
AUGUST	0.066
SEPTEMBER	0.066
OCTOBER	0.066
NOVEMBER	0.066
DECEMBER	0.066
JANUARY	0.066
FEBRUARY	0.082
MARCH	0.082
APRIL	0.082
MAY	0.082
JUNE	0.082

While feed supply exceeds feed demand in the period from July to January, the build up in pasture cover is used to meet animal demands in the period from January to July when feed demand exceeds feed supply. However, if extra feed was made available it could be utilised by activities profitably, provided it was supplied at a cost of less than 6.6 cents per KgDM from July to January, and/or less than 8.2 cents per KgDM from January to July. This explains the reason why it is not profitable (1) to conserve pasture as hay and (2) to apply nitrogen.

- 1) The hay making activities are not included in the optimal solution. Thus, the cost of making hay is greater than the extra income that can be generated by feeding out hay. The cost of making a 25 KgDM bale of hay is \$2.50. Assuming losses of 50%, it indicates that the direct cost of hay is 20 cents per Kg of dry matter (see Appendix 3).

- 2) The nitrogen activities assume a response of 10 Kg of dry matter per Kg of nitrogen applied. As the total cost of applying nitrogen is \$1.00 per Kg of nitrogen, this implies a cost of 10 cents per Kg of dry matter produced (see Appendix 4).

As the value of additional feed throughout the year varies between 6.6 and 8.2 cents per Kg of dry matter, within the production possibilities explored in this study it is not profitable to conserve pasture as hay or to apply artificial nitrogen fertiliser.

3.3 Comparison of Optimal and Current Plans

The differences between the existing farm plan and the optimal plan as derived in this study were presented in Table 6.1. At 1990 prices, the optimal plan has a \$171,930.00 advantage in Farm Surplus over the current plan.

In this section an analysis of the two plans is presented. Sheep and cattle activities are discussed separately.

When comparing current and optimal plans, the difference represents dollar gains assuming the adoption of the optimal plan.

3.3.1 Sheep Scenario

A comparison between the sheep activities in the current and in the optimal plan is provided in Figure 3.2 which shows the stock numbers for both plans.

Figure 6.2: Sheep Numbers for the Current and Optimal Plans

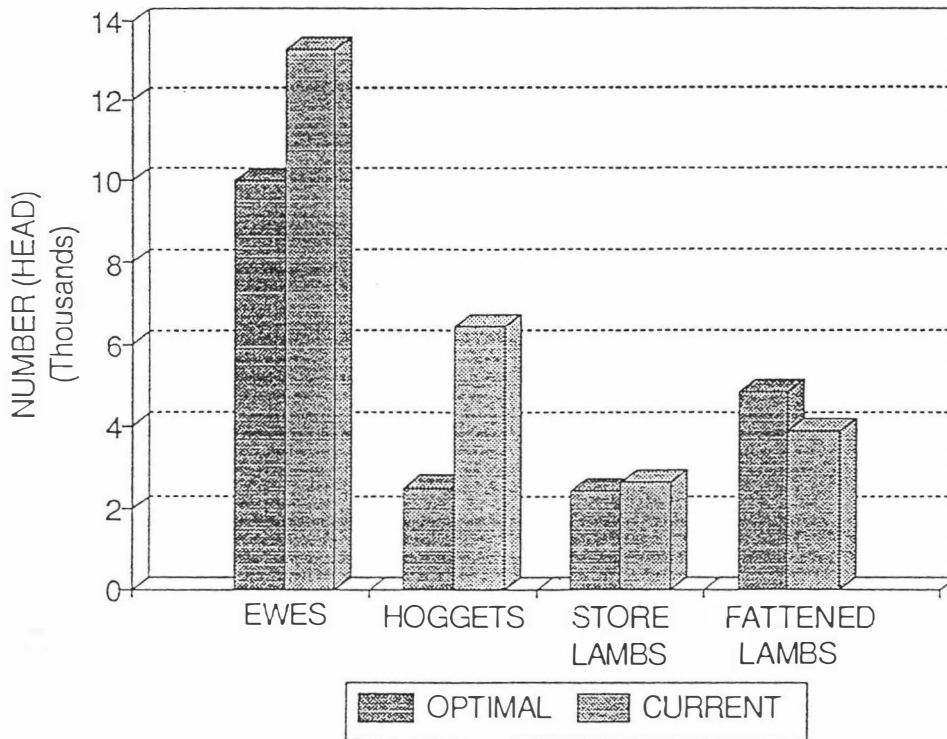


Figure 6.2 shows that the optimal plan includes 3,270 breeding ewes less than the current plan. As discussed in Section 6.2.2, this difference equates to a forgone income in the current plan of \$61,541.00 (\$18.82/ewe).

The effects of a reduction in the minimum number of breeding ewes required on the farm from 10,000 to 8,000 ewes are discussed in Chapter Seven.

Although the number of store lambs sold in both plans is very similar, for the current plan it represents ram lambs whilst in the optimal plan it represents ewe lambs. While in the optimal plan all ram lambs are finished and sold as prime, in the current plan 2,635 lambs (40%) are sold store. This represents a forgone income of \$17,786.00 (\$6.75/lamb) as discussed in Section 6.2.3.

In the optimal plan only the replacement ewe lambs are reared with the remainder ewe lambs sold store. In the current plan all ewe lambs are reared and the non-replacement stock (3,108 head) are sold as hoggets. As discussed in Section 6.2.3, this represents a forgone income of \$2,704.00, i.e., \$0.87/hogget.

For the 1991 season, a decision to reduce the number of hoggets on the property was made. This coincides with the results here discussed.

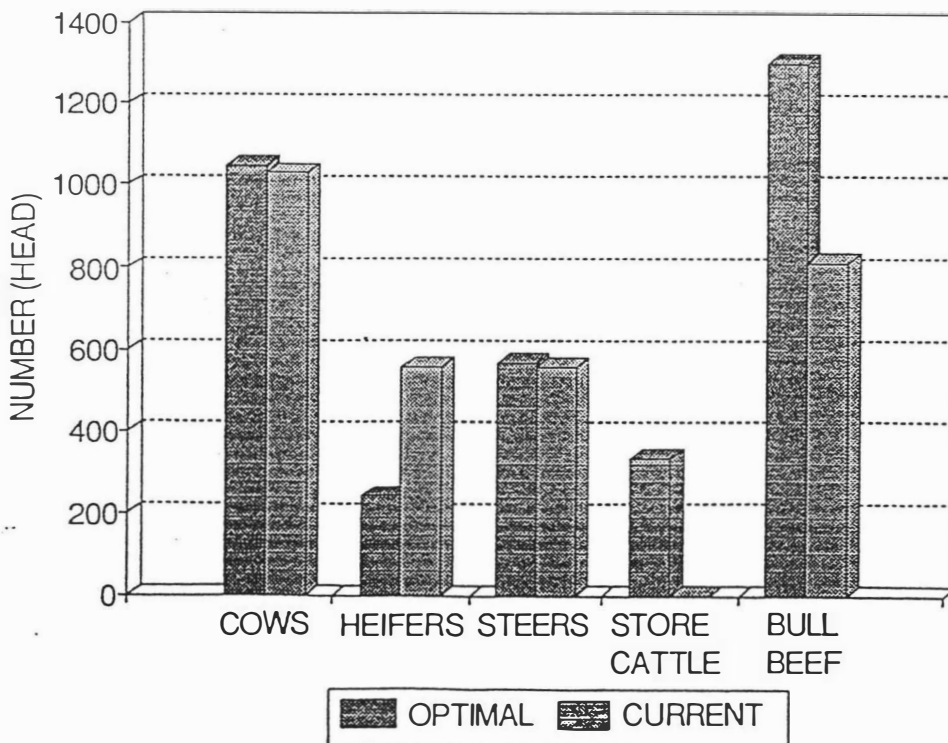
The amount of wool produced in both plans reflects the difference in sheep numbers, and in addition, the number of hoggets reared in the current plan further contributes to increased wool production.

Recently, the price received per kilogram of wool was drastically reduced from \$3.55 to \$2.40/Kg. The implications of such a reduction are discussed in Chapter Seven.

6.3.2 Beef Cattle Scenario

A comparison between the cattle activities in the current and in the optimal plan is provided in Figure 6.3 which shows the stock numbers for both plans.

Figure 6.3: Cattle Numbers for the Current and Optimal Plans



The number of breeding cows carried in both plans is very similar. The same applies to the number of steers sold as prime cattle. The major difference is in the number of heifers reared and, consequently, in the number of cattle sold store. While in the optimal plan the non-replacement heifers are sold store as weaners, in the current plan all the heifers are reared and the non-replacement ones (322 head) are finished and sold as prime cattle. As discussed in Section 6.2.5, these 322 heifers which are sold prime in the current plan represent a forgone income of \$20,000.00 (\$62.13/heifer).

The farm is at present running 471 fewer bulls than the constraints suggested by the manager. This equates to a difference of 180 bulls finished before their second winter on the farm, and 291 bulls taken through the second winter. As discussed in Section 6.2.4, this represents a forgone income in the current plan of \$17,984.00 (\$47.45/bull finished before the second winter and \$32.45/bull taken through the second winter).

The effects of releasing the constraints on bull beef numbers are discussed in the next chapter.

6.4 CONCLUSION

The results presented and discussed in this chapter indicate that, at the assumed prices, there is scope for a substantial improvement in overall farm profitability without having to make major changes in the current farm policy.

The proposed optimal plan represents the best way of allocating feed to different classes of livestock subject to a number of constraints. Although all these constraints are objectively expressed in the model, some of them represent subjective perceptions of the farm manager which were gained through experience and are revised and reformulated as a consequence of technological improvements. The extent to which some of these constraints affect farm profitability have been discussed in this chapter.

Chapter Seven

SENSITIVITY ANALYSIS

This chapter reports the implications of changes to some of the parameters specified in the model presented in Chapter Five. For each change made a new optimal plan arises. These resulting new plans are presented and discussed here.

7.1 INTRODUCTION

The results discussed in Chapter Six demonstrate that some of the constraints specified in the model have a major impact on overall farm profitability. In this section the significance of changing these constraints are investigated. Furthermore, the effects of the recent drop in wool price are analysed. These changes were made in order to answer the following questions:

- 1) What are the implications in overall farm profitability of the recent fall in wool price from \$3.55 to \$2.40/Kg?
- 2) What are the implications of reducing the constraint on minimum breeding ewe numbers from 10,000 to 8,000 ewes?
- 3) What are the implications of releasing the bull beef constraints MAX1YBULL and MAX2YBULL from 1,000 and 300 bulls to 2,000 and 500 bulls, respectively?
- 4) What is the overall effect of changing the constraints described in (2) and (3) above in the same plan?
- 5) What are the implication of withdrawing all of the constraints on livestock numbers?

For each one of these questions a new optimal plan was derived such that Plan I represents question (1), Plan II represents question (2), and so forth.

7.2 RESULTS

The outcome of the five resulting plans are shown in Table 7.1.

Table 7.1: Plans I, II, III, IV and V

Activity	Plan I	Plan II	Plan III	Plan IV	Plan V	Unit
BRDEWE	10000	8000	10000	8000	---	Head
STMALAMB	---	---	---	---	---	Head
FATMALMB	4854	3883	4854	3833	---	Head
STFELMB	2412	1930	2412	1930	---	Head
REPHGT	2500	2000	2500	2000	---	Head
HGTSELL	---	---	---	---	---	Head
WOOLSELL	73560	58848	73560	58848	---	Kg Wool
CULLEWE	1900	1520	1900	1520	---	Head
BRDCOW	1049	1276	374	601	---	Head
REPHFR	241	293	86	138	---	Head
STOHFR	334	407	119	191	---	Head
FATHFR	---	---	---	---	---	Head
FATSTAPR	---	---	---	---	---	Head
FATSTNOV	569	692	202	326	---	Head
CULLCOW	209	255	74	120	---	Head
FB1YFEB	96	87	947	939	6746	Head
FB1YJUN	874	883	993	1002	---	Head
FB2YDEC	291	291	485	485	---	Head
FBCABUY	1300	1300	2500	2500	6949	Head
BBSCH2	25480	23238	251189	248947	1787866	Kg Beef
BBSCH4	281660	284384	320024	322748	---	Kg Beef
BBSCH5	99611	99611	166019	166019	---	Kg Beef
BSCH1	---	---	---	---	---	Kg Beef
BSCH2	178792	217529	63731	102468	---	Kg Beef
FARM SURPLUS	768244	890479	906782	944422	1280517	Dollars

The pattern of change in pasture cover throughout the year for each of these plans is presented in Figure 7.1.

Figure 7.1: Pasture Cover Levels for Plans I, II, III, IV and V

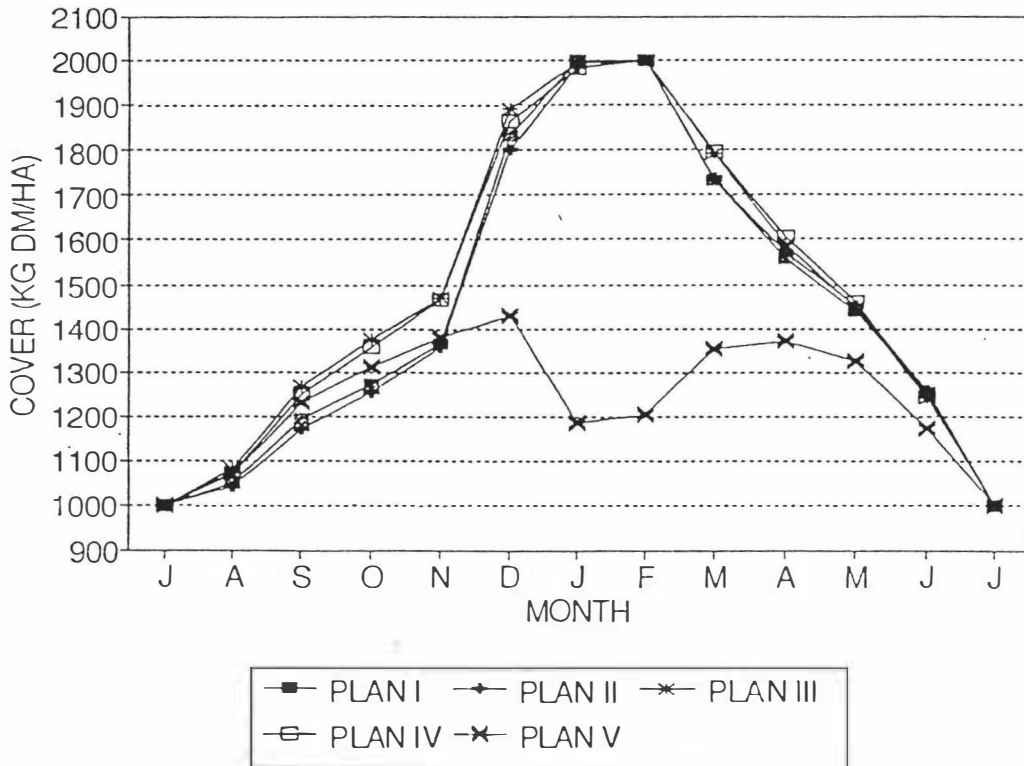


Figure 7.1 shows that, except for Plan V, all the other plans follow the same trend of pasture use. For Plans I to IV as well as for the Optimal Plan (as described in Section 6.2.10), from July to January feed supply exceeds animal demand. Thus, during this period there is an increase in pasture cover.

Conversely, from February to July animal demand surpasses the supply of feed and a decrease in pasture cover occurs.

Due to the fact that Plan V represents the whole farm as a bull beef system in which the calves are bought in November and sold 16 months later in February, during the period from November to February the number of bulls on the property is doubled. This explains the different trend of pasture use for this plan in relation to the other plans.

7.3 DISCUSSION

7.3.1 Plan I

Plan I comprises the same activities and activity levels as the optimal plan discussed in Chapter Six. The only difference is a reduction in the price received per kg of wool from \$3.55 to \$2.40. Such a reduction is responsible for a \$84,595.00 decrease in farm surplus.

Due to the fact that the MINEWE constraint prevented the reduction of sheep numbers (see Section 3.2.2), the implications of such reduction in wool price can only be expressed as changes in shadow prices for the sheep activities, such that:

- 1) An increase in breeding ewe numbers by 1 ewe would incur a decrease in total farm surplus of \$27.27. Conversely, the substitution of sheep by cattle would mean an increase in total farm surplus of \$27.27 per breeding ewe dropped. Since the number of Friesian bulls is at the maximum level allowed in the model, any increase in cattle numbers would be by means of an increase in breeding and finishing cattle.
- 2) Wintering ewe lambs and selling them as hoggets would reduce the farm surplus by \$6.16/lamb compared with selling them as store lambs. It must be emphasized that this figure was \$0.87 in the optimal plan (see Section 6.2.3). Thus, it highlights the importance of the wool price on the profitability of the hogget activity. Therefore, this analysis supports the manager's decision taken recently to reduce the number of ewe hoggets on the property.

7.3.2 Plan II

Plan II represents a reduction in the minimum requirement of breeding ewe numbers on the farm from 10,000 to 8,000 ewes. Due to the fact that the two constraints on Friesian bull numbers (see Section 5.3.5) were maintained, this decrease in breeding ewe numbers was compensated for by an increase in breeding and finishing cattle. The 2,000 breeding ewes (plus progeny) dropped allowed 227 extra cows (plus progeny) to be carried. Apart from the differences in the levels of the activities directly related to that of the BRDEWE and BRDCOW activities, the activities included in the solution for this plan represent the same activities included in the optimal plan discussed in the previous chapter.

The overall result of this plan is an increase in total farm surplus of \$37,640.00 over the optimal plan discussed in Chapter Six.

7.3.3 Plan III

In Plan III, the two constraints on bull beef numbers were released, such that:

- 1) $\text{MAX1YBULL} \leq 2000$, and,
- 2) $\text{MAX2YBULL} \leq 500$

Therefore, the number of yearling bulls on the property was limited to not more than 2000, and the number of bulls taken through the second winter was limited to not more than 500.

Note that the constraint on minimum breeding ewe numbers was maintained. Therefore, sheep numbers in this plan remained the same as in the optimal plan (see Section 6.2.1).

The solution for this plan represents an increase in bull beef numbers up to the new maximum limits specified. This equates to 1,200 extra bulls carried on the farm as to compensate for a decrease of 675 breeding cows plus progeny.

In this plan, changes in the level of the finishing activities in relation to the optimal plan arise. These changes are shown in Table 7.2.

Table 7.2: Percentage of Bulls in each Finishing Policy Option for the Optimal Plan and Plan III

Activity	Percentage of Bulls Optimal	Plan III
FB1YDEC	0%	0%
FB1YFEB	8%	39%
FB1YAPR	0%	0%
FB1YJUN	69%	41%
FB2YDEC	23%	20%

Table 7.2 shows that allowing more bulls to be run on the farm it increases the number of bulls finished in February with lesser bulls finished in June.

Due to the fact that the cattle activities are more profitable than the sheep ones and, of these, the bull beef activities are the most profitable activities carried out on the farm, the model responds to the bull constraints by carrying the lower numbers for longer.

The changes analysed in this plan generate \$53,943.00 more than the optimal plan discussed in Chapter Six.

7.3.4 Plan IV

Plan IV is a combination of Plans II and III, which means that the model was allowed to:

- 1) increase the number of bull calves bought in to a maximum of 2500;
- 2) decrease breeding ewe numbers to a minimum of 8000.

The solution for this plan (see Table 7.1) represents an increase in the number of bulls carried by 1200. This brought this activity level up to the new maximum upper limit of 2500 calves bought. As a result, a reduction in both sheep and breeding cattle numbers occurred, such that:

- breeding ewe numbers were decreased by 2000 ewes down to 8000, which is the new lower limit specified in the model. Consequently, the level of the related sheep activities was proportionally reduced.

- the level of the breeding cow activity was decreased by 448 cows in relation to that activity's level in the optimal plan. As a result, the levels of the other cattle activities associated with the breeding cow one were proportionally reduced.

The changes investigated in this plan represent a \$91,583.00 increase in farm surplus when compared with the optimal plan discussed in Chapter Six.

7.3.5 Plan V

Plan V consists of removing the constraints on minimum breeding ewe numbers and maximum bull beef numbers. Therefore, it allows the model to freely select between sheep, breeding cattle and bull beef activities, the best mix to maximise profit.

As presented in Table 7.1, the solution for this plan includes the purchase of 6949 bull calves of which 6746 (assuming losses of 3%) are sold in February after being on the property for 16 months.

This plan generates a farm surplus of \$1,280,517.00 which represents \$427,687.00 more than the optimal plan discussed in Chapter Six.

In this plan, it is assumed that the level of performance achieved by the Friesian bulls on the flat areas of the farm can also be achieved on the hills. Moreover, the pattern of pasture cover is quite different (see Figure 7.1). Further investigation of this option will require more information on the performance of bulls being fed on the hills and on the effect that the resultant low pasture cover levels may have on animal intake and pasture growth rates.

7.3.6 Other Responses to Constraint Variation

None of the five plans discussed in this chapter contain activities which were not included in the optimal plan discussed in Chapter Six.

Except for Plan V, all the other plans have the same shadow costs for hay making and nitrogen activities as discussed in Sections 6.2.8 and 6.2.9, respectively.

For Plan V, the shadow cost associated with the hay making activities increased to \$3.58/bale made for each of the three periods in which hay is allowed to be made. Conversely, the shadow cost of the nitrogen activities decreased to \$0.13/Kg of N applied for each of the four periods when nitrogen is allowed to be applied.

The feed wasting activities remained at zero level for all plans.

7.4 CONCLUSION

The five scenarios discussed in this chapter demonstrate that, at the assumed prices, the limit imposed on the maximum level of Friesian bulls that can be run on the property is the major impediment to the enhancement of higher profits. The second most important factor limiting farm profitability is the requirement of sheep on the farm.

Therefore, the increase in farm profitability for Limestone Downs is directly dependent on the rate at which these two major constraints can be overcome.

Chapter Eight

CONCLUSIONS

8.1 INTRODUCTION

In this section, the value of linear programming to this study is considered. The areas in which the lack of information available limited further conclusions is highlighted and the need for further research is outlined. Finally, the study is evaluated in relation to its objectives.

8.2 EVALUATION OF THE PLANNING TOOL

The use of Linear Programming (LP) has shown that the technique can be used within the context of a pastoral farm situation to indicate means of significantly increasing profits through the better allocation of the available resources, especially the feed resources. This increase was achieved without any per unit improvement in technical performance.

The LP procedure has enabled the farm under study to be analysed in a more comprehensive and practical way than would have been the case if the current budgetary planning methods were applied. The method enabled a greater range of alternative adjustments and their consequences to be analysed.

Part of the merit of Linear Programming is that an optimal plan which maximises profit is reached. With the budgeting procedure, it may be relatively easy to improve the existing system but the resulting plan can still fall a long way short of the optimal.

Furthermore, the solution data provided by LP showed the relative financial advantage of activities included in the optimal plan over those that were not included and the ranges over which these advantages held.

Also, the various plans computed in the sensitivity analysis provided an indication of what could be expected or could be done if changes in the assumptions made during planning were envisaged, i.e.,

the sensitivity analysis results showed how increasing or decreasing one or more resources would affect the optimal mix of activities and the overall value (Farm Surplus) of the plan.

Another advantage of LP over budgeting is that it allows the correct substitution rates between enterprises to be established. When using a budget to compare activities, the substitution rate is usually calculated by comparing stock units (s.u., a standardized estimate of annual feed requirements), actual annual feed requirements, or actual feed requirements at some key time of the year, usually winter. The substitution rate and hence the value of the comparison will vary depending on which criterion is used.

Within the LP model, one class of livestock substitutes another at the appropriate rate. This is determined by the availability of feed at the shortest time of the year, subject to the optimal adjustment of other sources of feed supply and demand (taking into account their costs and returns), and the constraints placed on feed transfer, in this case, pasture cover.

A major weakness of the LP model used in this study was that the best way of moving from the current situation to the optimal plans derived was not considered.

Also, the LP procedure does not explicitly consider risk. This is particularly important on a farm situation where overall farm performance is exposed to climatic vagaries and seasonal changes in pasture production.

Nevertheless, as stated by Simpson (1960) "the skillful use of linear programming should provide a guide to the direction in which a farm system ought to be developed if it is to return a high level of profits."

8.3 AREAS FOR FURTHER RESEARCH

The model developed for this study has revealed that, at the assumed prices, the more profitable activities currently exploited on the farm are the bull beef system, the breeding and finishing cattle system and the dual purpose sheep system, respectively.

It also demonstrated that the achievement of higher profits for Limestone Downs is dependent on the limit imposed for the bull beef and the sheep activities. Three questions then, are still to be answered:

- 1) What is the real significance of the constraints imposed by the need for sheep and the limit on bull beef numbers?
- 2) What are the effects of climatic variability and hence feed supply and feed quality on annual farm profitability?
- 3) Having considered the issues raised in questions (1) and (2), and decided on a plan that is optimal, how does the farm best move from its current plan to that plan?

Developing management skills and having confidence to handle the numbers have been the constraints limiting bull beef on the property. These have been overcome over the years, and so there has been a gradual increase in the number of bull calves bought. For the 1991 season, over 1,000 Friesian bulls will be wintered on the farm for the first time.

Currently, all the bulls have been run on the flat areas of the property. As their number increases a proportion of them will have to be taken to the hills. This is likely to reduce their performances. Therefore, the effects of feed supply and feed quality on hills will need to be monitored.

A substantial increase in the size of the bull beef system will result in a major proportion of farm revenue coming from one enterprise. This would expose farm profitability to the vagaries of that particular market. The supply of bull calves would also require investigation.

With regard to sheep, it was demonstrated that the higher the number of sheep the lower the profits. The reasons for having sheep include weed control (since ragwort could become a problem), and to help control pasture surplus and maintain pasture quality over the summer/autumn period. Furthermore, the production of lamb and wool would help on the risk side of the equation as a means of diversification.

To answer questions such as:

- 1) how many sheep are necessary to help control pasture quality?
- 2) whether or not the chemical control of weeds, particularly ragwort, would be more profitable than sheep?

data which is currently not available is required. Estimates of this data will need to be incorporated into the model so that the questions can be answered.

The extent to which combinations of the main production activities can buffer profit against risk, especially climatic variability, needs to be considered more than has been done in this study. For instance, the effects of a dry summer on the current and optimal plan may have little impact on overall farm profitability if part of the stock (e.g. breeding ewes and breeding cows) could be kept at maintenance levels and target weights could still be met so as to allow finishing stock to achieve their liveweight gain targets. By contrast, in Plan V, a reduction in the supply of feed would mean a reduction on liveweight gain of finishing stock, and hence a direct reduction of profit.

Such issues have not been addressed in this study but need to be before major changes in the current farm plan are contemplated.

If a more detailed consideration of the constraints imposed by the need to run set numbers of sheep or beef cattle leads to the acceptance of the need for major changes in farm plan, then the question of how best to change from the current plan to that new plan will have to be addressed. It is likely that an inter-temporal LP model will be required to handle this task.

8.4 CONCLUSIONS

The aims of the study were first, to develop a linear programming model for the case study farm. Secondly, to use this model to determine optimal farm plans and associated information. Thirdly, to evaluate the technique as to its suitability as an aid to farm planning.

The development of the model in Chapter Five, the discussion of the results in Chapters Six and Seven show that the first two aims are adequately met.

The LP model developed in this study has demonstrated that farm profitability for Limestone Downs could be substantially increased by allocating the farm resources optimally. The evaluation of the effects of changing the more important assumptions proved to be useful in defining quite clearly where further information and study is needed, so that management can plan and implement the necessary changes. However, major areas for further research, including the development of an inter-temporal model are needed, before major changes can be contemplated. While this, in effect, questions the value of the model reported in this study, its development has been a necessary first step in a more detailed approach to finding long term optimal plans for Limestone Downs.

Appendix 2: PASTURE PRODUCTION ACTIVITY

The values showed here represent total annual farm expenditure excluding the costs directly associated to other activities included in the model.

TOTAL FARM EXPENDITURES (2530 ha)

	\$
WORKING EXPENSES	
Salaries	190,073
Wages	13,908
ACC levies	2,833
Electricity	10,655
Fertiliser	120,113
Purchase dogs, etc.	1,949
Sundry expenses	2,656
Travelling expenses	10,861
Weed and Pest control	11,450
REPAIRS AND MAINTENANCE	
R & M Buildings	20,797
R & M Equipment	5,021
R & M Improvements	20,411
Vehicle expenses	15,365
ADMINISTRATIVE EXPENSES	
Expenses of Appointment	900
General expenses	3,365
Postage and Stationary	1,493
Supervision expenses	3,455
Telephones	4,896
STANDING CHARGES	
Accountancy Charges	7,500
Audit	2,000
Insurance	3,051
Rates	31,145
Supervision Fees	17,496

\$501,093

\$200/ha

Appendix 3: HAY MAKING ACTIVITY

Cutting, windrowing, baling, collecting (PER BALE) \$- 2.50

(Source: Lincoln College 1990 FINANCIAL BUDGET MANUAL)

Appendix 4: NITROGEN ACTIVITY

Nitrogen can be applied as Urea.

The cost per tonne applied is \$460. (Pers. comm. Elders Pastoral)

As Urea has 46% N this equates to a cost of \$1/kg of nitrogen.

The assumed response rate is 10 kg DM per kg of N applied.

Thus, this gives a cost of 10 cents per kg of dry matter.

Appendix 5: BREEDING EWE ACTIVITY

C.O.C.	\$30 for 12 mths @ 15%p.a.	\$-4.50	
Animal Health:	1 drench (docking)	\$-0.40	
	1 dip	\$-0.35	
	lambing vaccine	\$-0.10	
Shearing:	2 @ \$1.80	\$-3.60	
	dagging 2 @ \$0.40	\$-0.80	
			<hr/>
			\$-9.75

(C.O.C. = Cost of capital)

Appendix 6: REPLACEMENT HOGGET ACTIVITY

C.O.C.	\$17 for 15 mths @ 15%p.a.	\$-3.20	
Animal Health:	10 drenches @ \$0.14	\$-1.40	
	(mid Nov...mid Jun, shearing and mating)		
	3 dips @ \$0.35	\$-1.05	
	two-tooth vaccine	\$-0.10	
Shearing:	3 (lamb, hgt, 2th) @ \$1.80	\$-5.40	
	3 dagging @ \$0.40	\$-1.20	
			<hr/>
			\$-12.35

Appendix 7: RAM LAMB ACTIVITIES

Store ram lamb:	(STMALAMB)	\$18.00	
	1 dagging	\$- 0.40	<hr/>
			\$ 17.60

Finished ram lamb:	(FATMALAMB)		
C.O.C.	\$17 for 3 mths @ 15%p.a.	\$- 0.64	
Animal Health:	4 drenches (Nov..Feb) @ \$0.14	\$- 0.56	
	2 dips (weaning, shear) @ \$0.35	\$- 0.70	
Shearing:	(January)	\$- 1.80	
	1 dagging	\$- 0.40	
Mutton:	14 Kg c/c	\$34.00	<hr/>
			\$ 29.90

Appendix 8: EWE LAMB ACTIVITIES

Store ewe lamb:	(STFELAMB)	\$16.00	
	1 dagging	\$- 0.40	<hr/>
			\$ 15.60

Hogget selling:	(HGTSELL)		
C.O.C.	\$17 for 10 mths @ 15%p.a.	\$- 2.13	
Animal Health:	8 drenches (Nov..Feb) @ \$0.14	\$- 1.12	
	2 dips (weaning, shearing) @ \$0.35	\$- 0.70	
Shearing:	2 @ \$1.80	\$- 3.60	
	2 dagging \$0.40	\$- 0.80	
Selling hogget:		\$33.00	<hr/>
			\$ 24.65

Appendix 9: BREEDING COW ACTIVITY

C.O.C.	\$400 for 12 mths @ 15%p.a.	\$-60.00	
An. breeding:	pregnancy test	\$- 2.00	
Buying in breeding bull 3% @ \$2,500/5years (77%)		\$-11.55	
Selling breeding bull 3% @ \$1,300/5years (77%)		\$ 6.00	
			<hr/>
			\$-67.55

The 77% figure represents the percentage of breeding cows on the breeding herd.

Appendix 10: REPLACEMENT HEIFER ACTIVITY

C.O.C.	\$320 for 24 mths @ 15%p.a.	\$-96.00	
An. breeding:	2 pregnancy test @ \$2	\$- 4.00	
Buying in 2y breeding bull 3% @ \$2,500/5years 23%		\$- 6.90	
Selling 2y breeding bull 3% @ \$1,300/5years 23%		\$ 3.60	
Animal Health:	4 drenches @ \$1.00	\$- 4.00	
	(weaning, start/end winter, next winter)		
			<hr/>
			\$-107.30

Appendix 11: HEIFER FINISHING ACTIVITY

C.O.C.	\$320 for 13 mths @ 15%p.a.	\$-52.00
Animal Health:	6 drenches @ \$1.00	\$- 6.00 <u> </u>
		\$-58.00

Appendix 12: STEER FINISHING ACTIVITY

FATSTAPR

C.O.C.	\$340 for 13 mths @ 15%p.a.	\$-52.25
Animal Health:	6 drenches @ \$1.00	\$- 6.00 <u> </u>
		\$-61.25

FATSTJUN

C.O.C.	\$340 for 15 mths @ 15%p.a.	\$-63.75
Animal Health:	6 drenches @ \$1.00	\$- 6.00 <u> </u>
		\$-69.75

FATSTNOV

C.O.C.	\$340 for 20 mths @ 15%p.a.	\$-85.00
Animal Health:	6 drenches @ \$1.00	\$- 6.00 <u> </u>
		\$-91.00

Appendix 13: ONCE-BRED HEIFER ACTIVITY (OBHFR)

C.O.C.	\$320 for 21 mths @ 15%p.a.	\$-84.00	
An. breeding:	1 pregnancy test @ \$2	\$- 2.00	
Animal Health:	4 drenches @ \$1.00	\$- 4.00	
	(weaning, start/end winter, next winter)		
			<hr/>
			\$-90.00

Appendix 14: OBH HEIFER CALF ACTIVITIES

OBSTHFR			
Store heifer:	147Kg LW		\$270.00
OBFTHFR			
C.O.C.	\$320 for 15 mths @ 15%p.a.	\$-60.00	
Animal Health:	6 drenches @ \$1.00	\$- 6.00	
			<hr/>
			\$-66.00

Appendix 15: OBH STEER CALF ACTIVITIES

OBSTSTR

Store steer: 147Kg LW \$290

OBSTAPR

C.O.C. \$340 for 15 mths @ 15%p.a. \$-63.75
Animal Health: 6 drenches @ \$1.00 \$- 6.00 _____
-\$69.75

OBSTJUN

C.O.C. \$340 for 17 mths @ 15%p.a. \$-72.25
Animal Health: 6 drenches @ \$1.00 \$- 6.00 _____
-\$78.25

OBSTNOV

C.O.C. \$340 for 22 mths @ 15%p.a. \$-93.50
Animal Health: 6 drenches @ \$1.00 \$- 6.00 _____
-\$99.50

Appendix 16: FRIESIAN BULL BEEF FINISHING ACTIVITIES

FB1YDEC

C.O.C.	\$310 for 13 mths @ 15%p.a.	\$-50.40	
Animal Health:	7 drenches @ \$1.00	\$- 7.00	<u> </u>
			\$-57.40

FB1YFEB

C.O.C.	\$310 for 15 mths @ 15%p.a.	\$-58.15	
Animal Health:	7 drenches @ \$1.00	\$- 7.00	<u> </u>
			\$-65.15

FB1YAPR

C.O.C.	\$310 for 17 mths @ 15%p.a.	\$-65.90	
Animal Health:	7 drenches @ \$1.00	\$- 7.00	<u> </u>
			\$-72.90

FB1YJUN

C.O.C.	\$310 for 19 mths @ 15%p.a.	\$-73.65	
Animal Health:	7 drenches @ \$1.00	\$- 7.00	<u> </u>
			\$-80.65

FB2YDEC

C.O.C.	\$310 for 25 mths @ 15%p.a.	\$-96.90	
Animal Health:	7 drenches @ \$1.00	\$- 7.00	<u> </u>
			\$-103.90

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