

A MANAGEMENT STUDY OF LIGHT LAND FARMING IN
CANTERBURY, NEW ZEALAND

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by
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CONTENTS

| Chapter | | Page |
|---|--|------|
| I | Introduction | 1 |
| <u>Part I</u> THE LIGHT LAND OF CANTERBURY | | |
| II | Physical Characteristics of the Area | 6 |
| III | A Review of Research Relating to the Light Land of Canterbury | 21 |
| IV | The Technical Principles of Light Land Farming | 95 |
| <u>Part II</u> CASE STUDIES IN THE MANAGEMENT OF LIGHT LAND | | |
| V | A Linear Programming Study of a Light Land Farm | 121 |
| VI | The Development of Light Land | 174 |
| VII | Conclusions | 223 |
| | Acknowledgements | 229 |
| | References | 230 |
| | Appendices | 237 |

LIST OF TABLES

| Table | | Page |
|-------|---|------|
| 2.1 | Meteorological Data for Harewood, Winchmore and Levels | 9 |
| 3.1 | Production in Pounds of Dry Matter per acre | 28 |
| 3.2 | Capital Structure and Level of Production on a Sample of Light Land Farms in Canterbury | 70 |
| 3.3 | Pattern of Farming and Level of Stock Production of Five High Performing Dry Land Farms of less than 600 acres | 73 |
| 3.4 | Pattern of Farming and Level of Stock Production of Six High Performing Dry Land Farms of between 600 and 1000 acres | 74 |
| 3.5 | Changes in Output per acre on Light Land Farms, 1954-1963 . . . | 94 |
| 5.1 | Model Allowing the Level of Hay to be Determined Endogenously . | 142 |
| 5.2 | Model Allowing the Endogenous Determination of Feed Transfer . | 143 |
| 5.3 | Model Incorporating a Hay-Barley Ratio for Winter Feeding . . . | 144 |
| 5.4 | Model Incorporating a Technique for Reprogramming with Variable Prices | 146 |
| 5.5 | Land Utilisation for Programmed Plans | 155 |
| 5.6 | Livestock Numbers for Programmed Plans | 156 |
| 5.7 | Financial Results from Programmed Plans | 157 |
| 5.8 | Indexed Price Regimes Used in the Programming Study | 161 |
| 5.9 | The Effect of Price Changes on Two Management Systems | 162 |
| 5.10 | Model Allowing Exploration of Feed Requirements for Various Stock Policies | 164 |
| 5.11 | Comparison of BL.C and Corriedale Stock Policies under Changing BL.C Feed Requirements at Price Regime III | 166 |

| Table | | Page |
|-------|---|------|
| 6.1 | The Physical Components of Development and Movement in Overdraft during Development - Plan A | 195 |
| 6.2 | The Physical Components of Development and Movement in Overdraft during Development - Plan B | 198 |
| 6.3 | Summary of Financial Results of Development Programme A | 201 |
| 6.4 | Summary of Financial Results of Development Programme B | 201a |
| 6.5 | Summary of Analyses of Results Obtained in Development Programmes A and B | 212 |

LIST OF FIGURES

| Figure | | Page |
|--------|---|------|
| 2.1 | The Canterbury Plain | 7 |
| 4.1 | Production Patterns for Lucerne and Ryegrass-Subterranean Clover Pastures and Stock Requirement Patterns for 4.5 ewes | 101 |
| 4.2 | Fluctuations in Lucerne Production in Spring-Summer, and Stock Requirements | 101 |
| 6.1 | Carrying Capacity per acre During Development | 202 |
| 6.2 | Fat Lamb and Wool Production During Development | 202 |
| 6.3 | Financial Performance During Development | 202a |

CHAPTER 1

INTRODUCTION

By far the greatest proportion of the 1,150,000 acres of light land in Canterbury is found on the Canterbury Plain. This plain, originally covered by "low tussock" and of easy contour, was enticing to the early pioneers and became one of the earliest areas in New Zealand to be settled and farmed. Over the years it has developed into one of the most intensively farmed and productive areas of New Zealand.

The dominant characteristic of the light land of Canterbury is undoubtedly the climate. The rainfall is reasonably evenly distributed over the year, but because of the low humidity, high temperatures and warm winds experienced over the summer in association with a free draining soil, the effectiveness of the rainfall over this period is drastically reduced. Consequently active plant growth is severely restricted for several months over the summer, and occasionally extends into the spring and/or autumn periods. The uncertainty as to the length and severity of this restricted growth period and the associated problem of equating the variable feed supply to the stock requirements, both within and between years, is the basic problem confronting the light land farmer.

In spite of the environmental difficulties the productivity of the light land has increased several fold since early settlement. The original holdings on the Canterbury Plain were large with their boundaries on the rivers so as to provide access to water. Fine wool sheep were extensively grazed. However the introduction of refrigerated shipping and the extension of the water race system in the 1880's brought about a reduction in the size of holdings and a change in the pattern of farming. Dual purpose sheep were run and by the

1930's in response to favourable crop prices the system of diversified farming was firmly established. Unfortunately this system placed excessive emphasis on cash cropping, particularly on the light soils. Soil fertility was drained, structure severely damaged and subsequent pasture establishment and survival poor. In the late 1940's and early 1950's, with declining crop yields and with more favourable prices being obtained for fat lambs and particularly wool, the emphasis shifted from cropping to livestock farming. The carrying capacity however, was restricted by the reduced soil fertility and poor quality pastures and an environment in which climatic uncertainty tended to inhibit the rapid expansion of stock numbers.

The results of research work carried out at the various institutions in Canterbury over the years have undoubtedly promoted a greater understanding and appreciation of the problems confronting the farmer and the limitations of the particular environment in which he must operate. For example, pasture species more suited to the low fertility conditions and climate were introduced with spectacular results. The most significant of these was subterranean clover (introduced in the 1930's), noted for its ability to withstand the summer droughts, to regenerate in the autumn, and to provide an increased bulk of feed in the spring. Research work had shown that both lime and phosphate were necessary on the light land soils, if high pasture production and persistency was to be expected. Soil fertility increased subsequent to a reduction in the emphasis on cropping and with the higher levels of fertiliser application. High fertility pasture species (e.g. white clover and lucerne), were introduced and not only gave higher and more reliable total production but exhibited improved seasonal spread of production. Investigations into pasture diseases and stock health provided answers to specific problems. Research into flock management generally and in comparisons between the productivity of various sheep breeds indicated the most suitable type of flock and breed for the light land farmer.

From this and other research work (in conjunction with the observations of leading farmers in the area), an efficient system of light land farming has gradually evolved in which many of the basic problems have been overcome and which has resulted in a raising of the carrying capacity of the light land from $\frac{1}{2}$ stock unit per acre in the 1930's to $3\frac{1}{2}$ -4 stock units per acre at present. A central feature of this system (particularly at high stocking rates), is the high degree of flexibility incorporated in both the stock policies and feed supplies. Where the objective function is to maximise productivity over a period of years, it is essential to utilise the available spring feed efficiently while maintaining the ability to destock when confronted with feed shortages in the spring and early summer. Because of the fluctuating feed supply, which is characteristic of light land, the need to maintain feed reserves and to incorporate a high degree of flexibility in the stock policy is evident if the feed supply and demand are to be equated.

In summary, the increased productivity can be attributed to two factors:

- (1) The ability to grow a greatly increased quantity of herbage per acre with an improved seasonal pattern of production.
- (2) A more efficient utilisation of the herbage produced.

Unlike his counterpart in more reliable farming districts, the light land farmer operates in an environment of uncertainty. Yield uncertainty, particularly at high stocking rates, is the major problem to be overcome and this dictates very largely the system of farming adopted. Price uncertainty is also a significant aspect of light land farming because of the reliance on a limited range of products and the inability to diversify.

In an analysis of physical and financial data collected from a sample of light land farms in Canterbury ⁽¹⁾, there was no evidence to suggest that any one particular pattern of output was superior to all others. This result was surprising, but may reflect the uncertainty inherent in the environment.

(1) For a full discussion on this, see Section 3.3.2 (a).

Alternatively it may infer that the actual patterns of production are less important than the managerial skill with which they are implemented.

These results pointed to the need to explore more fully the following facets of light land management:

- (1) Given a developed farm, is there any one optimal pattern of production which (a) generates increased profit under average seasonal and price conditions, and (b) is subject to only small variations in profit under changing seasonal and price conditions?
- (2) Given the potential for the development and expansion of light land farming, how profitable is this from the individual farmer's viewpoint?

If, in an evaluation of the first problem, high levels of productivity are shown to be profitable on existing well developed farms, then a reallocation of resources to obtain the desired combination should be recommended. An optimum combination of enterprises shown by such an analysis might well serve as the goal where an undeveloped potential still exists on a farm and where a reallocation and intensification in the use of resources is necessary if productivity is to be increased.

In this study of light land farming two case farms have been used and although the results refer specifically to these particular farms, some conclusions of a general nature are possible.

In Chapter II the physical characteristics of the area are described. In Chapter III a review of the research into specific problems relating to the management of light land is presented. This is followed in Chapter IV by an explanation of the technical principles of light land farming which have evolved. Chapter V is devoted to the comparison of some of the production possibilities open to the light land farmer using linear programming. An

analysis of light land development is presented in Chapter VI, while Chapter VII presents the conclusions and summary of the study.

CHAPTER II

PHYSICAL CHARACTERISTICS OF THE AREA

2.1 The Locality

The light land of Canterbury, referred to in this study, includes the area of Lismore, Eyre and Chertsey soil types which have an average annual rainfall of less than 35 inches. This includes all the light land within the area bounded by the Waitaki River in the south, the Waiau River in the north, the sea coast in the east and the foothills in the west (Fig. 2.1). An estimated 1,150,000 acres ⁽¹⁾ of light land are included in this area. The dominating feature of this area is the Canterbury Plain. It is some 150 miles long and averages 30 miles in width and consists in the main of light land. Four major rivers, the Ashley, Waimakariri, Rakaia and Rangitata cut the plain at varying intervals (Fig. 2.1).

While this study refers specifically to the light land of Canterbury, there are other areas of comparable soil type and under similar rainfall elsewhere in New Zealand, to which this study might equally apply.

2.2 Relief

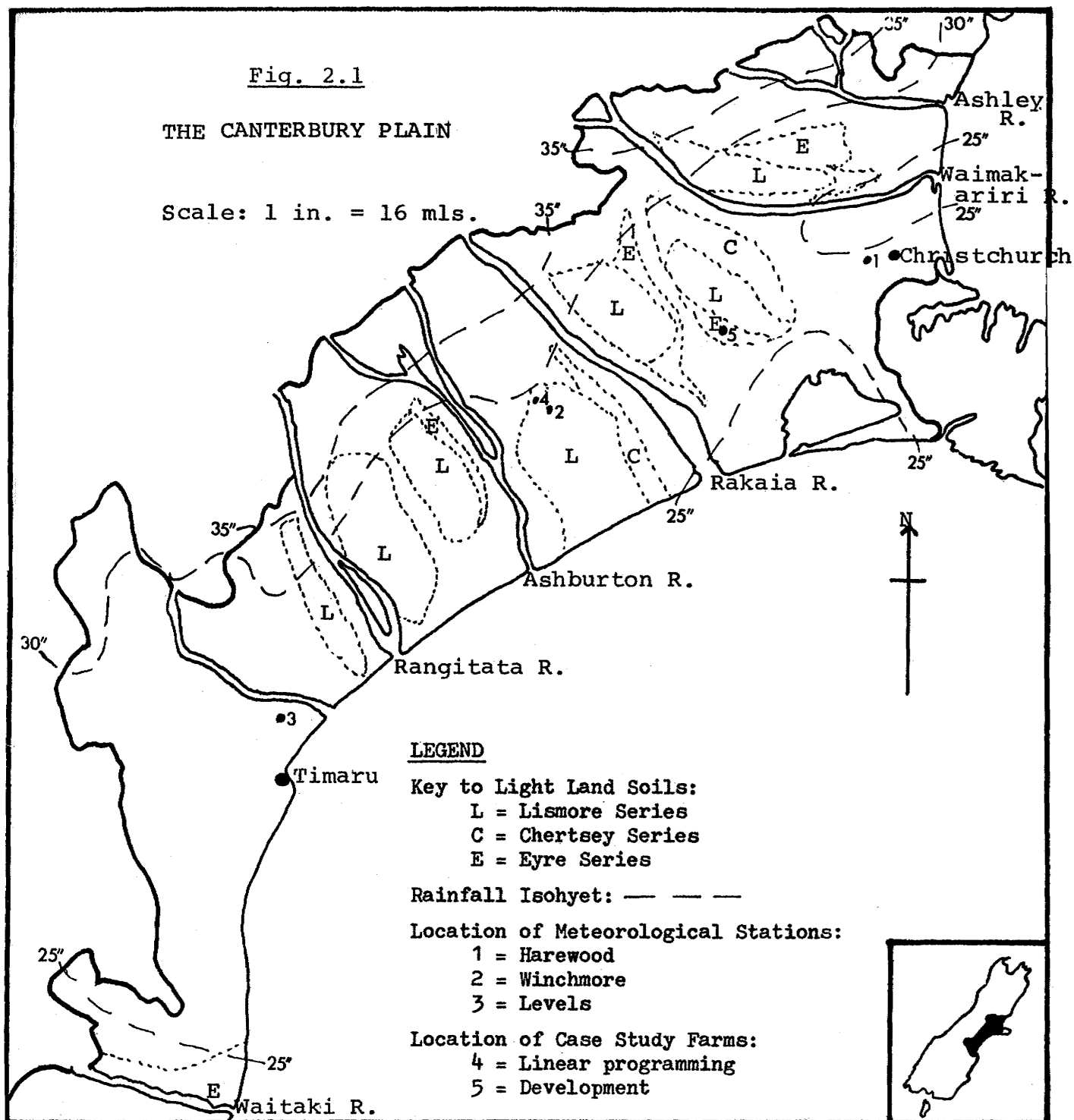
By far the greatest proportion of the light land of Canterbury is found on the Canterbury Plain, stretching from the Kowai River in the north to the Timaru-Fairlie Highway in the south. This plain of approximately 3000 sq.miles consists of a series of broad fans, terraces and flood plains with flat to undulating surfaces. These were built up by the Ashley, Waimakariri, Rakaia and Rangitata rivers with streams such as Eyre, Hawkins, Ashburton, Hinds, Orari,

(1) A.R. Dingwall, (1963), "Potential Stock Carrying Capacity of Canterbury".
Proc. N.Z. Inst.agric.Sci., 9, pp.140-149.

Fig. 2.1

THE CANTERBURY PLAIN

Scale: 1 in. = 16 mls.



Waihi and Opihi occupying interfan depressions.

The northern part of the plain has a slope of 50 feet per mile near the foothills at approximately the 1200 feet contour, but decreases to approximately 15 feet per mile near the coast north of the Rakaiā and south of the Rangitāta. In the Ashburton county, between these rivers, a gradient of approximately 30 feet per mile is maintained from the coast to the foothills. This gradient, along with the contour of the surface is of vital importance in those areas of Canterbury where irrigation is practised.

2.3 The Climate

This area of Canterbury has a severe climate, being exposed to all winds, especially the cold southerlies in the winter. The summers are hot and dry with low humidity.

The annual rainfall varies over the area, being in the range of 20-35 inches. A gradient in the rainfall from 22 inches near the east coast increasing to 45 inches at the foothills is characteristic of the plains of Canterbury. In any one district, the mean annual rainfall may vary considerably between years (see Table 2.1), and although on average it is quite uniformly spread throughout the year, it can vary markedly in any one year. Moisture is generally adequate for plant growth from March to early November, though over the greater part of the Canterbury light land the soil and air temperatures are below the minimum for pasture growth (i.e. 34°F.) for approximately 3½ months from early May. Frosts, while light on the coast, may reach 20°F. inland.

Plant growth, which normally starts in late August-early September, can be vigorous when temperatures rise in October and early November. Much of the summer rainfall however is ineffective owing to the high temperatures which often exceed 70°F, and occasionally even 90°F. Strong desiccating north-west winds are also prevalent and these adversely affect the soil moisture conditions

TABLE 2.1

Meteorological Data for Harewood, Winchmore and Levels*

| <u>RAINFALL (in.)</u> | <u>Jan.</u> | <u>Feb.</u> | <u>Mar.</u> | <u>Apr.</u> | <u>May</u> | <u>June</u> | <u>July</u> | <u>Aug.</u> | <u>Sep.</u> | <u>Oct.</u> | <u>Nov.</u> | <u>Dec.</u> | <u>Total</u> | <u>Mean</u> |
|-----------------------|-------------|-------------|-------------|-------------|------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|--------------|-------------|
| Mean - Harewood | 1.72 | 1.61 | 2.46 | 1.89 | 3.29 | 1.99 | 2.58 | 1.73 | 1.63 | 1.17 | 1.44 | 1.87 | 23.38 | 1.95 |
| - Winchmore | 2.37 | 2.28 | 3.39 | 2.52 | 3.51 | 2.02 | 2.83 | 2.19 | 1.70 | 2.22 | 2.35 | 2.80 | 30.18 | 2.52 |
| - Levels | 2.41 | 1.79 | 2.64 | 1.88 | 2.51 | 1.04 | 2.19 | 1.06 | 1.47 | 1.70 | 2.07 | 2.56 | 23.32 | 1.94 |
| Max. - Harewood | 3.10 | 2.52 | 3.87 | 3.87 | 4.18 | 6.62 | 4.90 | 3.99 | 4.28 | 2.86 | 2.51 | 3.02 | 32.70 | |
| - Winchmore | 5.68 | 2.86 | 6.22 | 3.97 | 5.87 | 5.38 | 3.78 | 5.19 | 3.44 | 4.48 | 3.43 | 3.92 | 37.34 | |
| - Levels | 4.44 | 2.09 | 6.12 | 2.89 | 4.31 | 1.88 | 6.19 | 2.19 | 3.05 | 3.48 | 3.21 | 5.79 | 30.28 | |
| Min. - Harewood | 0.33 | 0.57 | 0.58 | 0.53 | 0.53 | 0.84 | 0.53 | 0.53 | 0.32 | 0.12 | 0.34 | 0.45 | 17.29 | |
| - Winchmore | 0.70 | 1.03 | 1.93 | 0.18 | 0.77 | 0.85 | 0.54 | 0.49 | 0.45 | 0.34 | 0.98 | 0.71 | 23.64 | |
| - Levels | 0.68 | 0.47 | 1.47 | 0.55 | 0.92 | 0.07 | 0.34 | 0.12 | 0.46 | 0.52 | 1.33 | 1.32 | 17.32 | |
| No. of Rain Days | | | | | | | | | | | | | | |
| - Harewood | 9 | 8 | 11 | 8 | 13 | 9 | 12 | 9 | 7 | 10 | 9 | 10 | 115 | 9.5 |
| - Winchmore | 9 | 9 | 12 | 9 | 12 | 8 | 10 | 9 | 8 | 10 | 9 | 11 | 116 | 9.6 |
| - Levels | 8 | 7 | 9 | 9 | 10 | 5 | 7 | 5 | 8 | 8 | 9 | 9 | 94 | 7.8 |
| <u>TEMPERATURES</u> | | | | | | | | | | | | | | |
| (degrees F.) | | | | | | | | | | | | | | |
| Air, mean | | | | | | | | | | | | | | |
| - Harewood | 62.9 | 62.7 | 58.2 | 53.5 | 48.1 | 43.2 | 41.7 | 44.1 | 48.0 | 53.6 | 57.3 | 60.0 | | 52.8 |
| - Winchmore | 61.0 | 60.1 | 56.6 | 51.9 | 46.0 | 42.3 | 40.4 | 43.2 | 47.0 | 51.7 | 55.9 | 58.1 | | 51.2 |
| - Levels | 59.6 | 59.8 | 56.9 | 51.8 | 45.7 | 41.8 | 40.4 | 42.6 | 46.7 | 51.7 | 55.0 | 58.3 | | 50.9 |
| Highest max. | | | | | | | | | | | | | | |
| - Harewood | 91.1 | 93.8 | 89.7 | 82.3 | 79.0 | 69.5 | 67.2 | 71.5 | 76.7 | 81.6 | 89.6 | 90.6 | | |
| - Winchmore | 96.6 | 91.8 | 85.0 | 81.0 | 72.8 | 65.5 | 65.1 | 69.0 | 72.8 | 78.3 | 85.5 | 88.0 | | |
| - Levels | 94.4 | 90.2 | 92.0 | 76.4 | 69.3 | 68.0 | 66.0 | 71.5 | 73.9 | 80.6 | 89.4 | 94.5 | | |
| Lowest min. | | | | | | | | | | | | | | |
| - Harewood | 42.0 | 40.5 | 31.9 | 28.2 | 24.4 | 22.7 | 20.0 | 22.8 | 26.6 | 24.6 | 31.5 | 37.5 | | |
| - Winchmore | 37.6 | 34.9 | 32.9 | 28.5 | 19.0 | 18.0 | 18.2 | 19.0 | 22.0 | 24.5 | 29.8 | 33.2 | | |
| - Levels | 37.0 | 35.0 | 32.5 | 31.6 | 21.0 | 18.7 | 22.0 | 21.0 | 26.2 | 25.7 | 32.0 | 32.9 | | |

* Harewood 10 years mean 1953-1962
Winchmore 10 years mean 1953-1962
Levels 9 years mean 1957-1965

TABLE 2.1 (Continued)

| Number of frosts (Grass minimum of 32 degrees F.) | <u>Jan.</u> | <u>Feb.</u> | <u>Mar.</u> | <u>Apr.</u> | <u>May</u> | <u>June</u> | <u>July</u> | <u>Aug.</u> | <u>Sep.</u> | <u>Oct.</u> | <u>Nov.</u> | <u>Dec.</u> | <u>Total</u> | <u>Mean</u> |
|---|-------------|-------------|-------------|-------------|------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|--------------|-------------|
| - Harewood | 0 | 0 | 1 | 3 | 6 | 15 | 16 | 14 | 11 | 5 | 1 | 1 | 73 | 6.1 |
| - Winchmore | 1 | 0 | 1 | 5 | 13 | 20 | 22 | 20 | 13 | 7 | 3 | 1 | 106 | 8.8 |
| - Levels | 0 | 0 | 2 | 8 | 9 | 24 | 23 | 20 | 15 | 4 | 2 | 0 | 107 | 8.9 |
| <u>WIND</u> | | | | | | | | | | | | | | |
| Mean, miles per day | | | | | | | | | | | | | | |
| - Winchmore | 211 | 209 | 185 | 181 | 166 | 159 | 161 | 177 | 195 | 219 | 228 | 219 | 2310 | 192.5 |
| (Not available for Harewood or Levels) | | | | | | | | | | | | | | |
| <u>EVAPORATION (in.)**</u> | | | | | | | | | | | | | | |
| Mean - Winchmore | 5.76 | 4.72 | 3.94 | 2.40 | 1.49 | 0.97 | 0.85 | 1.34 | 2.35 | 3.58 | 4.96 | 5.15 | 37.51 | 3.13 |

** Sunken pan evaporimeter

SOURCE: "Meterological Observations", N.Z. Met. Services Misc. Publications.

"Guide to Field & Laboratory Experiments", (1962),
Winchmore Irrigation Station, N.Z. Dept. of Agriculture,
p.6.

of the free draining light land soils. In most years these two characteristics together cause the evaporation rate to exceed the rainfall for several months over the summer, and, as a result, pasture growth is at a minimum over this period. These high temperatures and desiccating winds not only dry out the top soil to a considerable depth, but can remove in a matter of days any surplus growth existing after the spring flush.

The variable nature and effectiveness of the rainfall, especially over the spring and summer months, and the severe winters, have an important bearing on the pattern of farming practised in the area.

2.4 Soils of the Area ⁽²⁾

The light soils of the plains are principally those of the Lismore, Chertsey and Eyre series. Of the total area of 1,150,000 acres of shallow stony soils, these three series account for 619,730 acres. The former two, which are among the oldest of the plains, developed as a veneer of loess, some 6-16 inches in depth. This was blown from the river beds over the coarser sandy gravels which were deposited as fans (the 'old fans') by the aggradation of the three big rivers, namely the Waimakariri, Rakaia and Rangitata.

The Chertsey soils lie nearer the south banks of the Waimakariri and Rakaia rivers and merge imperceptibly into the Lismore soils. These received a more sustained dressing of loess which has made them considerably more fertile (chemically) than the Lismore soils, though not much greater in depth or moisture holding capacity. The parent material is almost entirely derived from the greywacke rocks of the Alpine ranges. The Eyre soils are younger and marginal to the 'old fans' and have a thin covering of wind blown silt and sandy loam. In places the loam has blown off (sometimes in strips), exposing the loamy gravel subsoil.

(2) (a) B.S. Kear, H.S. Gibbs and R.B. Miller, (1966), "Soils of Downs & Plains Canterbury & North Otago, N.Z.", N.Z. Dep. scient. ind. Res., Soil Bureau Bull. No.14.

(b) Pers. comm. Soil Science Dept. Lincoln College.

Most of the soils in these three series are silt loams⁽³⁾ (as are the majority of the soils of the plains). They are "light" and droughty, not because of a lightness in texture, but on account of their shallowness over very free draining gravels. This has contributed to their being well leached of nutrients in spite of the modest rainfall. Acidity and plant nutrient deficiencies can be remedied easily and economically by established methods. Hence it is the combination of depth to gravels with texture that governs the moisture and nutrient holding capacity and therefore the fertility of the lighter plains soils. Where irrigation is practised this major limitation is largely removed and the changed conditions produce a "changed" soil. Those soils become different by the build up of organic matter, exchange capacity and moisture holding capacity which give them the acquired ability to withstand more intensive farming.

These soils have a pH of about 5.2-5.3 in their unimproved state and respond strongly to phosphorus, sulphur, molybdenum and/or lime. They are marginally deficient in potash, boron and manganese.

2.4.1 The Lismore Series. This series covers 447,990 acres on the fans of the Waimakariri, Rakaia and Rangitata rivers. The area is divided into six extensive areas by the entrenched valleys of these rivers on whose flood plains and terraces younger soils have developed. These fans consist of greywacke gravels, stones and boulders in a matrix of sand and silt. A thin veneer of loess from 6 inches to 18 inches blankets much of the fan surfaces; hence most of the soils are shallow to thin and stony.

Lismore soils have free to very rapid drainage through the profile and the soils are prone to wind erosion when under fallow. Crops suffer from a seasonal moisture deficit in most summers. However, the free draining nature and gentle gradient of the Lismore soils which occur in large areas on

(3) Profile descriptions and chemical analysis for the main soil types are given in Appendix A.

the plains, make these light lands very suited to border dyke irrigation. Water is available in abundance and there is sufficient depth of fine earth over gravels to make preparation of borders possible. Cropping on the Lismore series is usually restricted to forage crops for sheep in a process of pasture renewal. This restriction is necessary because of the weak structure of the light land, and of its being subject to summer droughts, and to wind-blow under cultivation. On the shallow and more drought prone phases of Lismore, pastures deteriorate rapidly to hair grass, danthonia, browntop and sweet vernal. The drought resisting subterranean clover and deep rooting lucernes are of considerable significance in the slowing down of this reversion.

2.4.2 The Chertsey Series. These soils are found in broad strips south west of the Rakaia and Waimakariri rivers and cover 63,790 acres. Deeper than the neighbouring Lismore soils, they lack stones in the top soil, are moderately free draining, and are subjected to slight droughts in the summer. The moisture holding capacity and fertility status are both higher than the Lismore soils. As a result they are used for mixed farming, with cash crops, small seeds, forage crops and short term pastures included in the rotation. These high producing pastures often fail to recover after a prolonged drought and as on the Lismore soils lower producing species, e.g. browntop and sweet vernal appear.

2.4.3 The Eyre Series. Eyre soils covering 107,950 acres, are in general, shallow and stony soils formed on stony ridges of greywacke alluvium on the low terraces and fan margins. They are widely distributed but most extensively between the Eyre and Ashley rivers.

Eyre soils are shallow and have low moisture holding capacity so that crops suffer from severe droughts. Pastures quickly revert to browntop and inferior grasses in three to four years.

2.5 Soils and Plants in Relation to Climate

Free draining soils, a low rainfall, and strong warm north-west winds

during the summer are characteristic of the plains area of Canterbury. Here the daily evapotranspiration rate normally exceeds the daily rainfall over the summer months and occasionally severely dry periods are experienced. These periods of drought can be prolonged and cause considerable management problems.

Thorntwaite and Mather⁽⁴⁾ in listing the numerous types of drought defined "Contingent Drought" as depending on the irregularity of rainfall and occurring in sub-humid and humid climates.

Rickard⁽⁵⁾ considered these droughts were of concern in New Zealand and in studying the frequency, duration and agricultural significance of such droughts at Ashburton, New Zealand, found that drought as defined by Bondy⁽⁶⁾, has little significance in relation to agricultural drought.

Bondy has defined absolute drought as:-

"... a period of at least 15 consecutive days, to none of which is credited 0.01 inches or more of rain".

Based on rainfall measurements, this definition takes no account of the moisture state of the soil and its effect on plant growth. Rickard thus defined drought as:-

"... existing when the soil moisture in the root zone is at, or below, the permanent wilting percentage. The condition continues until rain falls in excess of the daily evapotranspiration".

While there is no plant growth below permanent wilting point, there may be adverse effects on plant growth before soil moisture actually reaches permanent wilting point.

Rickard calculated the occurrence of agricultural drought at Ashburton over 44 seasons, using Thorntwaite's⁽⁷⁾ method of estimating change in soil

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- (4) C.W. Thorntwaite & J.R. Mather, (1955), "The Water Balance". Drexel Inst. Tech., Publ. Climatol 8 (1).
 - (5) D.S. Rickard, (1960), "The Occurrence of Agricultural Drought at Ashburton, N.Z.". N.Z. J Agric. Res., 3.3: 431.
 - (6) F. Bondy, (1950), "Drought in N.Z.", N.Z. J1 Sci. Technol., B.32: 1-10.
 - (7) C.W. Thorntwaite, (1948), "An Approach towards a Rational Classification of Climate". Geogr1 Review, 38.1:, pp 54-94.

moisture. This was determined from the 1st September to 30th April in the following year, using daily rainfall figures and mean daily values of evapotranspiration for each month.

Soil moisture changes were calculated until a deficit of 2.04 inches was obtained. This corresponded to the permanent wilting percentage of the Lismore stony silt loam soils which are representative of large areas of Canterbury light soil.

When a deficit corresponding to the permanent wilting percentage was obtained, each subsequent day was a day of agricultural drought until moisture fell in excess of the daily evapotranspiration rate.

Using the data available for the period 1912/13 to 1955/56, a total of 44 seasons, Rickard obtained the following results:-

1. The occurrence of agricultural drought.

- (a) The total number of days of drought in each season varied from 107 (1931/32) to 6 (1944/45) with a mean of 59.
- (b) Owing to the mean rainfall in September of 2.49 inches, and to the low evapotranspiration rate of 1.5 inches, drought conditions never occur in September and only occasionally in October.
- (c) Of the total days of drought 80% occurred in the months December to March when the rate of evapotranspiration is highest. (January and February are the driest months.)
- (d) Of the 44 seasons studied, 75% experienced more than 40 days of drought, 52% more than 60 days of drought, and in 25% of all seasons the days of drought exceeded 80.

While the number of days of drought in a season is important, the duration of consecutive drought days is of greater significance in farming. A continuous period of 10 or more days of drought will

severely check pasture or crop production and in the 44 seasons studied there were 90 such periods. There were up to 5 of these in one season (1964/65), and these ranged up to 42 days in duration.

2. Drought and agricultural production.

The effect of drought on pasture production in Canterbury has been demonstrated by Rickard. He used production figures from several non-irrigated plots on field experiments to investigate the possibility of relationships between production in a season and the extent of drought in that season. Data was available for the period 1950/51 to 1957/58. Using lucerne plots to investigate the effects of drought days on production, he found that production was strongly negatively correlated with the number of drought days in the season⁽⁸⁾. The greatest number of drought days recorded was 107, corresponding to a lucerne production of 4061 lbs., or 41.7% of the production expected in a season completely free from drought. Similar results were obtained for pasture production. Production in an average season of 59 drought days was about 50% of that in a season free of drought. Production in a drought free season will be lower than production under optimum irrigation, for, while in a drought free season soil moisture does not reach permanent wilting percentage, it could be close enough to affect production. Production is higher under optimum irrigation and the percentage reduction due to drought in an average season is correspondingly greater.

2.6 History of the Area

Much of Canterbury was originally covered by forest. On the shallow

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- (8) The regression equation for deriving dry matter production (lbs.) from the number of drought days was:

$$y = 9732 - 53x$$

where y = seasonal lucerne production

x = total number of drought days in the season

The correlation coefficient, r = -0.91.

soils, i.e. Lismore and Eyre series, kanuka scrub was dominant species, while on the deeper soils, i.e. Templeton series, podocarp species, e.g. Matai, was dominant⁽⁹⁾.

Following the arrival of the Polynesians fire destroyed the forest and drastically reduced the kanuka on the sub-humid well-drained soils⁽¹⁰⁾.

Evidence from carbon dating of charcoal and wood, indicates burning of these forests as long ago as 900 years. Climatic changes prior to the arrival of the Polynesians, may also have contributed to the forest contraction, especially on the lighter soils⁽¹¹⁾.

The natural vegetation of the well-drained areas of Canterbury plain at the time of European settlement was dominated by "low tussock". The main species was hard tussock (Festuca novae - zelandiae), and associated with it were blue tussock (Poa colensoi), blue wheat grass (Agropyrum scabrum), and spear grass (Aciphylla). Trees and scrub in the area included New Zealand flax (Phormium tenax), cabbage trees (Cordyline australis), matagouri or Wild Irishman (Discaria toumatou), kanuka (Leptospermum ericoides), New Zealand broom (Carmichaelia), and Kowhai (Sophora micophylla).

The early settlers in Canterbury took up large holdings from 5,000 to 50,000 acres and by 1855 the whole of the Canterbury Plain was occupied⁽¹²⁾. Water was scarce however and these early runs were divided so that each had access to one of the rivers that cut the plain.

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- (9) J.E. Cox & C.B. Mead, (1963), "Soil Evidence Relating to Post Glacial Climate on the Canterbury Plains". N.Z. Eccl. Soc. 10.
 - (10) P.B.J. Molloy, et.al., (1963), "Distribution of Sub. Fossil Forest Remains, Eastern South Island, N.Z". N.Z. Jl Bot., 1. 1:68.
 - (11) K.B. Cumberland, (1962), "Climatic Changes or Cultural Interferences?" In "Land and Livelihood". N.Z. Geogr Soc. Caxton Press, Ch.Ch. pp 88-142.
 - (12) L.G.D. Acland, (1930), "The Early Canterbury Runs". Whitcombe & Tombs. Ch.Ch.

In the early years of farming on the light plains land, fine wool Merino store sheep were extensively grazed. While wool was the major product, wheat, oats and barley were grown extensively, mainly on the deeper soils.

Water race systems were gradually being developed over the plains. The Malvern race system was opened in 1877, followed by the Methven scheme in 1881. By the end of the century most of the light land of Canterbury was covered by a network of races. Another event, important not only for the runholders of Canterbury, but for the whole of New Zealand occurred in the 1880's. This was the introduction of refrigeration in shipping.

These two developments accelerated the subdivision of the larger properties and in effect brought about sweeping changes in the pattern of farming. The wool producing Merino was replaced by the dual purpose half-bred (i.e. the Lincoln-Merino cross). Transport systems were extending throughout the province and with prices favouring cash cropping, the rate of cropping was increased, especially in the Malvern County where the new farmers found the virgin land capable of producing high yields. As a result of this, and along with the developing meat and wool export trade, a more diversified type of farming was established throughout Canterbury. Forage crops were grown for wintering stock and oats grown for horses, while on the deeper soils small seeds were saved for pasture renewal.

In the late 20's and early 30's the cost price relationship was such that greater emphasis was placed on cereal cropping. In some areas up to 20% of the farm was sown in wheat each year and yields of only 25 bushels per acre were expected. The trend to increase cropping was unfortunate as it severely damaged the structure and drained the fertility of these thin light soils. Little fallowing was practised and pastures "ran out" in three years. Gradually the natural vegetation was replaced by the low-fertility demanding grasses and very

few of the mixed award of grasses were able to survive in the low fertility conditions. The dominant species then were danthonia (Danthonia pilosa), browntop (Agrostis tenuis), redtop (Agrostis alba), Goosegrass (Bromus mollis), sweet vernal (Anthoxanthum oderatum), and hairgrass (Vulpia aertonensis). The carrying capacity of this area in the 1930's was only $\frac{1}{2}$ half-bred per acre. Fleming⁽¹³⁾ records in a farm management survey of the plains area of the Ashburton County that:-

"... over the last ten to twenty years, production in this country has remained almost stationary".

This could be attributed to the gradual decline in fertility of the soil and subsequent reduction in wheat yields and to the restriction on stock carrying capacity imposed by the droughty conditions and poor quality pastures.

Today farms within the area are smaller and the pattern of farming has changed considerably. The emphasis is on intensive export fat lamb production using Corriedale ewe flocks and Down-type rams. On the larger properties replacements are bred, while smaller units buy in replacements as ewe lambs, two-tooths, or two-year ewes. Cereal cropping on light land is of less importance and small seeds are saved as "catch crops" only in favourable years.

This system of farming allows efficient use to be made of the available feed supplies. The carrying capacity on this light land has increased from $\frac{1}{2}$ ewe equivalent in the 1930's to $3\frac{1}{4}$ at the present time. This dramatic increase has been made possible by the introduction of new highly productive pasture species, the use of D.D.T. for the control of the grass grub (Odontria zealandica) and porina caterpillar (Oxycaenus spp.), increased levels of lime and superphosphate application, and more flexible stock policies to match the fluctuating seasonal feed supplies which are characteristic of the area.

(13) J.R. Fleming, (1938), "Farm Management Survey. Plains Area, Ashburton County, New Zealand". N.Z. Dep. scient. ind. Res., Bull. No.58.

2.7 Irrigation

It was obvious to the early runholders that irrigation on the Canterbury Plains, as a means whereby the summer drought problem could be partially eliminated, was feasible. The many rivers provided a reliable supply of water. This, with the easy contour and the free-draining nature of the soils, made conditions for irrigation second to none.

As early as 1870 small scale irrigation was carried out from stock water races. However in 1937 the first large-scale flood irrigation scheme of 4,600 acres was opened at Redcliffe, using water from the Waitaki river. One year later 12,800 acres of light land on the Levels plains were irrigated with water from the Opihi river.

With labour so readily available during the depression and with the wide-scale support from the Canterbury Progress League, the Government began construction of yet another and larger scheme. This involved the construction of the Rangitata diversion race, designed to carry 1000 cusecs 42 miles across the plain, from the Rangitata to the Rakaia river. This diversion race was to provide water to 64,000 acres in the Ashburton-Lyndhurst scheme; 62,000 acres in the Valetta-Tinwald scheme; and 53,000 acres in the Barrhill scheme; and in the winter supply water to the Highbank Power Station.

Water was first made available to farmers in the Ashburton-Lyndhurst scheme in 1946, and to farmers in the Valetta-Tinwald scheme in 1958. In 1948 a temporary supply of water was taken from the Rangitata diversion race to supply 18,000 acres of the proposed 85,000 acres in the Mayfield-Hinds scheme. The original intention was to draw water from a separate intake on the Rangitata river, but this has not yet been constructed⁽¹⁴⁾.

(14) At the time of writing, (1966).

Large areas of light land elsewhere in Canterbury are equally well suited to the border-dyke system of irrigation. Dingwall⁽¹⁵⁾ in discussing the potential production of light land states:-

"Much of this light land area could be commanded for irrigation existing schemes enclose a gross area of approximately $\frac{1}{2}$ million acres. A further $\frac{1}{2}$ million acres could be incorporated in other coastal and northern plain areas.

Of this 1 million acres the nett area for full irrigation would be about $\frac{3}{4}$ million acres (which would include probably 100,000 acres of medium soil types). At the present time, work on additional schemes is still at the investigation stage".

2.8 Summary

While in Canterbury there are some of the most fertile soils in New Zealand the bulk of the arable land in Canterbury consists of thin light soils. This area of light land, consisting of some one million acres, is subject to frequent and prolonged agricultural droughts during the summer. The high summer evapo-transpiration rate often reduces soil moisture levels to below that necessary to support plant growth. Pasture production is normally limited over the summer and extremely variable over the remainder of the year. With present emphasis on high stock carrying capacities on the light land, the need for a flexible stock policy and high producing persistent pasture species is evident. The management problem on the light land then is one of devising and operating a profitable system of farming which is compatible with the ever changing environment. This study is concerned with the farm management problem on the Canterbury light land.

(15) A.R. Dingwall, (1963), op. cit.

CHAPTER III

A REVIEW OF RESEARCH RELATING TO THE LIGHT LAND OF CANTERBURY

3.1 The Development of Agricultural Research In Canterbury

Research on agricultural problems was first reported by R.W. Fereday who, in the 1860's was the authority in Christchurch on insect pests. Discussions on such problems were reported in the weekly "Press" of the time. Later, from 1877-99, the Canterbury Agricultural and Pastoral Association published "The N.Z. Country Journal", the first agricultural journal in which findings on extension and research were recorded.

In 1880 Lincoln College of Canterbury University was opened and since then has been prominent in agricultural extension and research, as well as teaching, not only in Canterbury, but in New Zealand and overseas.

The Department of Agriculture was established in 1893 and the first scientific experiments in Canterbury were conducted by A.W. Hudson during the period 1924-26. These and later experiments on field and pasture measurements⁽¹⁾ were the forerunners of the now comprehensive programme of field experiments conducted by the Department. When in 1936 the D.S.I.R. took over the plant research activities of the Department of Agriculture, the new Crop Research Division at Lincoln came into being. This has developed into one of the leading agricultural research centres in the world.

Specialist research units became attached to the D.S.I.R. and Lincoln College over the years. Today, at the D.S.I.R. station at Lincoln, there are divisions of Crop Research, Plant Diseases, Entomology, Soil Bureau and Grassland. At Lincoln College the Tussock Grassland and Mountain Lands Institute, the

(1) A.W. Hudson, B.W. Doak and G.K. McPherson, (1933), "Investigations into Pasture Production". N.Z. Dep. Scient. ind. Res., Bull. No.31.

New Zealand Agricultural Engineering Institute, and the Agricultural Economics Research Unit, have all been established while the new Wool Research Organisation is situated adjacent to the College.

The Department of Agriculture has continued its interest in irrigation at the Winchmore Irrigation Research Station, Ashburton, and Catchment Boards and commercial firms within the area are also engaged in research projects of various kinds.

The research units which have been established in Canterbury cover all phases of Agriculture. Their works have been a contributing factor to the increased productivity of the province over recent years. Philpott⁽²⁾ estimates that over the last 40 years, the volume of farm output has increased at a compound rate of 2.6% per year.

Blair⁽³⁾ in reviewing research in Canterbury in the last 100 years states:-

"Few would claim that the increase in productivity per acre or per farm worker has been primarily the consequence of research. Much of this increase is attributable to excellent extension work by officers of the Department of Agriculture - e.g. W.C. Stafford, G.K. McPherson, E.G. Smith; to those Lincoln College staff such as E.R. Hudson, R.H. Bevin, A.H. Flay and H.E. Garrett, whose laboratories were the farm fields".

In recent years the extension services have been extended and intensified throughout the province not only by the Department of Agriculture and Lincoln College, but by the Farm Improvement Club movement which, by December 1966, had expanded to include eight groups within the Canterbury province.

Another significant feature of the extension services in Canterbury is the weekly agricultural supplement in the "Press". This supplement has maintained a high standard throughout the years and provides an excellent source of current information for farmers. The "Press" has not only a wide

(2) B.P. Philpott, pers. comm.

(3) I.D. Blair, (1964), "100 Years' Research in Canterbury". Proc. N.Z. Inst. agric. Sci., 10:23.

circulation in the farming districts, but McMillion⁽⁴⁾ has shown that the farming supplement is read by almost every rural subscriber.

Extension is however based on some form of research findings; it is the dissemination of information to the farmer from the research centre. The New Zealand farmers are noted for their farming efficiency both in the level of output per labour unit and in the low cost of production. They have been ready to avail themselves of new technology and new ideas. The Canterbury farmer is perhaps fortunate in that the research centres in the province are well established, and of vital importance, in close liaison with existing extension services. This has enabled the farmer to keep abreast of recent developments from these research centres, and so the research centres have played an effective role in the evolution of farming in Canterbury.

While the local centres of research have, over the years, been the main source of information, developments of a more general nature from research centres outside the province, e.g. Ruakura (Hamilton), and Grassland Division D.S.I.R. (Palmerston North), have also had a marked impact on the development of the light land in Canterbury.

In this chapter some of the more recent and significant developments in agricultural research relating to the light land of Canterbury will be discussed. This is by no means a comprehensive summary of all the research carried out, but simply an attempt to discuss those findings which are of particular significance in light land farming.

3.2 Technical Research

3.2.1 Pasture Improvement. Since the light land is used predominantly for sheep farming, and in particular fat lamb production, the condition of pastures

(4) M.B. McMillion, (1960), "The Sources of Information and Factors which Influence Farmers in Adopting Recommended Practices in Two N.Z. Counties". Lincoln College Technical Publication No.19, p.12.

is of vital importance. They are important not only in relation to carrying capacity but also to stock performance.

In the 1930's pastures on the dry light land were poor. They consisted mainly of perennial ryegrass and white clover; a mixture designed on the experience and success of these pasture plants on damper and more fertile soils elsewhere in New Zealand. The fertility of the light land however, had been lowered markedly by the continual growing of oats and later wheat. As a result pastures lasted only two to four years and quickly reverted to the lower fertility species, i.e. browntop (Agrostis tenuis), sweet vernal (Anthroxanthum odoratum), and harefoot trefoil (Trifolium arvense)⁽⁵⁾. The carrying capacity of the light land in its unimproved state was less than one ewe per acre⁽⁶⁾.

1. Work at Ashley Dene. In 1937, E.R. Hudson, the then Director of Lincoln College, decided to use the College's Ashley Dene light farm land as an area on which to test management methods which might lead to the increased productivity of the lighter plains soils. (The carrying capacity of Ashley Dene in 1936 was only one ewe per acre.) The decision to use the Ashley Dene farm for this purpose was a milestone in the development of the Canterbury light land. Calder⁽⁷⁾ in discussing the problems of pasture establishment on these soils, states:-

"The real problems associated with these light dry soils were not recognised, but when these investigations commenced (i.e. at Ashley Dene) a search for the most suitable components of a pasture became the objective of research and field investigation.

The soil moisture conditions are so different from those of the more fertile lands, that pasture plants more particularly adapted to such conditions would be necessary to develop satisfactory pastures".

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- (5) R.H. Bevin, (1946), "Land Utilisation at Ashley Dene Farm". Lincoln College Technical Publication No.1, p.9.
 - (6) R.H. Scott and R.C. Stuart, (1956), "Economic Aspects of Farming Light Land in Canterbury". Proc. 18th Conf. N.Z. Grassld Ass., p.68.
 - (7) J.W. Calder, (1956), "Pasture Research at Ashley Dene". Proc. 6th Lincoln Coll. Emrs' Conf., p.54.

Hudson, in search for increased persistency and production introduced subterranean clover, with spectacular results, in the initial stages of the improvement at Ashley Dene. Subterranean clover had been established earlier on several farms in North Canterbury and it appeared that, given reasonable management, the increase in carrying capacity experienced with the plant in Australia, could be expected here. This work at Ashley Dene, along with that of some of the more progressive farmers of that period, laid the foundation for the great improvement which has since occurred on the light land soils.

The work at Ashley Dene on pasture improvement falls into four phases:

- (i) Subterranean Clover. In studying subterranean clover as a pasture plant in Canterbury, and its response to different fertiliser treatments, it was soon apparent that this was a first class pioneer legume for the light dry soils. As an annual it survived the hot dry summers in the form of a seed, and germinated in the autumn, giving greatly increased production. While it provides some feed in the autumn, winter and early spring, almost two-thirds of the annual production is in the spring and early summer⁽⁸⁾.

Fertiliser was shown to be essential to produce a vigorous subterranean clover stand on the light land and this was applied at 1 cwt. superphosphate and 5 cwt. lime in alternate years.

- (ii) Subterranean Clover and its Compatability with other Grasses.

When subterranean clover was established as the basic legume for the new pasture mixtures on the low fertility soils, its compatability with other grasses in the mixture was of importance. Poor

(8) C.E. Iversen and J.W. Calder, (1956), "Light Land Pastures". Proc. 18th Conf. N.Z. Grassld Ass., p.79.

establishment of the germinating subterranean clover seed in the autumn is often not only due to unfavourable weather conditions, but to competition for moisture from existing grasses. The work at Ashley Dene showed that where a thick sward of ryegrass and cocksfoot existed after normal sowings of these grasses, the amount of clover regenerating was significantly less than where the density of grasses was lower. As a result pastures became progressively more grass dominant and production fell. Where pastures become grass-bound or "run out" the recommended practice was (and still is) to revive the subterranean clover by top working the paddock in the early autumn, thereby reducing the density of grass and providing a more favourable seed bed for the germinating seed. The introduction of other grasses, e.g. short rotation ryegrass, at this stage gave markedly increased quantities of winter and spring feed.

Grasses must be sown if advantage is to be taken of the nitrogen provided by the subterranean clover, and in order to provide additional autumn, winter and early spring grazing. Calder⁽⁹⁾ found that where the fertility had been built up by several years subterranean clover, grasses such as perennial ryegrass, cocksfoot and phalaris could be included in the mixture, provided the sowing rate was light (e.g. 2, 2, and 6 lbs. respectively). Cocksfoot and phalaris, both deep rooting plants were shown to be more drought resistant than ryegrass, and provided useful summer grazing. Cocksfoot however, with its high crown, tended to make conditions

(9) J.W. Calder, (1956), op. cit., p.56.

unsuitable for clover establishment, and only when the density of cocksfoot was low, was it compatible with subterranean clover. Iversen and Calder⁽¹⁰⁾ have summarised the characteristics of the subterranean clover-based sward:-

- (a) Increased total production where the density of perennial species is low.
- (b) A concentration of production in spring (i.e. up to 60%), which creates management problems.
- (c) Annual production which is extremely variable. (Over a ten year period at Ashley Dene, subterranean clover based pastures yielded from 900 to 7,000 lbs. dry matter per acre.) When the clover germinates in the autumn, there is a small winter growth followed by an intense spring flush which dies off in November, but may provide paddock roughage for summer. Flowering occurs in early October and, in a wet year, a vast build up of seed may occur, but in a dry season, the clover may dry off before any seed is set. While this is important in a new pasture, it is of little consequence in an old pasture where regeneration can occur from hard seed. If autumn moisture is unfavourable either seed may fail to germinate, it may germinate early and fail to survive, or germinate late and be killed by the frost.

While the subterranean clover based pastures had enabled carrying capacities to be increased on light land, the variability in production did pose a management problem. Grasses in the mixture tended to reduce this variability slightly. However the

(10) C.E. Iversen and J.W. Calder, (1956), op. cit., p.80.

production of the sward depended heavily on the germination and growth of the clover. To this end Iversen and Calder⁽¹¹⁾ observed that:-

"a legume less subject to the vagaries of climate would be of value".

(iii) The Introduction of Lucerne to the Pasture Mixture.

The value of deep rooting lucerne on the light land was soon realised. Leitch⁽¹²⁾ stated:-

"More recently successful attempts have been made to establish cocksfoot and lucerne to bridge the gap when the subterranean clover goes off".

He also recorded that:-

"It is felt this mixture could be used more widely on some of the light plains country with definite advantage."

In 1949 lucerne was included in the pasture mixtures at Ashley Dene. Results over six years (Table 3.1) indicated greatest production from a pasture where lucerne was added to a low density grass-subterranean clover mixture.

Table 3.1

Production in Pounds of Dry Matter per Acre⁽¹³⁾

| | 6 year average |
|-----------------------------------|----------------|
| Subterranean clover & dense grass | 2,965 lbs. |
| " " " low density grass | 3,439 lbs. |
| " " " " " & lucerne | 4,497 lbs. |

(11) C.E. Iversen and J.W. Calder, (1956), op. cit., p.80.

(12) C.C. Leitch, (1948), "Pastures in Canterbury". Proc. 10th Conf. N.Z. Grassld Ass., p.17.

(13) J.W. Calder, (1956), op. cit., p.58.

This mixture, with light sowings of grass making it favourable for lucerne establishment, was sown in the early spring. It consisted of:-

- 4 lbs. Lucerne
- 4 lbs. Subterranean Clover
- 1 lb. Cocksfoot
- 2 lbs. Perennial Ryegrass
- 2 lbs. Short Rotation Ryegrass (H.1)
- $\frac{1}{2}$ lb. White Clover

Calder⁽¹⁴⁾ states:-

"Such a pasture has a very favourable combination of plants capable of providing maximum grazing under the special conditions existing on these light dry soils".

In addition to the normal subterranean clover pattern of production (described in the previous section) this mixture did provide increased late spring and early summer growth from the lucerne and cocksfoot. It appeared from this work that lucerne associated well with subterranean clover plus thin seedings of ryegrass, cocksfoot or phalaris.

Iversen and Calder⁽¹⁵⁾ compared a lucerne-phalaris-subterranean clover pasture with a subterranean clover-low density ryegrass pasture over six years and found:-

- (a) In each of the six years, the lucerne-phalaris-subterranean clover pasture out-yielded the ryegrass-subterranean clover pasture. (Average total production 4,757 lbs. dry matter per acre, compared with 3,300 lbs. dry matter per acre.)

(14) *ibid.*, p.57.

(15) C.E. Iversen and J.W. Calder, (1956), *op. cit.*, p.83.

- (b) The lucerne-phalaris mixture was subject to the least variability. (39% compared with 50% of ryegrass-subterranean clover.)
- (c) The lucerne-phalaris mixture gave a greatly improved seasonal spread.

The lucerne mixture used in these investigations gave 40% more production than the next best mixture and 100% more than the high density perennial ryegrass-subterranean clover mixture. Following this work Iversen and Calder⁽¹⁶⁾ recommended a combination of subterranean clover, cocksfoot, phalaris and lucerne as suitable for a grazing pasture on light land.

- (iv) Lucerne Production Trials. In 1954/55 a lucerne variety trial was commenced at Ashley Dene. The superiority of lucerne on the improved areas of light land had been demonstrated. However, while the area of lucerne was increasing on the light land, it was being used mainly for haying, with little used for grazing. This trial compared the new grazing types of lucerne - *Medicago glutinosa*, *Rhizoma*, and *Nomad*, with Marlborough in a subterranean clover-low density grass mixture. Production differences were found to be small.

In 1960 Iversen⁽¹⁷⁾ at Ashley Dene began a four year trial comparing *Glutinosa*, N.Z. Certified, Italian and Provence Lucernes, under two grazing treatments. The result of this trial, on the light Eyre soils can be summarised:-

- (a) Where a grass dominant pasture yields 2,500 lbs. dry matter

(16) *ibid.*, p.86

(17) C.E. Iversen, (1965), "Lucerne - Its Potentiality & Methods of Achieving its Potential". Proc. 15th Lincoln Coll. Fmrs' Conf., p.79.

per acre, with considerable variation, and a subterranean clover dominant pasture yields 3,500 lbs. dry matter per acre, with very high variation, lucerne mixtures grazed like pasture yield 5,000 lbs. dry matter per acre with little variation.

- (b) Pure lucerne grazed quickly at the hay stage achieved a yield of 8,000 lbs. dry matter with little variability in yield.

(6,000-9,000 lbs. dry matter for N.Z. Certified.)

While white clover and subterranean clover in a lucerne stand provide high quality feed, total production is reduced and suppression of the lucerne is likely. Iversen⁽¹⁸⁾ in discussing the situation states:

"If our aim is maximum production, then lucerne alone would appear to be the most satisfactory".

Considerable difficulties have been met by farmers in establishing pure lucerne stands in the past, however recent work by White⁽¹⁹⁾ indicates that these problems have now been solved.

The trials at Ashley Dene, over a period of years indicated that the variety of lucerne most suited to the light land soils of Canterbury is the Marlborough strain of *Medicago sativa*. The strain, which is quite different from *Medicago sativa* strains in Australia, U.S.A. and South Africa, and which originated in the Blenheim district, has been improved considerably by Hadfield and Calder at the Crop Research Division of the D.S.I.R. It is a persistent leafy variety and if not as winter active or as early

(18) *ibid.*, p.82.

(19) J.G.H. White, (1969, "Problems in Establishment of Lucerne". Proc. 15th Lincoln Coll. Fmrs' Conf., p.84.

in the spring as other varieties, it has the advantage of higher total production.

2. Ryegrass Improvements. Research was continuing on the improvement of existing strains of ryegrasses and the development of new special purpose varieties.

In 1946 the Grassland Division of the D.S.I.R. released a new stable strain of short rotation ryegrass (H.I.), a cross between Italian and perennial ryegrass. Iversen⁽²⁰⁾ has summarised its characteristics as:-

"Rapid establishment, high first year production, high production in late autumn, winter and early spring, palatability of seed head, palatability of threshed straw, compatibility with associated clovers and ability to reseed are its valuable characteristics. Faults are its low production at high temperatures, its lack of persistence under conditions of low fertility and moisture, its susceptibility to grazing damage and damage by grass grub".

H.I. ryegrass was designed to provide a short term pasture of three to four years. At first it was sown in place of Italian in mixed pastures on light land at rates of 5-10 lbs. per acre⁽²¹⁾. This concept of short term pasture generally failed because the fertility demands of the H.I. were not satisfied by the low fertility soils in the low rainfall areas of Canterbury.

Its persistence was poor, often lasting only one year and as a result it was not used extensively, except as a greenfeed crop sown on renovated subterranean clover pastures. This appears to be its main use on light land for it provides high quality pre- and post-lambing greenfeed. It is usually sown at $\frac{1}{2}$ -1 bushel per acre with 6 ozs. of York Globe turnips.

(20) C.E. Iversen, (1958), "Short Rotation Ryegrass". Canterbury Chamber of Commerce, Agricultural Bulletin, No. 343.

(21) C.E. Iversen, (1949), "Some Observations on Short Rotation Ryegrass". Proc. 11th Conf. N.Z. Grassld Ass., p. 192.

With the aim in view of breeding a dense perennial plant with more palatability and winter growth than the New Zealand perennial, Corkill, and later Barclay⁽²²⁾ crossed New Zealand perennial with short rotation ryegrass. Over a period of fifteen years, selection was made towards the dense leafy perennial plant, and, as a result, the long rotation or "Ariki" strain of ryegrass was developed⁽²³⁾.

This ryegrass was bred especially for the high fertility, cold conditions of Southland, but it has performed well in other areas of New Zealand also. On the medium-light soils it has given greater summer and winter growth than New Zealand perennial, having a wider spread of seasonal production. Generally it appears to be intermediate in production between short rotation and New Zealand perennial in all seasons except summer, when it is much superior to both. Trials⁽²⁴⁾ have shown Ariki to be as persistent as New Zealand perennial and quick to recover after grazing or droughts. Both leaf and seed head are highly palatable.

Effect on stock health has not yet been fully investigated though some scouring has occurred when ewes were grazed on Ariki. Lower lamb weight gains were also recorded when the new strain was compared with short rotation and New Zealand perennial. It does appear that Ariki performs better under high fertility conditions, and on poor soils production was shown to be less than from New Zealand perennial.

Investigations are continuing on this aspect of the new ryegrass.

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- (22) P.C. Barclay, (1963), "Ariki - A New Selected Perennial-type Ryegrass Variety". Proc. 25th Conf. N.Z. Grassld Ass., p.128.
 - (23) P.D. Sears, (1961), "New Long Rotation Ryegrass". N.Z. Jl Agric., 103.6:524.
 - (24) L. Bascands, (1963), "Field Performances of Grassland Division's New Selected Perennial-type Ryegrass - Ariki". Proc. 25th Conf. N.Z. Grassld Ass., p.137.

It does not appear that Arika will find a universal acceptance on the light land of Canterbury except where fertility has been built up by increased application of fertiliser, lime, increased stocking and sound husbandry.

There is no doubt that the introduction of subterranean clover to the light land in Canterbury in the 1930's initiated the transformation which was to occur on these soils. This plant, with its greater persistency on the thin soils, allowed longer pasture life, and through its greater production, higher stocking rates and thus a gradual build up of soil fertility. Eventually, as fertility increased, lucerne was introduced to the mixture to provide increased production (especially in summer), and with less variation. It was soon realised, however, that lucerne, sown on its own, gave even greater production and the current view is that where maximum production is required, lucerne should be sown pure.

These two species, subterranean clover and lucerne, have been foremost in the development which has, and still is, occurring on the light land of Canterbury.

3.2.2 Forage Crop Improvement. In the 1930's forage cropping was practised extensively on the light land soils. This was necessary to satisfy the requirements for wintering ewes, fattening lambs and for the provision of chaff for both horses and sheep. This pattern of production fitted in well with the constant need for pasture renewal, which made extensive ploughing and resowing imperative. However, as pastures became more permanent and more high producing, the area under cultivation each year diminished. Lucerne hay replaced chaff and with the increased stock prices in the late 1940's, the area of cash cropping on the light land diminished. Crop yields were poor and so the pattern of production changed in favour of fat lamb farming.

As a result, the need for more reliable and highly producing forage crops on the light land increased. New varieties of swedes and turnips gave increased production. The swede "Calder", bred by R.A. Calder, proved to be well suited for growing on light lands which were marginal for swede growing. It exhibited a measure of resistance to dry rot, clubroot, mosaic⁽²⁵⁾, brown heart, and aphid attack and has been widely accepted on the more fertile phases of light land.

Turnip varieties were gradually being improved through selection and the main crop variety which is grown extensively on light land at present is the New Zealand Green Globe. This variety combines high production with extremely good keeping qualities. New Zealand York Globe, a quick maturing variety, is now very popular where fertility has been built up and has the advantage that it can be sown in late summer when early sown crops have failed, or with new grass, or renovated subterranean clover.

Both turnip and swede varieties are unfortunately susceptible to Brown or Mottled heart, a physiological disease which causes internal disorders in the bulb. This is due to a boron deficiency in the soil. Lynch⁽²⁶⁾, has shown that this condition can be prevented by the application of up to 40 lbs. of Borax, either before or after sowing. The present practice is to broadcast borated superphosphate when sowing the seed. Brown heart may be induced by heavy liming since plants are less able, under alkaline conditions, to take up boron from the soil.

Perhaps the most serious disease in turnip crops in Canterbury is the turnip Mosaic. This is a virus infection which causes necrosis of the leaves

(25) E.E. Chamberlain, (1948), "Varietal Resistance of Swedes to Turnip Mosaic". N.Z. J1 Sci. Technol., A29: 273-276.

(26) P.B. Lynch, (1941), "Control of Brown Heart in Turnips and Swedes". N.Z. J1 Agric., 63.2: 109-12.

and, in serious cases, a rotting of the bulb and hence complete loss of crop. Blair⁽²⁷⁾ has suggested that transmission of the virus by the Cabbage aphid (Brevicoryne brassicae) from infected rape crops is the chief menace to turnip crops. He considers that the widespread use of an aphid resistant rape would effectively control the spread of this virus. Lowe⁽²⁸⁾ has shown that aphides in brassicas can be eradicated by spraying with Lindane and Metasystox. Time of spraying is important and must be carried out to coincide with maximum aphid build up.

Recently Palmer⁽²⁹⁾ has had success in breeding a virus resistant turnip "Kapai 66", which is a hybrid cross between swedes and turnips. At present it is lower yielding and grows more deeply in the soil than either Green or York Globe Turnips, however these defects will be eliminated. It is sufficiently virus resistant to produce good crops where other varieties would fail. The new variety promises to be of considerable value to the light land farmer for it will enable him to sow earlier than normal on light land, and, where necessary, hold a crop until late winter without fear of loss through virus attack.

While rape⁽³⁰⁾ has been the main lamb fattening crop grown on the light land over the years, it has not always been a reliable crop. This is due to the affect of the dessicating north-west wind during the summer and to the severe attack of the Cabbage aphid which is most common in dry summers. The aphid, having over-wintered on other brassicas, causes leaf fall and renders

(27) I.D. Blair, (1958), "Disease in Turnips & Related Crops." Canterbury Chamber of Commerce, Agricultural Bulletin, No.347.

(28) A.D. Lowe, (1956), "Recommendations for the Control of Insect Pest on Brassica Crops in New Zealand." N.Z. Jl Agric., 93.4:341-358.
A.D. Lowe, (1958), "Effect of Metasystox on the Cabbage Aphid". N.Z. Jl Agric. Res., 1. 1:37-43.

(29) T.P. Palmer, (1965), "Kapai 66". N.Z. Jl Agric., 111.7:55.

(30) J.L. Symons, (1961), "Rape". N.Z. Jl Agric., 102.1:51.

those leaves remaining on the plant unpalatable to stock. After several years of investigations, Palmer⁽³¹⁾ made a significant contribution. He selected a hybrid form of rape (a cross between Calder swede and Clubroot resistant rape) exhibiting the aphid resistance of the Calder swede and the form, production and palatability of the rape. This cross has proved to be the equal of other varieties in years when aphid attack is low. When aphid attack is severe however, the aphid resistant variety remains clean and highly producing.

This new variety has not only been accepted widely in Canterbury, but also in several countries overseas.

3.2.3 Fertiliser Research. The realisation in the 1930's that applications of superphosphate and lime were necessary to promote more permanent and vigorous pastures was undoubtedly one of the milestones in the development of the light land. Until then:-

"No systematic topdressing was practised because of the short duration and uncertainty of the pasturage"⁽³²⁾.

Forage crops, along with new grass, were sown with 1 cwt of superphosphate, but no lime was applied. Bevin⁽³³⁾ recorded that early topdressing trials at Ashley Dene indicated that the response of subterranean clover to superphosphate was greatly improved when lime was also applied. The recommended rate of topdressing then was 5-6 cwt. of lime and 1 cwt of superphosphate per acre at sowing, with a maintenance dressing of 1 cwt. of superphosphate and 5 cwt. of lime in alternate years. This was increased during the late 1940's and the general practice was to sow pastures with 1 cwt. of superphosphate and 1 ton of lime. Maintenance dressings consisted of up to 1 cwt. of superphosphate on new

(31) T.P. Palmer, (1960), "Aphid Resistant Rape." N.Z. Jl Agric., 101.4:375-6.

(32) R.H. Bevin, (1946), op. cit., p.9.

(33) ibid., p. 10.

pastures and 1 ton of lime every 4-5 years.

Responses to superphosphate and lime on the light land were marked during this period, and this led to the belief that phosphate and lime were the only real deficiencies inherent in the soil.

This theory was maintained until Lobb⁽³⁴⁾ obtained widespread sulphur responses in North Otago. Walker⁽³⁵⁾ was prompted by this finding to investigate sulphur responses on light land at Ashley Dene using rape as an indicator plant. The response to sulphur was slight, but this may have been due to the residual effects of previous superphosphate applications. Walker did however obtain sulphur responses further inland and especially on the low foothill country⁽³⁶⁾.

Following the work in North Otago, Lobb and Bennetts⁽³⁷⁾ used a series of trials over a wide area of the light land in Canterbury to investigate fertiliser responses on these soils. The trials on virgin land gave responses to sulphur and phosphate though the responses to phosphate were poor in the absence of sulphur. Lobb and Bennetts thus concluded that previous responses to superphosphate were in fact not only due to the phosphate content but to the sulphur also. On the trial sites the response to sulphur alone was greater than to phosphate alone.

While earlier work on these soils had referred to phosphate deficiencies only, Lobb and Bennetts found that phosphate without sulphur was of little value and vice versa. The response was greater when both were applied together.

(34) W.R. Lobb, (1953), "Sulphur Responses in North Otago". N.Z. J1 Agric., 86. 6:559.

(35) T.W. Walker, et.al., (1954), "Some Effects of Sulphur and Phosphorous on the Yield and Composition of Rape". N.Z. J1 Sci. Technol., A36:103-110.

(36) T.W. Walker, (1964), "Correcting Sulphur & Phosphate Deficiencies in South Island Soils". N.Z. Fertil. J., No.25 p.9.

(37) W.R. Lobb and R.L. Bennetts, (1959), "Fertiliser Responses on Plains Soils of Canterbury". N.Z. J1 Agric., 99.4:317.

Where molybdenum and lime were applied with the phosphate and sulphur, the response was greater than when either molybdenum or lime was added independently; while phosphate and sulphur responses, without either molybdenum or lime, were extremely low. Lime is effective in two ways. It raises the pH level and releases molybdenum. Molybdenum responses were found on most of the sites where only 1 ton of lime had been applied which suggested that insufficient molybdenum had been released by the lime. This is of considerable significance for the molybdenum deficiencies were wide-spread on the unimproved soils. The application of small quantities of molybdenum instead of several tons of lime to correct this deficiency would result in a considerable financial saving. Lobb and Bennetts came to the same conclusion as had Walker, et.al.⁽³⁸⁾ in their trials at Ashley Dene on the non-response of improved pasture to sulphur applications. They had suggested that this was due to the residual effects of sulphur supplied by superphosphate, for on the virgin soils both phosphate and sulphur were limiting.

In recent years most of the light land has been topdressed with superphosphate and since these soils do not readily fix phosphate in a form which is unavailable to the plant, Lobb and Bennetts suggested that there is likely to be a phosphate reserve built up in the soil. Where the level of topdressing was reduced then sulphur responses would immediately appear and fertility may be maintained by the application of sulphur alone, especially where previous superphosphate dressings had been high. Trials already started had indicated that this hypothesis may be correct.

In another series of trials at Winchmore Irrigation Research Station,

(38) T.W. Walker, et.al., (1954), op. cit.

Lobb⁽³⁹⁾ made further studies of the phosphate and sulphur responses and on maintenance topdressing on the light land. These trials, which were started in 1952/53⁽⁴⁰⁾ indicated that the greatest response to superphosphate topdressing on the light soils was at the $1\frac{1}{2}$ cwt. per acre per annum level. Further applications of another $1\frac{1}{2}$ cwt. (i.e. 3 cwt. per acre per annum) gave only an additional 10% production. However the phosphate level in the soil, prior to this trial commencing, was not stated.

The ratio of phosphorous to sulphur in fertilisers was also investigated in this experiment. (1 cwt. of superphosphate contains 10 lbs. of phosphorous and $12\frac{1}{2}$ lbs. of sulphur.) Lobb found that while there was little response to more than 10 lbs. of phosphorous, there was a response to sulphur up to 18 lbs. per acre, and in the initial stages up to 36 lbs. This indicated that the increased response to superphosphate at rates above 1 cwt. was due to the greater amount of sulphur added.

These results supported the use of sulphur-fortified super on the light land. Lobb suggested that dressings of 3 cwt. of superphosphate initially, followed by 2 cwt. maintenance dressings would be optimum for the light land. However 1 cwt. of 200 lbs. sulphur-fortified super as maintenance would achieve the same result.

The results of this experiment indicated that while initial topdressings should be liberal, there was no evidence to support high maintenance rates on the light land. In fact at Winchmore, under irrigation, seven ewes per acre were being carried on pasture maintained with $1\frac{1}{2}$ cwt. superphosphate per acre

(39) W.R. Lobb, (1962), "Phosphorous & Sulphur Fertilisation: Some Recent Investigations in Canterbury". Proc. 24th Conf. N.Z. Grassld Ass., p.42.

(40) This experiment has been continued. The 1964/65 figures are given in the Winchmore Irrigation Research Station Annual Report, Dept. of Agriculture.

per year. The final results suggested that maintenance dressings of $1\frac{1}{2}$ cwt. superphosphate per acre per year was near the optimum for light land.

With the increasing area and importance of lucerne on the light land, more accurate information on fertiliser responses on lucerne was sought. Some areas of the light land in Canterbury have had difficulty in establishing and maintaining strong and healthy stands⁽⁴¹⁾ while in other areas under almost similar conditions and treatments the lucerne has given high production.

At Winchmore, Harris and Lobb⁽⁴²⁾ found that both phosphate and sulphur were necessary for satisfactory lucerne production. They also observed that where high yields of lucerne were being produced by heavy superphosphate dressings under irrigation and the lucerne being removed in the form of hay, that potash reserves in the soil were being depleted. As a result the supply of potash to the plant became inadequate for optimum plant growth and the stand deteriorated. They suggested that this situation could be overcome by the application of 2 cwt. of potash, where an annual topdressing of 3 cwt. of superphosphate is being applied. Where hay is being fed back on the paddock, there is no problem with potash depletion. This last method has generally been used on the light land and few cases of potash deficiencies in lucerne stands have been recorded.

Harris and Lobb suggest that for the maintenance of healthy lucerne stands lime, sulphur and probably phosphate and molybdenum are required. Where the lucerne is removed as hay, then muriate of potash is also required.

In early liming trials by Hudson and Montgomery⁽⁴³⁾ in Canterbury, only

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- (41) I.D. Blair, (1965), "Deterioration in Lucerne". Canterbury Chamber of Commerce, Agricultural Bulletin, No.434.
 - (42) P.B. Harris and W.R. Lobb, (1964), "A Fertilising Mixture for Stimulating the Growth of Lucerne". Proc. 14th Lincoln Coll. Fmrs' Conf., pp.34-39.
 - (43) A.W. Hudson and A.Y. Montgomery, (1930), "Pasture Topdressing Experiments in Canterbury". N.Z. Jl Agric., 41.4:249.

5% of these failed to give a visible response. They found that ryegrass as well as clover responded to lime and that 1 ton per acre gave effective results for five to six years.

During⁽⁴⁴⁾, in reviewing lime in Canterbury noted that since large areas of light soils were shown to be molybdenum deficient in their unimproved state⁽⁴⁵⁾, the use of molybdenum in place of lime would result in considerable savings to the farmer. The application of molybdenum could however accentuate the copper deficiencies which exist in pastures on these soils. During recommended applications of 1 ton of lime when sowing down pasture on light soils with a maintenance of 1 ton every six to eight years. Recent soil testing by the Department of Agriculture on light land soils in Canterbury, indicate that many of the improved farms have been over-limed in recent years and maintenance dressing on these farms could well be reduced. Evidence suggests that a pH of 6.2 is adequate on virtually all the improved light land.

3.2.4 Grass Grub and Porina Control. Grass grub (Odontria zealandica), and subterranean caterpillar (Oxycanus spp.), are by far the most serious pasture pests encountered by farmers on the low-rainfall light land. These pests attack sown pastures most severely on the light land, causing widespread and usually permanent damage. The subterranean caterpillar (or porina), attacks the plant at ground level leaving the roots intact. The plant sometimes recovers. However the grass grub attacks the plant roots causing permanent damage. Before any measure of control was found, pasture life was severely checked. At Ashley Dene, pasture life expectancy was only two or three years and this tended to encourage the sowing of temporary or short term pastures. Pasture production was uncertain

(44) C. During, (1961), "Liming in Canterbury". N.Z. Jl Agric., 103.6:585.

(45) R.W. Lobb and R.L. Bennetts, (1959), op. cit.

and there is no doubt that these two pests retarded the development of the light land by the shortening of pasture life.

In 1942, poison baits of bran were used with some success in the control of porina and at a reasonable cost. In 1947 D.D.T. dusts and sprays were found to give good control but at an additional cost. When bran became difficult to obtain, Kelsey, Hoy and Lowe⁽⁴⁶⁾ ⁽⁴⁷⁾ demonstrated that D.D.T. incorporated in superphosphate and sown at 2 lbs. of D.D.T. per acre gave three years control of both porina and grass grub⁽⁴⁸⁾. Some natural controlling agents (e.g. carabid beetles) were present but these have been found unreliable for overall control.

As a result of the work of Kelsey, Hoy and Lowe, D.D.T. incorporated in superphosphate, or in a pelleted form, was used extensively on light land pastures and gave excellent results⁽⁴⁹⁾. Unfortunately recent complications have occurred. D.D.T. residue has been found in export meat carcasses at levels unacceptable in some overseas markets. This has been caused by the adherence of the D.D.T. superphosphate to long or damp pastures and subsequent intake by grazing animals. Legislation to prevent this has been introduced⁽⁵⁰⁾ specifying the length of pasture to be treated, the percentage of the farms which may be treated annually, and the period of time before grazing can commence on the treated pasture. The D.D.T.

- (46) J.M. Kelsey, J.M. Hoy and A.D. Lowe, (1950), "New Treatment for Control of Subterranean Grass Caterpillar". N.Z. Jl Agric., 80.22:123.
- (47) J.M. Kelsey, (1964), "Control of Pasture Pests under New Regulations". Proc. 14th Lincoln Coll. Fmrs' Conf., pp.40-42.
- (48) J.M. Kelsey and J.M. Hoy, (1950), "Grass Grub Control". Proc. 12th Conf. N.Z. Grassld Ass., p.88.
- (49) J.M. Kelsey, (1955), "Control of Grass Grub and Subterranean Caterpillar". Ent. Res. Sta. (N.Z) Publ. 14.
- (50) J.M. Kelsey, (1962), "Developments in Grass Grub Control". Proc. 12th Lincoln Coll. Fmrs' Conf., pp.25-26.

is now available only in a pelleted form which carries easily to the ground surface, thus reducing the likelihood of intake by animals.

The discovery that D.D.T. would effectively prevent grass grub and porina attack has contributed probably more than any other single innovation to the improvement of the light land in Canterbury. Not only is pasture life considerably lengthened, but production in any one year can be viewed with much greater certainty.

3.2.5 Livestock - Production and Performance. Stock production and performance on the light land farms in Canterbury has vastly improved over recent years. Improved feeding and breeding have led to high carrying capacities, increased fertility and greater output of wool and fat lambs, both per head and per acre.

The current export market demands high quality, light-weight lambs. Using quick maturing sires, and especially when mated with crossbred ewes (e.g. Border Leicester X Corriedale), rapid lamb growth rates are being achieved on the fat lamb farm, enabling export lambs to be ready for drafting at 10-12 weeks of age. Where meat output is of such importance, and where the feed supply is so uncertain over the summer months, rapid fattening of lambs is an extremely desirable characteristic.

The higher carrying capacities have been made possible by increased total production from the pastures, and, through a better understanding of feed requirements of the ewe, a more efficient utilisation of the available feed,

The control of ill-thrift in lambs with selenium and the use of improved drenches, have both made significant contributions towards the increased efficiency and level of production of the light land farms in Canterbury.

(a) Crossbreeding. Crossbreeding has always been considered advantageous in fat lamb production. Crossbred lambs mature earlier, fatten more

easily, and produce a better quality meat than lambs of a pure breed. The conventional system of New Zealand fat lamb farming consists of using pure bred ewes as dams, mated to Down type sires. This system is simple and gives conformity in the wool and lamb growth and takes advantage of crossbreeding in the final stage through the use of the Down sire. It has one disadvantage however, in that the ewes, bred mainly in the hill country, may not be the ideal breed to use as fat lamb dams in the more favourable conditions existing on the fat lamb farms. The lambing percentage and growth rate normally achieved under these conditions are extremely low compared with performances overseas and especially when compared with performances attained with crossbred ewes in Scotland and elsewhere.

Coop⁽⁵¹⁾ was aware that higher levels of production were possible using crossbred ewes. The low lambing percentage and slow lamb growth rate of the lowland Corriedale and Romney ewe offered great scope for improvement, especially where a breed of high fertility and milk production was available to give first cross ewes.

In 1950, Coop, at Lincoln College, began a programme of crossbreeding for fat lamb production under New Zealand conditions. He compared first cross ewes from the crossing of Border Leicester rams with Corriedale ewes, with Corriedale ewes. These were mixed age flocks, run and managed as one mob and mated to Down rams for fat lamb production. Replacements for the flocks were bred and the trial, which began in 1952, was carried out on the light land of Ashley Dene.

Coop obtained the following results over five years:-

- (i) The Border Leicester X Corriedale (BL.C) ewe lambs were 9.0 lb.

(51) I.E. Coop, (1957), "Border Leicester Cross Ewes for Fat Lamb Production", N.Z. J1 Sci. Technol., A38:966.

heavier at weaning, grew faster as hoggets, and were 15-20 lbs.

heavier at maturity than were the Corriedales.

- (ii) The BL.C clipped 0.9 lb. more wool per ewe than did the Corriedale but the wool was lower in value by 10%, financial returns per fleece were approximately equal.
- (iii) The BL.C ewes dropped 23% more lambs per ewe lambing compared with the Corriedale and weaned 23% more lambs per ewe mated.
- (iv) Weaning weights of single and twin BL.C lambs were 5-6 lbs. heavier than those of the Corriedale.
- (v) BL.C gave a higher percentage of lambs fat off the mothers with a 1.7 lb. higher carcass weight of a slightly better conformation.
- (vi) The financial returns per acre from the BL.C exceeded those from the Corriedale by 29% for lamb only, and 16% for lamb and wool.

The results of these trials comparing first-cross ewes with the pure breed have been quite spectacular and there is no doubt as to the improvement in performance when compared with the Corriedale. Lambing percentages, growth rate in lambs, and the time of maturity are all improved, making the BL.C ewe much better suited to the local conditions than the Corriedale.

While the BL.C ewes have been accepted in certain areas on the plains their numbers have not been expanded as could be expected. This can be attributed to several factors, most important of which is probably their unavailability. Few BL.C hoggets or two-tooth ewes appear on the market, so that it becomes necessary to breed the cross.

The additional feed required for maintenance of the heavier BL.C ewe, which has the effect of reducing the superiority of the crossbred, may have been over emphasised at the expense of the BL.C⁽⁵²⁾. The

(52) H.E. Garrett, (1962), "Lambing Percentages on Light Land". Proc. 12th Lincoln Coll. Fmrs' Conf., pp. 68-72.

slightly lower quality of the wool, and the tendency for more rapid teeth deterioration are both factors which have probably impeded the expansion of the crossbred.

Where crossbreds have been carried for several years on commercial farms on light land, the improvement in lambing performance has been a significant feature of the flock. At Ashley Dene, the BL.C ewes consistently give higher lambing percentages, lamb growth rates, and weaning weights, than do the pure Corriedales.

- (b) Fat Lamb Sire Comparisons. Rams used on the fat lamb farms are supplied from stud flocks throughout the country. In the South Island approximately 80% of the sires used are Southdown, the remaining 20% include the heavier breeds, i.e. Border, Leicester, Ryeland, Suffolk, Dorset Horn, English Leicester, and crossbred rams such as Southdown X Border Leicester, and Southdown X Suffolk (South Suffolk).

The distinct characteristics which make the Southdown-cross lambs so popular are the high percentage of lambs which can be drafted fat off ewes and their excellent conformation enabling them to be drafted at light carcase weights, i.e. 28-36 lbs.

Since New Zealand is the only country in the world where the Southdown is regarded so highly, Coop and Clark⁽⁵³⁾ felt that the characteristics of the other breeds available should be investigated. They began a trial in 1947 to compare the various breeds under the following:-

- (i) Percentage drafted fat off the mothers.
- (ii) Carcase weight.
- (iii) Carcase conformation and grading.

(53) I.E. Coop and V.R. Clark, (1952), "A Comparison of Breeds of Ram for Fat Lamb Production". N.Z. J1 Sci. Technol. A34:153.

In the trial at Kirwee (on medium-light soil) and Ashley Dene (on light soil) over a four year period, Corriedale, Southdown, Ryeland, South Suffolk, Border Leicester, Dorset Horn and Suffolk sires were used on Corriedale ewes. Also Romney, Southdown and Border Leicester sires were used with Romney ewes.

The results can be summarised:-

- (i) With the exception of the pure bred lambs, all the crosses gave similar percentages of lambs drafted fat off the mothers.
- (ii) The growth rates of the lambs by the heavier sires (Border Leicester, Dorset Horn and Suffolk) were greater than those of the Southdown cross lambs by approximately 0.09 lb. live weight, gain per day.
- (iii) The carcass weight of the lambs by the Border Leicester, Dorset Horn and Suffolk rams was approximately 4.0 lbs. heavier than that of the Southdown cross lambs, both as milk lambs and as rape lambs. Intermediate between these were the lambs by Ryeland and South Suffolk rams.
- (iv) There were no differences in the commercial grading of the carcasses though those by the Southdown were superior in regard to blockiness and shortness of leg.

The percentage of lambs drafted off the mothers is of paramount importance on fat lamb farms in New Zealand and especially in Canterbury where pasture growth and quality decline rapidly in late November and December. While supplementary fattening feed (i.e. rape) is often sown on these Canterbury farms, the need for this is reduced when a high percentage of lambs is sold at, or before, weaning. Unless a ram can give this high drafting percentage, it is of little value to the light

land farmer. The belief that the Southdown gives this high percentage is one of the reasons for its popularity throughout Canterbury. However Coop has shown that it is, in fact, no better than the other breeds in this respect.

These trials have shown that increased carcass weights are obtainable with heavier breeds, but at the expense of shortness and blockiness in the carcass. There is no doubt of the superiority of the Southdown in the production of a short blocky carcass, as compared with the long-legged carcass in the Border Leicester and Dorset Horn. It appears that with crosses (i.e. excluding the pure breeds) conformation and grading are inversely related to growth rate and carcass weight. As Coop⁽⁵⁴⁾ has explained, the schedule ruling at the time of this trial made it more profitable to produce the heavy weight lamb.

This trial was extended over the period 1953-1956⁽⁵⁵⁾ for two reasons:-

- (i) To provide information on sires not included in the original trial, or those on which little information was gathered. These included the Hampshire, Dorset Horn, Border Leicester X Southdown, and the South Suffolk.
- (ii) To provide information on the various sires under the conditions of early drafting of lambs at light weights.

In the original trial Coop and Clark⁽⁵⁶⁾ killed their lambs at mean ages of 122-132 days (in one year at 100 days). However after 1954 the demand increased for very light lambs, below 29 lbs. carcass weight.

(54) I.E. Coop, (1951), "Fat Lamb Sires." Proc. 1st Lincoln Coll. Fmrs' Conf.p.53.

(55) I.E. Coop and V.R. Clark, (1957), "Breeds of Rams for Fat Lamb Production". N.Z. Jl. Sci. Technol, A38:928.

(56) I.E. Coop and V.R. Clark, (1952), op. cit.

Premium prices were paid and consequently it became necessary to study relative performances when the lambs were killed at about 90 days.

In the first two years of this trial, Suffolk, Border Leicester, Hampshire, Dorset Down, South Suffolk, Border Leicester X Southdown and Southdown sires were crossed over Corriedale ewes and in the second two years Suffolk, Dorset Down and Southdown sires were crossed over Corriedale and Border-cross ewes.

The following conclusions were drawn from the trial:-

- (i) Compared with the weaning weight of the Southdown the heavy sires, Suffolk and Border Leicester increased weaning weight by 8 lbs. at 110 days, but only 4.0 lbs. at 86-95 days. The percentage of lambs drafted fat off the mothers was similar to that from the Southdown, but a lower percentage of prime lambs was drafted due to their inferior grading. Carcase weight was however increased by 4.0 lbs. with the later drafting and 2.0 lbs. with the 86-95 day drafting.
- (ii) The medium-weight sires, Hampshire, Dorset Down, South Suffolk and Border Leicester X Southdown, increased weaning weight by 6.0 lbs. at 110 days and 3-4 lbs. at 86-95 days. The percentage of prime lambs drafted fat off the mothers is the same as the Southdown at the early drafting. Carcase weight is increased by 2.0 lbs. at the late drafting and by 1.5 lb. at early drafting.
- (iii) The Southdown was much superior in carcase conformation to the medium-weight sires which in turn were superior to the heavy-weight sires.

- (iv) Early drafting penalised the heavy sires relative to the Southdown on the score of grading, or percentage of prime lambs drafted; and penalised to a lesser extent the medium-weight sire.
- (v) The medium-weight sire represents a compromise between rate of growth and conformation. Of these, the Hampshire and Dorset Down give the most satisfactory performances.

This trial indicated, as had earlier trials, that the Southdown is outstanding for the production of light-weight lambs. It produces lambs with the slowest growth rate and lightest carcass weight but the best conformation.

As long as the demand for the light-weight lamb continues, it seems likely that the Southdown sire will retain its popularity. Where the Southdown sire is used with small Corriedales on the light land the resulting lamb tends to be small in frame and hence lower in weight at maturity. This problem has been overcome in some instances by using the medium-weight sires, including the South Dorset Down, a recently introduced cross between the Dorset Down and the Southdown. This cross is somewhat longer than the Southdown, has extremely good growth rates and the good carcass conformation of the Southdown. On the light land fat lamb farm where the aim is to draft maximum numbers of lambs fat off the mothers, the Southdown will in general provide a high percentage of light-weight, high quality carcasses. When drafted at very early ages, i.e. 10-12 weeks, which is often necessary on the light land, the lower-weight of the carcass places the Southdown at a disadvantage when compared with the other sires. In this respect, the medium-weight sires are more suitable, for while

they tend to be of poorer conformation at drafting, the additional weight more than compensates for any drop in price incurred through the carcasses' being down-graded. This tendency has led to the increased use of the Dorset Down and South Dorset Down sires on the light land in recent years. As Coop has demonstrated in trials at Ashley Dene, the medium-weight sires represent a compromise between high growth rates and excellent conformation, while allowing high percentages to be drafted fat off the mothers.

- (c) **Post-Weaning Treatment of Ewes.** The treatment of ewes after weaning and during mating has been the subject of considerable research in recent years. This research has been of great value to the light land farmer for, while the feed supply on the farm is normally at the lowest level reached during the year, the nutrition of the ewe flock during this period decides to a major degree the reproductive performance of the flock.

Until recently it was thought that the ewe flock need not be well fed during the period from weaning until flushing starts three weeks prior to mating. In Canterbury ewes were mob grazed on what paddock roughage was available. Where stock water was adequate, the quality and quantity of feed provided for ewes was in general poor. On the light land any high quality feed which is available during this period is required either for fattening lambs or ewe hoggets and the system of hard grazing ewes over the summer fitted in well with the local system of farming.

There is a widely held view that ewes should not become overfat prior to mating because fatness is a cause of infertility. Research has shown that where ewes are in store condition over the summer, a rising

plane of nutrition prior to and during mating is conducive to higher fertility. This appears to have led to the practice of hard grazing, and even to the reduction of body weight over the summer followed by a flushing period of three weeks before tupping. There is no evidence however, to suggest that higher lambing percentages are obtained from ewes treated in the above manner as compared with ewes which have been well fed throughout the period.

Wallace⁽⁵⁷⁾ observed that in a mob of mixed age ewes which were weighed in February prior to mating, lambing percentages were always highest in years when the ewes' condition were highest. This prompted him to investigate more fully the management of ewes after weaning⁽⁵⁸⁾.

In a trial, three groups of 120 ewes were fed at high, medium and low planes respectively so that the high plane ewes became excessively fat and the low plane ewes very thin by mid-February. Three weeks prior to mating all groups were combined and treated as one mob from then on. Wallace found that:-

- (i) The different feeding planes had little effect on time of onset of the breeding season or the speed with which ewes took to the ram.
- (ii) The high plane ewes which became very fat before mating, became pregnant more readily than those which were on the low plane and then flushed.
- (iii) There were fewer dry ewes in the high plane group.
- (iv) The ewes that returned and that failed to go into lamb were mainly ewes in poorer than average condition.

(57) L.R. Wallace, (1958), "Breeding Romneys for Better Lambing Percentages". Proc. Ruakura Fmrs' Conf., p.62.

(58) L.R. Wallace, (1961), "Influence of Liveweight and Condition on Ewe Fertility". Proc. Ruakura Fmrs' Conf. p.14.

- (v) The high plane ewes produced the greatest number of lambs per ewe lambing, and gave the highest overall lambing percentage on number of ewes mated.
- (vi) The high plane ewes produced more wool throughout the period than did either of the other groups.

Wallace suggested that feed should still be conserved for flushing ewes but that there was a definite improvement in stock performance when ewes were not hard grazed over the post-weaning period.

These results were contrary to the widely held views of the time. However they have since been confirmed on many commercial properties on the light land of Canterbury and elsewhere.

Coop, for some time, had been investigating at Lincoln the influence of liveweight on maintenance requirements, productivity and efficiency⁽⁵⁹⁾. He was stimulated however by Wallace's observations and extended the investigations at Lincoln College to include the influence of liveweight at mating on reproductive performance.

Data from various experiments carried out over a period of years at Lincoln was analysed for relationships between breeding performance and liveweight at mating. The following observations were made:-⁽⁶⁰⁾

- (i) Ewe and lamb mortality, 3.8% and 12.0% respectively were independant of liveweight of the ewe, except at liveweights below 90-100 lbs.
- (ii) Barrenness (mean 6%) was relatively independant of liveweight above 90-100 lbs. but below this critical weight barrenness increased rapidly.

(59) I.E. Coop, (1961), "The Energy Requirements of Sheep". Proc. N.Z. Soc. Anim. Prod., 21:79.

(60) I.E. Coop, (1962), "Liveweight Productivity Relationships in Sheep". N.Z. Jl agric. Res., 5:249.

- (iii) Twinning increased approximately linearly with increasing liveweight at a rate of 6% per 10 lbs.
- (iv) The lower breeding performance of two-tooth ewes in comparison with that of older ewes was explained almost entirely in terms of liveweight at mating.

The relative significance of liveweight and flushing as factors influencing lambing percentages is of importance to the fat lamb farmer in Canterbury. Feed supplies are limited in the post-weaning period and as a result the body weight of ewes has often suffered. This reduction in body weight has undoubtedly affected lambing percentages. How much of the effect of flushing can be attributed to liveweight is not yet apparent. Coop suggests that more than 40% of difference in lambing percentages may be due to liveweight difference at time of mating. The answer has not yet been provided. Early trials compared only flushed and non-flushed ewes which were at different weights at mating. More recent work by Wallace⁽⁶¹⁾ however placed ewes on a steady medium level of feeding so as to reach the same liveweight as flushed ewes at the time of mating.

These two groups were compared and the results to date indicate:-

- (i) That liveweight per se is important and can account for a considerable proportion of the response caused by flushing.
- (ii) That liveweight cannot account for all the response.
- (iii) There is some response to a 'rapidly rising condition' in ewes (i.e. the liveweight of the sheep and the dynamic rising condition are both of importance).

(61) L.R. Wallace, (1961), op. cit.

(d) **Liveweight and the Level of Production.** It is well known that the quickest way to increase sheep production is to increase sheep numbers. Experiments by Walker⁽⁶²⁾, Clarke⁽⁶³⁾, Suckling⁽⁶⁴⁾ and Walker⁽⁶⁵⁾ have demonstrated that increased production per acre can be achieved by increasing carrying capacity.

Performance improves at first with increased stocking, as the increased stocking gives greater pasture control, and then declines as feed available per sheep declines. Body weight, fleece weight, lambing percentage and lamb growth rate all decline in this second phase. The important point is, however, that these declines are more than offset by the greater number of sheep carried, and the greater utilisation of pasture grown.

The actual relationship between the size of animals and production, and between the various phases of production, i.e. fertility, milk, and wool production in multi-purpose animals has not been well documented. Generally it has been considered that within a breed large sheep produce more than small sheep, but this has not been shown quantitatively. Coop and Hayman⁽⁶⁶⁾ used information collected from 36 different mobs over several years to study the relationship between liveweight at mating, lamb drop, lamb growth rate, and fleece weight in Corriedale ewes. They found that:-

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- (62) D.E.K. Walker, (1954), "Meat Production per Acre". Proc. Ruakura Emrs' Conf., p.17.
 - (63) E.A. Clarke, (1962), Annual Report, Ruakura, p.48.
 - (64) F.E.T. Suckling, (1962), "Recent Trials at the Te Awa Hill Pasture Research Station", Sheep Fmg A., pp.181-197.
 - (65) S.D. Walker, (1962), Annual Report, N.Z. Dep. Agric., p.48.
 - (66) I.E. Coop and B.I. Hayman, (1962), "Liveweight Productivity Relationships in Sheep". N.Z. Jl agric. Res., 5:265.

- (i) Lamb drop and twinning were significantly and positively correlated with liveweight of ewes at mating.
 - (ii) Lamb weaning weight was correlated with ewe liveweight - a 10% increase in liveweight of a 100 lb. ewe gave a 1.8% increase in weaning weight of lambs.
 - (iii) Fleece weight increased by 4.3% for each 10% increase in liveweight.
 - (iv) The increase in lamb and wool production with increasing liveweight was approximately of the same magnitude as increases in feed requirements. Coop and Hill⁽⁶⁷⁾ estimated that the maintenance in sheep is proportional to liveweight, to the power of 0.73, and since maintenance accounts for the greater part of the annual feed requirements, this factor may be used as an approximation of feed intake, i.e. a 7.3% increase in feed intake for a 10% increase in liveweight. This would suggest that the theoretical efficiency of conversion of feed to lamb and wool is fairly independent of liveweight.
 - (e) The Feed Requirements of Sheep. With the increasing emphasis on increased production per acre, the concept of efficiency of feed conversion rather than individual production per sheep is becoming more important. This implies a knowledge of the fundamental feed requirements of sheep and factors affecting them.
- In recent years, Coop⁽⁶⁸⁾, Coop and Hill⁽⁶⁹⁾, and Coop and Drew⁽⁷⁰⁾,

(67) I.E. Coop and M.K. Hill, (1962), "The Energy Requirements of Sheep for Maintenance and Gain". J1. agric. Sci., 58:187.

(68) I.E. Coop, (1961), op. cit.

(69) I.E. Coop and M.K. Hill, (1962), op. cit.

(70) I.E. Coop and K.R. Drew, (1963), "Maintenance & Lactation Requirements of Grazing Sheep". Proc. N.Z. Soc. Anim. Prod., 23:53.

investigated the problem of estimating feed requirements of sheep under New Zealand conditions. They found that figures for maintenance of pen fed sheep, produced by research workers in the U.S.A. and U.K. and used in New Zealand in the past were up to 60% higher than those determined at Lincoln. The work at Lincoln was concerned with:-

- (i) Studying factors affecting maintenance,
- (ii) Estimation of feed intake of the lactating ewe.

Coop and Drew found that in comparison with pen feeding of sheep, grazing of long pasture for a short time increased maintenance requirements by 20-30%, but grazing of short pasture which just allowed sheep to maintain body weight, caused 50-80% increase. It was suggested that this was due to the high cost of harvesting the grass, and that this cost varied markedly with length and density of pasture available. These increases in requirements for the grazing sheep tended to some extent, to offset the over estimation of requirements of pen fed sheep by U.S.A. and U.K. workers. Their figures for the pen fed sheep approximated the figures for grazing sheep under N.Z. conditions. Coop and Drew found that in the first month after shearing in the autumn, maintenance requirements were increased by 20-40%. Measurements of the intake of the lactating ewe were also made and requirements were found to be 20% above those of existing U.S.A. and U.K. feeding standards.

This basic information on local feeding standards formed the basis of a review of the ewe equivalent system in which Coop⁽⁷¹⁾ converted all different species and classes of stock to a common unit - the

(71) I.E. Coop, (1965), "A Review of the Ewe Equivalent System".
Jl N.Z. Inst. agric. Sci., 1.3:13.

breeding ewe. The ewe equivalent, or stock unit system is invaluable as a method of expressing present and potential productivity of farms. It is not a measure of what animals actually produce, but a measure of the grass they harvest by grazing. On a per acre basis, ewe equivalents represent carrying capacity.

This system has been used for some time by Government Departments, Agricultural Colleges, and extension workers, all of whom have calculated their own values, based on U.K. and U.S.A. feeding standards. Coop⁽⁷²⁾ has shown however that these overseas standards calculated for stall fed animals deviate quite widely from local requirements where grazing animals are of prime importance.

This revised ewe equivalent system based on the feed requirements of the breeding ewe under New Zealand conditions, has enabled greater accuracy and uniformity in the calculation of the coefficients used by those engaged in applied farm management in New Zealand.

- (f) Early Weaning and Lamb Fattening. Where drought conditions occur in late spring on the light land the optimum utilisation of the available feed is imperative especially under high carrying capacities. Both early drafting of light-weight lambs, and early weaning help to overcome this problem. While it appears that lambs can be weaned at eight to ten weeks without any ill effects, there is little known as to which type of pasture provides maximum lamb growth rates from then until drafting.

McLean et.al.,⁽⁷³⁾ studied lamb growth over a period of years on five

(72) *ibid.*, p.17

(73) J.W. McLean, et.al., (1965), "The Quality of Lucerne Pasture for Lamb Production". Proc. 15th Lincoln Coll. Fmrs' Conf. pp.88-92.

pure species, i.e. lucerne, white clover, timothy, short rotation ryegrass and perennial ryegrass.

White clover and lucerne were found to give the highest lamb growth rates over the spring-summer period. Lambs from Border Leicester-Corriedale ewes mated to Dorset Down rams, weaned at 7 weeks grew at 0.68 and 0.64 lb. liveweight per day on white clover and lucerne respectively. This was almost twice the growth rate obtained on the ryegrasses. In the autumn however, with lambs at twenty-five weeks of age, the growth rate was 0.47 lb. per day on clover and only 0.35 lb. per day on lucerne. In mid-May, the lucerne appeared to become lower in its nutritional quality, almost approaching that of perennial ryegrass.

A plant which provides for rapid and efficient fattening of lambs is of great benefit to the light land farmer. It allows him quicker turnover of high quality fat lambs, and hence less risk of loss through the effects of summer drought. Where this plant can be incorporated as a pasture species, replacing the specially sown supplementary fattening crop, e.g. rape, then considerable savings are made.

The value of clover and lucerne in this respect has been demonstrated by McLean et.al. Lambs from the clover and lucerne plots at the end of the 1963 trial (December 9th) weighed over 100 lbs. liveweight when less than four months old. An analysis of fat content of the 50 lbs. carcasses indicated that the fat percentage was only 2% higher than that of the 26 lb. carcasses from the ryegrass plots. The inference therefore is that in crosses such as the lamb from the Border Leicester X Corriedale ewe mated to the Dorset Down ram, good

nutrition over the active growth phase of the animal leads to high meat production, without excess fat.

This trial has shown the value of clover and lucerne in lamb fattening. Growth rates compare favourably with those obtained on rape later in the season, and as a result, the dependence on this crop for lamb fattening has decreased. Clover based pastures, and especially lucerne are more reliable on the light land than rape, and have the advantage that they can be grazed much earlier in the season, should early weaning necessitate this.

One of the most significant features of this trial, from the light land farmer's viewpoint is the demonstration that very early weaning of lambs is possible. McLean et.al.⁽⁷⁴⁾ have shown that provided high quality feed is available, lambs weaned at only seven weeks of age continue to grow at satisfactory rates. This knowledge is of immense value in areas subject to late spring and early summer drought, especially where stocking rates are high. Hence early weaning is an effective means of achieving efficient utilisation of the feed available, without sacrifice in lamb meat production.

- (g) Pre-lamb shearing. The practice of pre-lamb shearing on the light land in Canterbury is, like the shearing of lambs, not universal, but adopted by a small percentage of farmers. The advantages and disadvantages of this system of shearing have been discussed in detail elsewhere^{(75) (76) (77)}.

(74) *ibid*, p.89.

(75) A.R. Mackintosh, (1949), "Pre-lamb Shearing of Ewes". N.Z. Jl Agric. 79.6:559.

(76) I.E. Coop, (1950), "Shearing Ewes before Lambing". Lincoln College Technical Publication, No.4.

(77) I.A.M. Lange, (1953), "Pre-lamb Shearing & Early Shorn Wools". Wool, 1.5:49.

Little research has been carried out on this topic, although Coop⁽⁷⁸⁾ has shown that the feed requirements for the pre-lamb shorn ewe increase markedly in the period immediately following shearing. He has estimated that the increase is of the order of 30% more than woolled sheep at the same period. This is of extreme importance on the light land farm, especially where carrying capacity is high. In the pre- and post-lambing periods, the normal feed supplies have usually to be supplemented by special greenfeed crops. When ewes are pre-lamb shorn, the resulting increased demand for feed over the immediate post-shearing period is often difficult to supply on the light land farm. While the increased demand is only for a short period, ewe losses can be high where the demand is not satisfied and especially if cold conditions are encountered.

The only real advantages of pre-lamb shearing on the light land farm appear to be in the spreading of the work load over the year and in the reduced need for shepherding over the summer months. Where the aim is to increase the carrying capacity, pre-lamb shearing should not be considered because of the increased demand for feed over what is already a pinch period on the light land farm.

- (h) Synchronised Lambing. Following on from work already carried out in Australia and at Ruakura, Coop began a series of trials to investigate the effectiveness of synchronised lambing in Canterbury. The principles of synchronisation are adequately described by Coop⁽⁷⁹⁾ elsewhere.

(78) I.E. Coop, pers. comm.

(79) I.E. Coop, (1965b.), "Synchronized Lambing". Proc. 15th Lincoln Coll. Fmrs' Conf. pp. 60-65.

The technique has several advantages especially on the light land farm where the equation of feed supply and stock requirements is an ever present problem.

- (i) The lambing date can be advanced by two to three weeks which may be an advantage on the light land.
- (ii) The lambing is concentrated especially where mating is carried out in March (as it is in Canterbury).
- (iii) The period of peak lambing can be accurately predicted.
- (iv) Through being able to predict the periods of peak mating and lambing, the management of the flock can be made more efficient in winter, pre- and post-lambing feeding, and in lamb drafting.
- (v) There is no evidence to suggest that the technique affects lambing percentage.

The only disadvantage with this technique is the possibility of a storm occurring during the critical week of very concentrated lambing. While this is always a possibility, the necessary precautions can be taken since this period can be predicted. Furthermore, different mobs can be synchronised for different lambing dates.

In trials at Lincoln, where 80% of the ewes were mated in one week, only 60% lambed within the predicted week, with another 25% lambing in the second predicted week, 17 days later. At the peak lambing, 12% of the ewes were lambing per day.

The synchronisation then gave a concentrated lambing for one week, followed by a lull of ten days, and then a second week of concentrated lambing. In the Ashley Dene trials in 1964 involving 1,000 ewes, only four were still left to lamb after 28 days.

Further trials aimed at determining the optimum dates for synchronisation are being carried out at Lincoln. In the trials so far, successful synchronisation has been achieved for Border Leicester X Corriedale ewes on 9th February, and for Romneys on 19th February and 1st March, but so far attempts to calculate optimum synchronisation dates for Corriedales have been unsuccessful.

The technique has been adopted by some farmers in Canterbury, with varying degrees of success. It does appear to have value as a means of advancing lambing dates, should this be desirable, and of concentrating the lambing. The concentration of lambing to coincide with the peak pasture growth should enable more lambs to be fattened at a greater rate.

3.3 Farm Management and Economic Research

3.3.1 Farming and Farm Management Studies on the Light Land. The light land of Canterbury has been the subject of several general, as well as specific area studies in farm management.

(a) Canterbury - General. In a comprehensive article, Connell⁽⁸⁰⁾ described in detail the main types of farming being carried out in Canterbury at that time, and outlined the main factors affecting farming in the province. This was followed by a second article in which he discussed pastures and trends in production⁽⁸¹⁾.

In discussing the potential production, Connell listed the following as likely to give an expansion in output:-

- (i) Use of high quality seed.
- (ii) Increased liming.

(80) R.P. Connell, (1947), "Farming in New Zealand - the Canterbury District". N.Z. Jl agric., 75 4:369-383.

(81) R.P. Connell, (1947), "Farming in New Zealand - The Canterbury District". N.Z. Jl agric., 75 5:465-476.

- (iii) Increased phosphatic topdressing.
- (iv) Increased use of lucerne.
- (v) Increased use of subterranean clover.
- (vi) The introduction of irrigation on the dry land.

Later, Stephens⁽⁸²⁾ in a series of four articles discussed in considerable detail the development of farming in Canterbury up to 1951.

(b) Ashburton County. One of the earliest and most comprehensive studies was a farm management survey of the plains area of the Ashburton County by Fleming⁽⁸³⁾. In this he discussed in detail the farm management of the County according to the various areas and the land utilisation at that time. The purpose of the study was:-

- (i) To provide detailed information as a guide for proposed irrigation schemes in the County.
- (ii) To provide information on the optimum size of farms on the various soil types.
- (iii) To provide present day (1935/36) "average producing values of the land at certain stated prices", the borrowing potential, and capitalised values of the farms.
- (iv) To outline successful management systems.

Discussion of the survey here will be confined where possible, to the light land only.

While outlining the effects of climate and soil on farming, Fleming recorded that with the low mean annual rainfall, and low moisture holding capacity of the thin soils, the area was almost barren over the summer and early autumn

(82) P.R. Stephens, (1950), "Farming in Canterbury". N.Z. Jl Agric. 81.5:405-420.
 " (1950), " " " N.Z. Jl Agric. 81.6:503-517.
 " (1951), " " " N.Z. Jl Agric. 82.1: 15-26.
 " (1951), " " " N.Z. Jl Agric. 82.2:109-117.

(83) J.R. Fleming, (1938), op. cit.

months. The soils, when under cultivation tended to break down to powdery dusts and were liable to wind erosion.

Approximately 25% of the light land farm was sown in fodder crop each year. On the better phases of soil 10-15% of the farm was sown in wheat with yields up to 24 bushels per acre. The carrying capacity of the light land was less than one ewe per acre and on the poorer class of country, less than $\frac{1}{2}$ a ewe per acre. Up to 20% of the lambs were sold fat off the mothers.

Income was mainly from fat lambs, wool, the sale of cast-for-age ewes, and on the better land, wheat.

Fleming studied average farms in each area in detail, using budgets to estimate financial returns. Total farm expenses (including wages of management and depreciation) were deducted from total income and the balance capitalised at 5%. This figure was then divided by the farm area to give the "producing value" per acre. Fleming calculated that on the light land the producing value varied between £3-£11 per acre.

In concluding the survey Fleming made some recommendations. These concerned:-

- (i) The most economic type of management in each area.
- (ii) The most economic farm size in each area. (On the best light land at least 500 acres, and on the lighter areas at least 1,000 acres.)
- (iii) Suggested improvements on these farms. These were sound, and included the sowing of 1 cwt. super with all pastures, and the introduction of subterranean clover as a fertility builder, especially in the permanent pastures.

(c) The Malvern County. Stewart⁽⁸⁴⁾ in a study of farming in the Malvern County gave a description of climatic conditions, soils, land utilisation and farm

(84) J.D. Stewart, (1949), "Malvern County". N.Z. Jl Agric., 79.4:337.

management. In discussing the light grazing and cropping land in the area, the author recorded that holdings of 900 acres were necessary to provide a satisfactory level of income. Fine wool sheep were carried and on the more improved areas lambs were fattened. The average carrying capacity was just over one ewe per acre with replacements bought in as two-tooths or two-year ewes.

Due mainly to the effects of drought, grass grub and porina attack, the effective life of pastures was short and hence large areas were under cultivation each year.

Stewart recorded that the development of the area depended on the building up of the light land, and important factors in increasing production were the increased use of lime, phosphate and subterranean clover.

In 1950 Stuart and Tocker⁽⁸⁵⁾, carried out a farm management study of the light land farms in the Malvern County. They collected management data relating to the 1948-49 season from 39 farms, and financial data from 19 of these.

The objectives of the survey were:-

- (i) To describe the present organisation and methods of farming on the Malvern County light land.
- (ii) To determine the economic results being achieved on the farms.
- (iii) To discover the factors of farm organisation and management associated with good economic results.

In the area emphasis was on the production of wool and fat lambs, with limited amounts of small seeds and cash cropping. Pastures had short productive life (average 3-4 years), so that farming was organised on the basis of short rotations and hence large areas of cultivation. Carrying capacity was one ewe per acre though where good pasture management was practised two ewes were run.

(85) R.C. Stuart and H. Tocker, (1952), "Farm Management on Light Lands of Malvern County". N.Z. Jl Agric. 84.2:127.

Except on the large properties, replacements were bought in as two-year ewes. The wool clip was 9 lbs. per head, and lambing percentage 96.

Superphosphate was sown with all crops and lime was sown with new grass, but lack of maintenance top dressing allowed pastures to revert to inferior grasses rapidly.

The economic aspect of farming the light land was described using financial data from 19 farms. The farms were grouped according to size and compared on economic returns, using "interest surplus" which was obtained by the residual imputation method. From the interest and management surplus (gross farm income less working and maintenance expenses) an allowance for "wages of management" was deducted (this sum of £442 was to cover the manager's wage only, and this was similar for all sizes of farms). The residual or "interest surplus" was, according to Stuart and Tocker "the best available single measure of the average business efficiency of the farms in each group."

From the results the authors concluded that the then current methods of managing the light lands were most efficient economically, when the farm unit was from 700-1,000 acres in size. (Stewart⁽⁸⁶⁾ had suggested earlier that units of 900 acres were necessary to provide satisfactory levels of income.) The average interest surplus earned in the 300-399 acre group was well below the average for the 19 farms, and this was said to highlight the economic difficulties associated with small farms on this light land. A significant feature of the result was that over half the farms on the light land in the survey were less than 700 acres. Where there was little chance of acquiring more land the only means of providing more economic returns was to increase in the carrying capacity.

(86) J.D. Stewart, (1949), op. cit.

Mason⁽⁸⁷⁾ in reviewing the article suggests that the subtraction of equal sums for wages of management in order to arrive at "interest surplus" appears to favour the large farm. On the larger farms scope for labour and management input was greater, so that in such an analysis, comparatively higher management and labour rewards should be awarded.

He also suggests that when between farm comparisons were made on interest surplus, this surplus was more properly expressed as a percentage of the factor to which it is attributed, namely the value of land and improvements, than per acre. When this was done for the 19 farms in the survey, the larger farms compared more favourably.

A comparison was made to determine the significance of subterranean clover on the financial returns. Interest surplus per acre was compared between properties that had used subterranean clover based pastures for several years, and properties that had not used subterranean clover at all. Where subterranean clover had been used interest surplus was £1.75 per acre, and where no subterranean clover was used £0.34 per acre.

This difference was striking. It should not however be inferred that the difference in the interest surplus per acre was due only to subterranean clover. It was almost certainly due to a complex of factors of which increased use of fertiliser and lime, increased areas of lucerne, as well as subterranean clover, were important. There is little value in this type of analysis in farm management, where high financial performance is attributed to one factor, when it is almost certainly a response to a combination of many factors.

Stuart and Tocker, in concluding the study, made some sound recommendations

(87) G. Mason, (1958), "Resource Productivities from a sample of Light Plains Farms, Canterbury, N.Z." Unpublished Thesis for M. Agr.Sc., Lincoln College, University of Canterbury.

for the development of the light land. These included the building up of fertility through wide use of subterranean clover, lime and phosphate, the establishment of more lucerne, and the use of special-purpose pastures to reduce the effects of the summer droughts and grass grub attack.

(d) Light Land in Canterbury. From a survey of light land farms throughout Canterbury, Scott and Stuart⁽⁸⁸⁾ compared production on the unimproved light land with that of the better managed highly improved properties. A summary of the details is given in Table 3.2

Table 3.2
Capital Structure & Level of Production
on a Sample of Light Land Farms in Canterbury

| <u>Capital:(£)</u> | <u>Unimproved Farms</u> | <u>Improved Farms</u> |
|--------------------------------|-------------------------|-----------------------|
| Unimproved value per acre | 4.6 | 8.8 |
| Value of improvements per acre | 3.42 | 10.3 |
| Value of Livestock per acre | 2.91 | 7.2 |
| Value of Plant & Machinery | 1.13 | 3.5 |
| Total Capital per acre: | <u>£12.06</u> | <u>£29.8</u> |
| <u>Production:</u> | | |
| Stock units per acre | 0.9 | 2.3 |
| Wool output per acre | 8.5 lb. | 21.0 lb. |
| Meat output per acre | 17.5 lb. | 45.7 lb. |
| Owner's Surplus per acre: | <u>£1.6.0d.</u> | <u>£4.0.0d.</u> |

They also observed that the development of the light land had increased in momentum in recent years. Department of Agriculture data on 30,000 acres in the Malvern County indicated that between 1949 and 1956 the average carrying capacity had increased from 1.2 to 1.7 ewe equivalents per acre, wool production from 10.3 to 15.6 lb. per acre, and the number of lambs fattened per acre from 0.8 to 1.4.

(88) R.H. Scott and R.C. Stuart, (1956), op. cit.

This rapid increase had been made possible by the favourable meat and wool prices which existed over the period, and which enabled greater investment of farm profits. The expenditure on lime and superphosphate was markedly increased, and with the more widespread use of subterranean clover and lucerne, the standard of pasture was vastly improved. This reinvestment, along with the introduction of D.D.T. for grass grub and porina control, enabled farmers to increase their carrying capacity. In the five year period from 1949/50 to 1954/55 sheep numbers in the Malvern County increased by 44%.

3.3.2 Economic Studies on the Light Land.

(a) The pattern of Farming on High-performing Light Land Farms.

In discussing the results of a survey he carried out in the Ashburton area, Stewart⁽⁸⁹⁾, indicated that the average owner's surplus being achieved on dry-land farms in the Ashburton County was greater than that being achieved under irrigation, where farms were grouped according to farm size. This was somewhat surprising, and in order to study these farms more closely, the original survey data was analysed in detail⁽⁹⁰⁾.

Forty-three dry-land farms were included in the survey, but nine farms above 1,000 acres were excluded from further study on the assumption that they were atypical of the area. The remaining thirty-four farms were divided into two groups, comprising sixteen below 600 acres, and eighteen between 600 and 1,000 acres. This grouping was made on the assumption that farming methods and management input and objective were different between large and small farms.

(89) J.D. Stewart, (1963), "The Comparative Profitability and Productivity of a Sample of Irrigated & Non-Irrigated Farms in the Ashburton-Lyndhurst Area of Mid-Canterbury, N.Z.", Lincoln College Publications, No.1, p.10.

(90) The writer was engaged in the field work and data analysis in Stewart's survey and made a comprehensive study of the major production and management features of the high performing farms. It was thought that these high performing farms may exhibit some uniformity in their farming pattern which could be associated with their financial success.

Eleven high-performing farms were selected for more detailed study.

Table 3.3 shows the main features of five farms less than 600 acres, and Table 3.4 the main features of six farms greater than 600 acres. (Details of these tables are outlined in Appendix B.)

These high performing farms show no consistency in the pattern of production. The area of small seeds is low, varying from nil to 6% on the five small farms, and nil to 4.3% on the large farms. Similarly the area in cash crop varies from nil to 14% on the small farms, and nil to 15% on the larger farms. While the advantages of lucerne on the light land have been widely publicised in recent years, the analysis of these farms show that the area in lucerne in the area is extremely low. The area on the small farms varies from 4% to 19% and from 5% to 29% on the larger farms.

Whereas the carrying capacities range from 2.3 to 3.8 stock units per available acre on the small farms, the range on the larger properties is 1.9 to 4.3. It is noteworthy that the farm with the highest carrying capacity also has the largest area in lucerne.

The stock replacement policies used differ quite widely in each group of farms, almost all policies being included, with however a dominance of 'buying in' policies. The stock production figures in terms of meat and wool per acre depend to a large extent on the replacement policy practised, and for this reason direct comparisons can not be made. In general however, and as the figures indicate, lamb meat production per acre tends to be higher where replacements are bought in and all ewes mated to fat lamb sires, while with a breeding policy, wool output is usually higher.

The eleven farms analysed have widely differing management policies and yet all achieve highly satisfactory financial results. This tends to suggest that the pattern of management and production is not of paramount importance,

TABLE 3.3

Pattern of Farming and Level of Stock
Production of Five High Performing
Dry-land Farms of less than 600 acres
(Figures are the average of 3 yrs
1959/60, 60/61 61/62)

| Farm | Area (acres) | Owner's Surplus (£) | % Small Seeds | % Cash Crop | % Total | % Lucerne | Stock Units per Available Acre | Lamb Meat per Avail- able Acre (lb.) | Wool per Available Acre (lb.) | Replacement Policy |
|------|-----------------|---------------------------|---------------------|-------------------|------------|--------------|---|---|-------------------------------------|-----------------------|
| 1. | 490 | 2511 | 1.2 | 14.0 | 15.2 | 9 | 3.8 | 101 | 36 | A |
| 2. | 440 | 2507 | 6.0 | 13.0 | 19.0 | 19 | 3.8 | 86 | 33 | F |
| 3. | 300 | 2128 | 4.5 | 12.7 | 17.2 | 11 | 3.0 | 115 | 33 | D + E |
| 4. | 520 | 1668 | - | 3.5 | 3.5 | 4 | 2.3 | 87 | 31 | F |
| 5. | 420 | 1618 | 1.0 | - | 1.0 | 14 | 3.7 | 85 | 34 | G |

TABLE 3.4

Pattern of Farming and Level of Stock
Production of Six High Performing Dry
land Farms of between 600 and 1000 acres
(Figures are the average of three years
1959/60, 1960/61, 1961/62)

| Farm | Area (acres) | Owner's Surplus (£) | % Small Seeds | % Cash Crop | % Total | % Lucerne | Stock Units per Available Acre | Lamb Meat per Avail- able Acre (lb.) | Wool per Available Acre (lb.) | Replacement Policy |
|------|-----------------|---------------------------|---------------------|-------------------|------------|--------------|---|---|-------------------------------------|-----------------------|
| 1. | 805 | 3755 | 1.6 | 13.0 | 14.6 | 5.0 | 3.4 | 116 | 36 | E |
| 2. | 600 | 3717 | 4.3 | 15.0 | 19.3 | 19.0 | 3.2 | 107 | 33 | E |
| 3. | 955 | 3336 | - | - | - | 5.0 | 1.9 | 55 | 33 | D |
| 4. | 670 | 2988 | - | 1.9 | 1.9 | 29.0 | 4.3 | 59 | 31 | B |
| 5. | 600 | 2355 | - | 8.7 | 8.7 | 10.0 | 3.0 | 103 | 38 | D |
| 6. | 730 | 2044 | - | 1.6 | 1.6 | 11.0 | 3.1 | 78 | 30 | D |

but what is important, is the management skill with which the various patterns are executed, and the associated financial control.

(b) Resource Productivities on Light Land. In 1957 Mason⁽⁹¹⁾ carried out a survey of 50 sheep farms on the light land in the Malvern County. Physical and financial data were collected for the 1955/56 season and used to derive an average production function for the 50 farms. These farms, covering 39,700 acres on the Lismore soils, exhibited a high degree of homogeneity in their management.

Replacements for the fat lamb flocks were bought in, and the winter carrying capacity was 1.7 stock units per acre. All lambs were fattened.

The importance of forage cropping was indicated by the fact that 12.2% of the area was in winter forage crops, and 5.6% in summer crops. Cash cropping and small seeds (at only 5.4% of the area) were relatively unimportant. Only 5% of the area was in lucerne.

Fertiliser application was relatively high. 1 ton of lime was applied to 22% of the total farm area each year, and 1.2 cwt of superphosphate on 37% of the pasture and lucerne area per year.

Mason outlined the purpose of his studies, viz:

- (i) To determine the practicability of estimating a production function from survey data.
- (ii) To explain the methods and difficulties encountered.
- (iii) To assess the usefulness of the production function for estimating resource productivities compared with other methods.
- (iv) To derive marginal productivities for certain inputs.

The model used for this study was of the Cobb-Douglas form:-

$$Y = a \prod_{i=1}^n (x_i)^{b_i}$$

where Y is the Gross Income and x_1, x_2, \dots, x_n , the inputs.

(91) G. Mason, (1958), op. cit.

One of the major problems involved in the study was the determination of the inputs which were significant in the production relationship. The products of each farm were combined in one output category, which was expressed in monetary values.

Inputs considered in varying combinations in the regressions, were land, total farm capital, plant and machinery, labour, superphosphate and lime. It was found that total farm capital introduced multicollinearity so that this variable was discarded. The marginal productivities derived were:-

| <u>Input</u> | <u>Gross Income per £1 Input</u> |
|---------------------|----------------------------------|
| Land | £2.5 |
| Labour | £0.85 |
| Super | £3.9 |
| Lime | £1.2 |
| Plant and Machinery | £14.0 ⁽⁹²⁾ |

Mason recorded in discussing the results that:

"The superiority of the production function technique over traditional methods of productivity analysis lies in its ability to provide simultaneous assessment of marginal productivities of the inputs under consideration. Not only can it be concluded that the gross income will be augmented in descending order by equal sums spent on plant and machinery, superphosphate, land, lime and labour, but the estimated marginal productivities may be manipulated within the framework of economic theory so as to define the most profitable levels of input" (93).

He concluded that all the inputs except labour were being used at less than optimum levels because their marginal value products exceeded their costs. Lime usage approached the optimum level, but plant and machinery, land and superphosphate, all indicated that high marginal returns were being obtained and that additional use of these inputs would increase profits.

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- (92) In a later paper by Mason, (1960), "Resource Productivities from a sample of Light Plains Farms, Canterbury, New Zealand," in the Australian Journal of Agricultural Economics, 4.2, the marginal productivity of plant and machinery was reduced to £2.3. This is accounted for by the inclusion of depreciation, repairs and maintenance, and annual running expenditure in the costs associated with the use of each £1 capital value of plant and machinery.
- (93) G. Mason, (1958), op. cit, p.62.

Increasing returns to scale were assumed to be operating as an overall 1% increase in each of the inputs was associated with 1.12% increase in gross income. Where farms below and above 700 acres were analysed separately, the larger farms appeared to be operating under diminishing returns, whereas the smaller farms were enjoying increasing returns.

Mason, in concluding the study, recorded that subject to the limitations of the Cobb-Douglas technique (which he had outlined) the estimated production function for the area provided approximate, rather than precise, estimates of quantitative relationships. He drew the following conclusions from the results however:-

- (i) The high productivities recorded for the inputs of land, superphosphate, plant and machinery tended to justify the high prices being paid for land, encouraged the continued use of superphosphate (to which there was proven response), and more profitable use of plant and machinery.
- (ii) Increasing returns to scale existed, with the smaller farms in a position to make greater profits from overall expansion.
- (iii) The estimated productivity for lime usage suggested that for the area as a whole, lime had been used at levels not far short of the optimum.

There are however serious shortcomings to the production function approach. Mason's average production function for the area is a "hybrid" function. It is an average of the many individual functions which are at different levels of technology, stages of development and levels of management. In all probability the average function does not describe the position of any one particular farm. Being a combination of high and low performing farms, it in no way indicates the

optimum association between output and certain inputs for a given farm. Because of the serious practical and theoretical limitations which are inherent in the use of the production function for assessing resource productivities, its value in producing estimates of the marginal productivity of inputs must be extremely limited. Even with the knowledge of the resource productivities, the problem of defining an optimum allocation of resources, and the determination of a method of moving resources to obtain that situation, is considerable.

To this end the average function is of little practical value in making "on the farm" recommendations as to resource allocation. Unless the actual position of the particular farm in relation to the average function is known, incorrect conclusions can be drawn as to the direction of resource shifts required to bring about the optimum combination of resources. A study of the production function on which the high performing farms were situated would be of greater value in this respect. Even then however, the optimum allocation of resources still refers to an historic situation.

(c) Factors Associated with Output on Light Land Farms. Mason⁽⁹⁴⁾ more recently attempted to use a simple multiple linear regression to examine farm data with the aim of isolating those farm management practices which were associated with output.

Five years production data (1954-59) were collected from 39 farms in the Burnham-Aylesbury area of Canterbury. These were similar units in respect of soil type, climate, and farming type (wool and fat lambs being the major products).

A correlation matrix including output, and 24 explanatory factors provided the basis for selection of the most important variables for further examination by multiple regression. Mason found that each of the following variables, total

(94) G. Mason, (1961), "Factors Associated with Output on a Sample of Light Land Farms". Proc. N.Z. Inst. Agric. Sci., 7, pp.129-134.

farm area, unimproved value of land per acre, fertiliser expenditure per acre, labour expenditure per acre, total expenses per acre, personal rating, total capital per acre, and proportion of total farm area in lucerne was significantly associated with gross income per acre, when the effects of the other variables were allowed for.

He found that, although the coefficients of the multiple regression equation were of limited application, a high proportion of the variation in gross income per acre was 'explained' by relatively few of the factors with which it was known to be associated, i.e. unimproved value per acre, fertiliser expenditure per acre, labour expenditure per acre, and personal rating, explained 89% of the variation in gross income per acre.

The use of such a linear equation as a predictive model has serious limitations. Mason notes that the estimated parameters were only tentative since the linear model used may have been only a rough approximation of the true structural relationships among the data. The problem of inter-related inputs (where it is impossible to measure accurately the individual effects of two factors on the dependent variable), and the danger of substitution in the equation of data outside the range present in the sample, were both serious limitations.

The major deficiency in Mason's approach however appears to be in the choice of a model which fails to conform to concepts of economic theory, such as diminishing marginal productivity, and diminishing marginal rates of factor substitution. These are well known characteristics which are typified in agriculture. While there are problems in this type of analysis, in determining the appropriate model to use, Mason would have been much more realistic in this instance had he used the linear regression, as a 'linear approximation of a curvilinear relationship'.

Mason⁽⁹⁵⁾ using the same data found that a relationship between intensity

(95) G. Mason, (1960), Unpublished Data on the "Malvern Light Land Survey", Lincoln College.

of farming and attainment of net profit per acre existed. The 39 farms were divided into nine groups according to total farm income per acre. Farms within each group were averaged, giving 9 points on which the curvilinear relationship was based. The curve, of logistic form, embraced regions of increasing, constant, and decreasing rates of net profit per acre as total farm income increased.

The conclusion drawn from the curve was that where farms had total incomes of less than £10 per acre, significant increases in the net profit per acre could be achieved (i.e. the range of increasing returns), while above £10 per acre the increases were likely to be smaller (i.e. decreasing returns).

With farm income predominately from sheep, Mason estimated that carrying capacities of 1, 2 and 3 ewe equivalents per acre were comparable with farm incomes of £4.5, £9 and £14 per acre respectively. When related to the curve Mason suggested that:-

"....it appears that big increases in net profit may be obtained by raising carrying capacity on these soils to about two ewe equivalents per acre. Beyond this level the rate of increase starts to drop off until at about three ewe equivalents, further increases are unlikely to be obtained".

This statement was refuted by Watson⁽⁹⁶⁾, who claimed that he had in fact shown a 20% return on additional capital when carrying capacity was increased from 2 to 3½ ewes per acre. Guise⁽⁹⁷⁾ however had found that the range of Mason's function, where the rate of increase in net profit per acre was at a maximum, was equivalent to a 30% return on additional capital. It would appear then that Watson, in claiming a 20% return over the range from 2 to 3½ ewes, was entering a range of diminishing returns (and possibly even a range of negative returns). Watson was unable to indicate the marginal return to further intensification at the three ewe level, whereas Mason suggested that at that point additional

(96) D. Watson, (1962), "Light Land Development". Proc. 12th Lincoln Coll. Fmrs' Conf., p.112.

(97) J.W.B. Guise, pers. comm.

increases in net profit per acre were unlikely (i.e. Mason was suggesting that at this point the marginal return from the additional inputs was equal to the marginal costs, so that this was the point of maximum total profit).

Whether Mason was justified in drawing such rigid conclusions from a function of this nature is debatable. A fundamental weakness exists in that the relationship is based on the mean figures for each groups of farms, and therefore assumes that the differences between group means are significant. If, however, variance analysis indicated that this is not the case, then the differences between group means could have arisen purely by chance, and as a result, could not be ascribed to differences in the intensity of farming.

The function, a 'hybrid' relationship, does not represent the situation existing on any one farm, but represents the average of the many different functions on which the survey farms were situated. The efficiency of the 'hybrid' relationship depends on the degree of variance which occurs in some of the principal factors determining the individual functions, especially management.

The wide dispersion of a comparatively small number of farms in the region of decreasing returns (i.e. at high levels of intensity and high net profit per acre) would appear to make the calculation of the point of maximum total profits (where marginal revenue equals marginal costs), extremely difficult. Mason not only calculated this point, but based on this his conclusions as to the optimum intensity of stocking.

In making recommendations for individual farms based on the 'hybrid' relationship, Mason failed to take into account the stages of development, levels of technology, and fixed cost structure (especially in relationship to labour), of these farms. Those factors which allow some farms to be high performing are concealed when average figures are used as in this study. An analysis of the methods used by those farmers achieving high net profits per acre

may have been of greater value as a guide to increased productivity in the area.

3.3.3 Drought Models

(a) Introduction. In low rainfall areas, where the grazing animal provides the main source of income, the likelihood of drought occurring is an ever threatening problem to the farm manager. The severity of a drought depends not only on the level of pasture production on a particular property in that season, but also on the level of stocking. Thus a lightly stocked property may survive a drought, while on a neighbouring highly stocked property it may be necessary to drought feed stock for several weeks, or even months.

A grazing drought has been defined by Mauldon and Dillon⁽⁹⁸⁾ as:-

"... a period of natural feed shortage such that the supply of vegetation for grazing is inadequate to maintain the desired number of livestock without permanent adverse effects on the animals".

While this situation does occur for short periods in some areas of New Zealand, it is much more severe in Australia where the large areas usually affected mean that there is little chance of stock movement. As a result considerable work has been done on the economics of drought reserves, drought strategies, and optimum stocking rates under these conditions in Australia.

An attempt is made here to review this work and to assess the application and value of this type of planning under New Zealand, and particularly Canterbury, conditions.

(b) The Strategies. The various strategies which can be followed in drought conditions vary according to the situation of the particular farm. They include:-

(i) The carrying of a reserve large enough to fulfil the requirements

(98) R.G. Mauldon and J.L. Dillon, (1959), "Droughts, Fodder Reserves and Stocking Rates". Aust. J. agric. Econ., 3.2:45.

through the longest known drought. (This however, is expensive, and few farmers attempt to carry reserves of such magnitude.)

(ii) The carrying of a smaller reserve, taking a risk that the drought will not be of more than a specified duration.

(iii) The carrying of no reserve.

In the case of (ii) and (iii) the farmer must make a further decision once a drought occurs. Where the fodder reserve is not large, the farmer will either:-

(i) Hope the drought will end before the reserves are consumed, or

(ii) buy in more fodder before the price rises too much, or

(iii) sell stock before their price falls too much.

Where no reserves are held, the farmer must either buy in feed, or sell stock. He may gamble on its being a short dry spell, in which case he would follow neither of these two courses. If the drought is prolonged, however, then the cost of purchasing feed will be increased, and the market for selling stock depressed. The probability of buying grazing during a drought is not recognised as an alternative in the Australian work, no doubt because of the wide areas which are affected simultaneously.

(c) The Problem. In drought prone areas, one of the most complex problems confronting the farmer is in determining the level of fodder reserve to carry so as to minimise losses over a given planning period. Once drought conditions prevail, even more important management decisions must be made. Where information on the probability and duration of droughts in an area is available, then more rational decisions can be made.

The use of inventory analysis to determine the optimum ex ante stocking rate and level of drought reserves in drought prone areas, depends basically on matching the risk of incurring heavy expenditure on replacement stock (should losses be incurred in a drought) against the probable cost of feeding the flock

through the drought, and of maintaining a feed reserve.

The major problems associated with a drought are the uncertainty of its occurrence and its duration. If future feed requirements could be determined with certainty, then the drought problem would be overcome, adequate reserves could be built up to meet the drought requirements, and costly reserves could be dispensed with.

(d) The Size of the Reserve. The size of the fodder reserve carried is dependent on several factors. However it tends to be greater where:-

- (i) The probability of a drought is increased.
- (ii) The cost of purchasing fodder in a normal season is decreased.
- (iii) The cost of purchasing fodder during a drought is increased.
- (iv) The stock are valued highly in relation to fodder.
- (v) The probable replacement cost of stock is high.
- (vi) The opportunity cost of the capital involved is low.

Candler⁽⁹⁹⁾ in discussing the economics of drought reserves suggests that there are two costs associated with such a reserve.

- (i) The opportunity cost of the capital involved in a fodder reserve when it is not needed.
- (ii) The cost of not having a reserve when it is needed.

(e) The Models. In a simple hypothetical example, Candler assumed that in one year in ten, a grazier would have to drought feed for six months. He estimated the cost of feeding a sheep for six months with reserves varying from none to 6 months. The 10 year total cost of a 6 months' fodder reserve was calculated as the sum of one (drought) year of fodder, and nine year's interest on the capital involved in the reserve.

(99) W. Candler, (1961), "On the Economics of Drought Reserves".
Rev. Mktg agric. Econ., 26. 4:216.

Candler extended the example to consider a more realistic situation where droughts occurred one year in five, were of differing duration, and where the cost of feed increased during a drought. The aim was to minimise the long-run or average feeding costs.

The probability of drought (in months) over a 50 year period was assumed to be⁽¹⁰⁰⁾:

| <u>Total Months Feeding Required</u> (i.e. length of drought) | <u>Years out of 50</u> |
|--|------------------------|
| 0 | 40 |
| 1 | 3 |
| 2 | 2 |
| 3 | 1 |
| 4 | 0 |
| 5 | 1 |
| 6 | 1 |
| 7 | 0 |
| 8 | 1 |
| 9 | 0 |
| 10 | 1 |

He calculated the costs of the grazier's eleven alternative policies (from zero to ten months' fodder reserve) when the droughts lasted from zero to ten months. For example, where a 7 month reserve was held, but only three months' feeding was required, the cost of the reserve was made up to the cost of the 3 months' feed, which is used, plus the interest on the value of the 4 months' 'surplus' reserve.

This example indicated that drought reserves can be too large, as well as too small, and that it is uneconomic to store fodder to meet the worst possible drought. On the feed costs, and drought probability figures used, the lowest cost fodder reserve was one of 5 months' supply. However Candler notes that:

"The least-cost fodder reserve will vary with every change in physical conditions, management policy, and economic outlook" (101).

The problem of purchasing feed once a drought has commenced is of equal

(100) *ibid.*, p.218.

(101) *ibid.*, p.219.

importance. A decision has to be made as to whether it is worth purchasing the feed (which normally increases in cost as the drought progresses), in order to maintain the sheep, or whether it would be better to sell the sheep. Dillon and Mauldon⁽¹⁰²⁾ suggest that the decision procedure to be followed is the usual economic one.

"If the expected marginal cost of the additional fodder is greater than the expected marginal revenue from such fodder, then sell sheep, or let them die. If the expected marginal cost of additional fodder is less than the expected marginal revenue of fodder, then buy more fodder."

The danger in purchasing feed is that the drought may end leaving the grazier with large stocks of very costly feed on hand. Candler has shown that, using historical data, it is possible to estimate with more accuracy, the chances of the drought being serious, as it progresses.

While Candler's example was simple, it does indicate a useful method of approaching the problems of the risk and uncertainty associated with drought reserves, where the relevant information on feed prices before and during a drought, and on the frequency and duration of droughts is available.

In an algebraic statement of the problem, Candler⁽¹⁰³⁾ calculated the cost of a drought reserve as:-

$$C_k = c \sum_{j=1}^k P_j + d \sum_{i=k+1}^n P_i + cr \sum_{j=1}^k (1 - P_j)$$

Where C = the expected annual cost of the reserve.
 k = the number of months' feed held in reserve.
 c = the cost of one unit of fodder in the normal season.
 P_j = probability that the reserve will be needed for j months,
 where j = 1, 2, -----k.
 d = the cost of one unit of fodder in a drought.
 n = duration of the largest expected drought.
 P_i = probability of having to drought feed for i months,
 where i = k + 1 -----n.
 r = the internal rate of interest.

(102) J.L. Dillon and R.G. Mauldon, (1959), "Inventory Analysis and the Economics of Fodder Conservation". Economic Record, 35.71:217.

(103) W. Candler, (1959), "The Optimum Fodder Reserve - An Inventory Problem". J. Fm Econ., 41.2:259.

The first term on the right of the equality sign is the cost of stored fodder, multiplied by the probability that it will be needed. The second term is the cost of purchasing succeeding months' feed if required. The third term is the annual cost of storing one month's fodder supply if it is not used, multiplied by the probability that it will not be needed.

The minimum expected cost of the fodder reserve $C_{\min.}$ is given by

$$C_{\min.} = \min_k C_k$$

where $k = 0, 1, 2, \dots, n$.

Thus the complex problem of deciding the annual cost of a given reserve when the demand for it is unknown, can be broken down quite simply into the cost associated with the feed if it is needed, plus the cost of purchasing additional feed at inflated prices, plus the cost of storing the feed reserve if it is not needed⁽¹⁰⁴⁾.

Waring⁽¹⁰⁵⁾, has suggested that while drought strategies vary between stock owners and districts, two distinct strategies are commonly used. These are:-

- (i) to maintain a flock intact through all droughts,
- (ii) to reduce numbers, when fodder reserves are reduced to some level dictated by experience, or a drought of some specific length seems imminent.

One of the factors motivating the manager into adopting one or other of these policies is the relative values he places on the various classes and ages of stock. Waring maintained that drought and risk of drought should also vary the relative valuations of different classes of stock.

Where the probability distributions of drought are known, and where the likelihood that once started, they will continue for given lengths of time, and

(104) *ibid.*, p.260.

(105) E.J. Waring, (1960), "Drought Strategies and Resource Valuation in Pastoral Areas". *Rev. Mktg agric. Econ.*, 28.3:163.

where the manager can estimate the corresponding sale, or replacement value for restocking at the end of a drought, then the present value for stock can be calculated at any time throughout the drought. The present value is the difference between replacement value and feeding costs, net of wool grown, for droughts of given lengths multiplied by the appropriate probability of each drought length.

This information enables a decision to be made as to which, if any, of the various classes of stock on the property should be disposed of, or whether more fodder should be purchased at known prices at any time during the drought.

Again the greatest deficiency in the application of this method is the great lack of precise information. Not only does the method imply knowledge of drought probabilities and duration, but also the replacement cost of stock at the end of a given length of drought. The hypothesis that the value of stock relative to feed should influence the manager in the choice of drought strategies is, however, quite realistic.

The economic relationship between stocking rate, drought possibilities and fodder reserves has been explored by Mauldon and Dillon⁽¹⁰⁶⁾. They have shown that for any given pattern of drought incidence, an optimum stocking rate can be ascertained. The model used took account of wool, stock, and fodder prices as they affected the optimum stocking rate and size of fodder reserve.

There are, however, several limitations in this pre-drought model. Land is assumed to be constant, whereas in fact agistment may in some areas be possible. Other factors may also be limiting, e.g. working capital and stock water, but these are not included in the model. The only answers that are given are optimal *ex ante* and may be incorrect *ex poste*, however this must be accepted.

When the within drought situation arises, and the reserves of fodder prove

(106) R.G. Mauldon and J.L. Dillon, (1959), *op. cit.*, p.45.

to be inadequate, a decision must be made as to whether more fodder should be bought, or sheep disposed of. Mauldon & Dillon's model is adaptable to this situation and allows any additional information regarding the droughts to be used.

(f) Summary. There is no doubt as to the economic benefits which would accrue where drought models were used to minimise the long term effects of drought. Research workers in this field in recent years (especially in Australia) have produced models which are in specification, difficult to fault.

The sheep industry in Australia is characterised by large grazing properties, the areas of which are measured in square miles, and large flocks of sheep, comprised of both breeding ewes and wethers. Drought conditions are fairly common in most of the grazing areas, so that the problem of feeding stock through a drought period is perhaps the greatest that faces the grazier in Australia. He can, under prolonged drought conditions, stand to lose heavily.

Not only are droughts severe in terms of the periods without rain but vast areas are affected at one time. As a result fodder prices rise, stock prices fall, and with the uncertainty as to the length of the drought, the environment under which the grazier operates does not make for easy decision making. The drought model is of value in stating the problem in economic terms, and in such form allowing more rational decisions to be made.

Unfortunately its greatest deficiency is in its requirement for data pertaining to the planning period. Because of this, the method has had limited application to date.

A knowledge of the probability of drought occurring in an area, and of the duration of these droughts, is implied in the models. While historical meteorological data on this is available for many areas in Australia, it may be of limited value, especially where drought, as defined by Maldon and Dillon⁽¹⁰⁷⁾ is considered.

(107) *ibid.*, p.45.

Assuming that the probability of a drought being of a given length is known, then livestock prices prior to, during, and after the drought, must be estimated. Similarly, changes in fodder prices must be estimated for the within drought period. Historical data is of some value in this respect. Changes in wool prices are reflected in stock prices year to year however, and must be taken account of.

(g) The Application of Drought Models to New Zealand Conditions. The model appears to have limited value when considered under New Zealand conditions. Drought conditions, as defined for the Australian conditions, generally do not occur in New Zealand. Certainly several areas are prone to drought, but these droughts tend to be confined to the summer period only, and are more regular in nature, so that the farming pattern is adjusted accordingly. The uncertainty and length of the Australian droughts are unknown in New Zealand, where, even in Canterbury, a 2-3 month drought is regarded as quite serious. Another point in which the New Zealand situation differs is that areas subject to severe droughts are, as a rule, isolated, and it is unusual for large areas, e.g. a whole province, to be affected. This not only allows fodder to be bought in quite readily, and at reasonable cost, but also allows stock movement out of an area where this is necessary.

In a random survey of 49 light land farms in the Ashburton County during the 1964/65 season⁽¹⁰⁸⁾, not one farmer indicated that it was necessary for him to sell capital stock because of drought, which was the worst for twenty years. Few found it necessary to buy in feed during the drought, and only one farmer moved any stock off his farm. A significant feature of the survey was the large proportion of farmers who indicated that they fed out more hay over the summer than the winter. This summer feeding is generally very low-cost, and consists in the main of low quality ryegrass straws, conserved in years of surplus feed or bought in from other areas at low cost.

(108) This work was carried out by the writer as part of a separate research project.

As with fodder, stock prices do not slump violently during a drought, due to a large extent to the fact that only a small proportion of stock in an area changes hands because of a drought alone.

With the drought being shorter in duration and less severe in nature, the strategies open to the New Zealand farmer are not as costly as those facing his Australian counterpart. Stock are often carried through a drought in Canterbury on the available paddock roughage, so long as the water supply is satisfactory. When the dry spell is prolonged, then additional feed in the form of ryegrass straws, and sometimes lucerne hay will be fed for a limited period, until the autumn rains relieve the situation. In recent years, grain (usually barley), has become more popular where supplementary feeding is necessary.

The cost of maintaining reserves for this short period is low, yet a number of farmers do not carry reserves, but rely on buying in grain or low quality hay should it be necessary. As a result, the necessity to sell stock during a drought, because of a feed shortage, is rare in Canterbury.

Information on the occurrence of droughts as defined by Mauldon and Dillon⁽¹⁰⁹⁾ is, to the writer's knowledge, not available in New Zealand. Recordings taken at the Winchmore Irrigation Research Station, Ashburton, over 44 years have been used by Rickard⁽¹¹⁰⁾ to estimate the probability and duration of drought at Ashburton. Rickard's definition of drought however was based on soil moisture levels, and as such was of value in estimating irrigation requirements. However, emphasis was placed on the production of vegetation, and not on the use of it. Mauldon & Dillon⁽¹¹¹⁾ suggest that the only way to approach the drought situation, where the grazing animal is of importance, is through a knowledge of the probability

(109) R.G. Mauldon and J.L. Dillon, (1959), op. cit., p.45.

(110) D.S. Rickard, (1960), op. cit., p.431.

(111) R.G. Mauldon and J.L. Dillon, (1959), op. cit. p.45.

and duration of those periods, where, at a given stocking rate, drought feeding is necessary.

Severe droughts in New Zealand are of relatively short duration and infrequent, so that considerable changes in technology occur between these severe droughts. Stocking rates and the efficiency of pasture production and utilisation change over time, so that where two droughts of equal length and severity, as defined by Rickard, occur at, for example, an eight year interval, the need for feeding in the two situations may be quite different. Rickard would suggest, however, that the two drought periods were similar in nature, and in fact soil moisture conditions may be similar.

(h) Conclusion. The usefulness of drought models under Australian conditions, when the relative information is available, is unquestioned. The farming environment in New Zealand is, however, less severe. The incidence and duration of drought as defined by Rickard, has been recorded at Ashburton, but this is of little value in estimating the need for drought feeding at a given stocking rate. Droughts in New Zealand are generally only extensions of the normal summer dry period experienced in these areas, and of only 3-4 months duration. As a result of this and the fact that severe droughts are generally localised, stock and fodder prices do not fluctuate violently as a direct consequence of the drought. Thus the decision-making environment in which the farmer has to operate, either before or during a drought, is less severe than under Australian conditions. The need for a technique as discussed above as an aid in the long term planning on the light land in New Zealand is therefore correspondingly less.

3.4. Summary

The increase in production which has taken place on the light land of Canterbury in recent years is due to a large extent to the application of research findings from the local research centres. The farming environment is quite unique

in New Zealand and for this reason (as it was soon realised), the techniques required for successful farming in the area were markedly different from those already proven in other areas.

The introduction of pasture species which were more suited to the severe local conditions, enabled pasture production and persistency to be increased. Subterranean clover as a pioneer legume on the thin soils made a significant contribution to the fertility build up. The response of subterranean clover especially to the application of superphosphate and lime was quite spectacular, and when D.D.T. for grass grub control was introduced, the semi-permanent perennial ryegrass-subterranean clover pasture became the basic sward on the light land. This was relatively highly producing and allowed considerable increases in stock numbers.

When it was demonstrated that lucerne gave even higher dry matter production than subterranean clover, and with less variability between seasons, more emphasis was placed on this plant as the basic legume for the light land. The full potential of this plant has by no means been fully exploited. Under the present levels of knowledge of light land management, potential carrying capacities achievable with ryegrass subterranean clover pastures can be exceeded, where a high proportion of the farm is in lucerne-based pastures.

The uptake of the proven light land methods of farming by a high proportion of farmers in the area, has enabled the output of the area to increase. Research has shown that, using crossbred ewes and light to medium-weight sires, a rapidly growing lamb is produced, and one which is well suited to the export trade. The knowledge that early weaning is possible has allowed more efficient utilisation of spring-early summer feed, and the use of the crossbred ewe to give a higher lambing percentage, have both contributed towards the higher output per acre on many farms.

The increase in output per acre on this class of land in recent years has been quite substantial and has resulted from a combination of higher dry matter

production and more efficient utilisation of this available feed, especially over the spring and early summer period. The considerable change in the per acre level of output which has occurred on this type of farm is indicated by average production figures of light land farms in the Meat and Wool Boards' Economic Service Survey⁽¹¹²⁾. Table 3.5 gives the changes in output per acre over a nine year period for these farms. (Details of the Table are given in Appendix C.) Figures for Ashley Dene are also given for comparison⁽¹¹³⁾.

TABLE 3.5

Changes in Output per Acre on Light Land Farms, 1954-1963

| | <u>Economic Service Survey Farms</u> | | <u>Ashley Dene</u> | |
|-----------------------------------|--|-------------|--------------------|-------------|
| | <u>1954</u> | <u>1963</u> | <u>1954</u> | <u>1963</u> |
| 1. Sheep carried per acre (s.u.) | 1.8 | 2.7 | 2.5 | 3.5 |
| 2. Meat Production per acre (lb.) | 47 | 82 | 60 | 96 |
| 3. Wool production per acre (lb.) | 18 | 29 | 26 | 36 |

While the research centres in the province have been instrumental in bringing about the increases in production through their invaluable research findings, the exploitation of the vast potential which still exists may well be taken advantage of by the more efficient implementation of existing knowledge. To this end the development of more intensive advisory services and improved management i.e. in the planning, execution and control of farm programmes, may lead to even higher production on the light land than has been envisaged, without the further development of irrigation⁽¹¹⁴⁾.

(112) F.L. Ward, pers. comm.

(113) A.H. Flay, (1965), "Ashley Dene 1949-1963". Lincoln College Publication No.3.

(114) A.R. Dingwall, (1963), op. cit., p.145.

CHAPTER IV

THE TECHNICAL PRINCIPLES OF LIGHT LAND FARMING

4.1 Introduction

The objective of this chapter is to outline briefly the technical principles of farming light land, and their incorporation into a management system. The management system which has evolved over the years has resulted from a deeper understanding of the problems encountered by the farmer in the particular environment under which he operates (see Chapter II). Research work (as outlined in Chapter III), has led to an improved understanding of the climate, soils, and plant and animal relationships encountered on the light land of Canterbury. Trial work has for example exposed high producing pasture species, the most suitable fat lamb sires, and the correct type and rate of fertiliser required. Leading farmers in the area have built these and other findings into the successful management system which has evolved over the years.

4.2 The Environment

The shallow light land soils of Canterbury under a rainfall of less than 30 inches, and subject to summer droughts, present an environment in which high levels of pasture production and persistency are difficult to achieve.

While the annual rainfall is evenly spread throughout the year the high evaporation rate over the summer markedly reduces the effectiveness of the rainfall over this period. Autumn rainfall is erratic, and while in winter the moisture level is satisfactory, the low soil temperatures prevent any significant pasture growth from mid-May to mid-August, except from perennial and short rotation ryegrass. In the spring, soil temperatures and moisture levels are adequate and

the bulk of the season's growth takes place at this time. The variation in rainfall between years is quite large, and consequently pasture production and feed supplies in general, are subject to considerable fluctuations between years, as well as within any given year. This feature is of major significance in the management of the light land of Canterbury.

Soil fertility was depleted quite seriously by the widespread cereal cropping which was practised in the past. This, with the nature of the climate contributed to the reduction in the productive life of the pastures. The shallow soils, naturally deficient in sulphur, phosphorus, calcium and molybdenum, have low nitrogen status and organic matter content. In recent years however, improved management techniques have produced a significant improvement in soil fertility. A primary requirement is an adequately topdressed legume dominant pasture.

The combination of climatic and soil conditions, create an environment which requires special management of a policy designed primarily to increase pasture production and persistency, and to equate the variable feed supplies with the stock requirements.

4.3 Environmental Influence on the Management of Light Land

The basic objective in the management of this type of land must be to minimise the detrimental effect of the variable environment. Where this is achieved, then high levels of output per acre are possible, so that the system of light land farming which has evolved over recent years, places emphasis on this particular aspect. Critical features of this system include:-

- (i) Improved soil fertility, through the use of subterranean clover, and application of increased quantities of superphosphate and lime.
- (ii) Higher pasture production and persistency. Subterranean clover, by virtue of its ability to reseed annually, has proved to be

well suited to the severe summer conditions which exist on the light land. It not only gives increased total pasture production, but also contributes towards the fertility building process. It is the basic plant for the light land pastures. Where the soil fertility has been improved, lucerne pastures are used to give greatly increased total production, with less variation between seasons than was the case with the ryegrass-subterranean clover-white clover sward.

- (iii) The equation of feed supply and demand, so as to minimise the effect of the variability in pasture production on output. This is achieved through:-
 - a) The maintenance of a reserve for both winter and summer feeding in the form of hay and/or grain.
 - b) Flexibility in the stock policy. This enables more efficient utilisation of the available feed, and allows the variable feed supply and stock requirements to be equated.

Where a high degree of flexibility is incorporated in the stock policy and fodder reserves are maintained to meet the demands of poor seasons, the effect of variations in seasonal pasture production on stock output is considerably reduced.

4.4 The Critical Management Features of Light Land Farming and their Integration into a Management System

4.4.1 Increased Pasture Production.

(a) Subterranean Clover. The basic pasture on the light land over the last thirty years has been the subterranean clover dominant sward. This sward has proved to be an essential feature in the initial stages of improvement of the low fertility light land. (Characteristics of the subterranean clover sward have already been outlined under section 3.2.1.)

Active growth of the subterranean clover begins in August and reaches a peak in November when it dries off under hot summer conditions. The seasonal growth pattern of the subterranean clover dominant pasture then, fits in well with the system of fat lamb farming on light land, where early lambing and early drafting of light-weight lambs has been the key to success in recent years.

Lambs fatten rapidly on subterranean clover dominant pastures in the spring and should the bulky herbage dry off in early November, lambs will continue to fatten on the dried pasture. Unfortunately this herbage does not last long when subjected to high temperatures and stock trampling over this period. Stock thrive particularly well on the high quality feed produced by the subterranean clover sward and as a result these pastures generally produce the earliest fat lambs.

The ability of subterranean clover to survive under the severe summer conditions, and to provide high quality feed suitable for lamb fattening, makes the plant ideally suited to the light land fat lamb farm. However, it has some disadvantages. Production of the subterranean clover pasture is determined largely by the amount of rainfall in the early spring and autumn, with the result that production varies markedly. (Iversen at Ashley Dene, over a ten year period, has recorded production ranging from 900 lbs. to 7,000 lbs. dry matter per acre.) This fluctuation in production, combined with the concentration of production in the spring period (in fact $\frac{2}{3}$ of the total production is concentrated in this period), requires special management of stock when pasture production is low. Where fertility has been built up, production from the subterranean clover sward is low when compared with lucerne.

Subterranean clover in association with perennial ryegrass, and white clover, provides high quality feed, which in turn allows rapid lamb growth rates in the spring. This, along with the persistency of the subterranean clover,

makes the plant ideally suited to the environment and system of farming practised in the area.

(b) Lucerne. Following the build up of fertility on the light soils, the key to further improvement is undoubtedly through increased use of lucerne as a pasture. Until recently lucerne was used primarily as a source of hay, but work by Iversen⁽¹⁾ at Ashley Dene has shown that 50% more dry matter per acre can be produced from lucerne pastures when compared with the ryegrass-subterranean clover pasture. The seasonal spread of production is greater and even in the driest season, production is considerably higher than that obtained with the ryegrass-subterranean clover pasture. This has led to an increased interest in the lucerne sward for grazing.

Because of its importance on light land, lucerne and its management will be discussed in some detail⁽²⁾.

(i) Lucerne in the Grazing Mixture. When sown on its own lucerne is highly productive and easier to manage as a pasture, but on its own it provides little winter feed. Mixtures of subterranean clover, white clover and cocksfoot, with light sowings of ryegrass, were sown on the light land, while more recently only subterranean clover and white clover has been included with the lucerne. These mixtures give a sward of high feeding value and with better spread of production, but unfortunately the competition in the sward tends to reduce the productive life of the lucerne. It is difficult to maintain a satisfactory balance between the grass and lucerne in the sward, and where the lucerne is dominated by the

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- (1) C.E. Iversen, (1964), "Pastures for Droughty Soils". Canterbury Chamber of Commerce, Agricultural Bulletin, No. 416.
- (2) Some of this section has already been published r.f. J.D. Stewart and N.W. Taylor, (1965), "Management Considerations in Farming Lucerne on Low-Rainfall Light Land". Proc. 15th Lincoln Coll. Fmrs' Conf. pp.93-99.

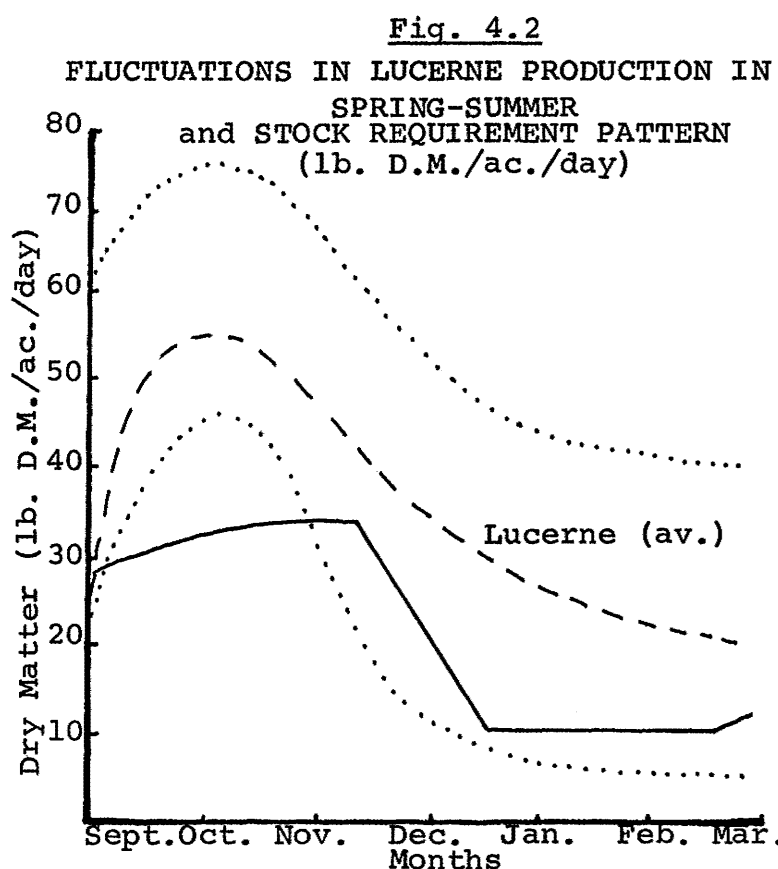
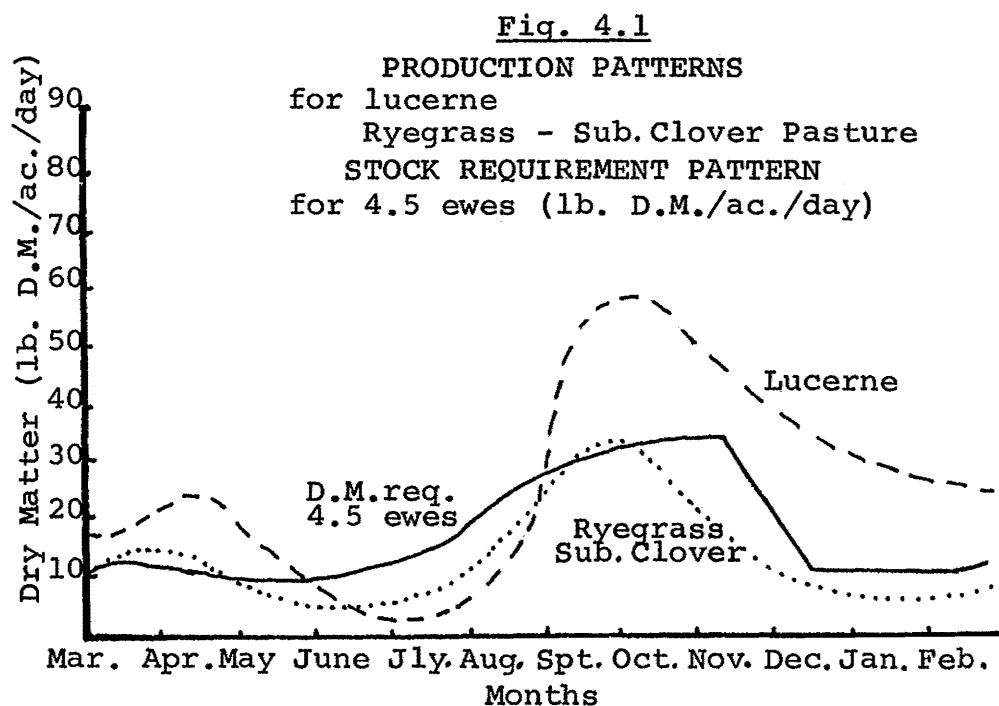
grass and clover component, total production is considerably reduced, especially when compared with that from pure lucerne. As a result of this competition, the lucerne rapidly disappears from the sward.

Until recently cocksfoot was the main grass sown with lucerne. Current experiments with prairie grass however indicate that this grass may be more compatible, and, being less competitive than cocksfoot, appears to have promise as a grass when sown in combination with lucerne⁽³⁾. Where maximum perennial production is required, then lucerne should be sown on its own.

- (ii) The Level and Pattern of Production. In Fig. 4.1 the seasonal production pattern of lucerne is compared with that of a perennial ryegrass-subterranean clover pasture. The respective annual production levels represented are 7,500 lbs. dry matter and 4,500 lbs. dry matter. These are based on the results of trials at Ashley Dene and the Winchmore Irrigation Research Station⁽⁴⁾. If the 7,500 lbs. dry matter of lucerne could be harvested then this would represent a theoretical carrying capacity of five ewes per acre. The relationship between these production patterns and stock requirements is shown by the third curve representing the seasonal demands of four and a half ewes. In Fig. 4.2 the maximum variation from the average spring and summer production in the Ashley Dene experiments is shown, again with the dry matter requirements of four and a half ewes included. Only in the extremely dry year does the potential productivity of

(3) C.E. Iversen, (1964), op. cit.

(4) pers. comm.



Source of Data: Plant Science Department, Lincoln College, Winchmore Irrigation Stn.

lucerne fall short of that required by four and a half ewes, and this shortage could be overcome by weaning 2-3 weeks earlier than normal. While Fig. 4.2 indicated high variation in lucerne production, this is considerably less than that experienced with conventional pastures.

Fig. 4.1 illustrates the superior production of lucerne in the autumn and of the ryegrass-subterranean clover in the late winter and early spring. It also emphasises the point that lucerne pastures on light land provide an opportunity for a considerable increase in present carrying capacity.

- (iii) The Place of Lucerne in a Management System. While lucerne is undoubtedly a superior plant on the light land, more than 70% of the farm in lucerne would cause management problems. High oestrogen intake of ewes grazed almost entirely on lucerne prior to mating may depress and delay lambing. Autumn saved pasture is a vital feature of the winter feeding system on light land. For this purpose good ryegrass-subterranean clover pasture is necessary as this pasture is less affected by frost damage and provides a higher quantity of high quality feed pre- and post-lambing.

It is clear that the most efficient utilisation of lucerne is made where the plant is grazed "in situ". Considerable losses in technical efficiency are incurred where pasture is transferred from one season to another. This applies particularly where lucerne is made into hay. (Up to 30% of the feeding value is lost when the hay is moderately good.) Where a high proportion of the large spring flush of lucerne can be grazed "in situ",

rather than made into hay, the more technically efficient the system becomes. While feeding "in situ" is undoubtedly efficient, it must be included in a system which is compatible with the need to provide flexibility in the feed supply by having adequate reserves of hay to meet the demands of the poor seasons.

The lucerne growth begins later in the spring but carries on longer into the summer than the subterranean clover-perennial ryegrass pasture. Greater efficiency in utilisation of this growth can be achieved by later lambing, i.e. mid-September. This would be more compatible with the pattern of production of lucerne than is the conventional early August lambing, and may even allow higher lambing percentages. Pre-lambing feed in August can be provided by greenfeed cereals or Italian ryegrass oversown on the lucerne in the autumn.

If it were possible to make sufficient hay for the summer and winter requirements from lucerne closed in mid-November, then high stocking rates could be achieved on the light land. With mid-September lambing the stocking rates could be increased to the capacity of the September-October-early November lucerne production. Early drafting and weaning at 10-12 weeks would enable late November, December and January lucerne production to be used for lamb fattening and hay production. But only occasionally is it possible to make hay when lucerne is closed in November. To this end, the making of hay is a direct competitor with ewe carrying capacity in the spring and early summer.

Fig. 4.2 indicates that it is possible to have a stocking rate which utilises a high proportion of the average lucerne production "in situ", while conserving hay mainly in good years, and adjusting

stock management in poor years. This implies a reliance on turnips for winter feed with hay used only as a supplement.

Lucerne in the autumn provides adequate feed to enable body weight of ewes to be increased. Unfortunately there is the possibility of a depression of lambing performance due to the presence of oestrogens. Either this is disregarded or a special flushing feed, e.g. rape or York Globe turnips sown in November and fed in February and March, must be provided.

The value of lucerne as a means of increasing stocking rates on the light land is clear, and while many farmers have increased their areas of lucerne in recent years, the percentage of lucerne on light land is still surprisingly low. An analysis of data from Stewart's⁽⁵⁾ survey indicates that lucerne was grown on only 10% of the total farm area of the light land farms in the area surveyed. Iversen⁽⁶⁾ has suggested that failure in establishment of lucerne stands, low production of lucerne due to ingress of grass and clover, stock health problem (e.g. white muscle disease) thought to be due to lucerne, the oestrogenic effect on fertility, and satisfaction with lower stock numbers, may all have contributed to the slow adoption of this plant to the light land.

Iversen has shown that maximum production is achieved under a quick grazing system where the lucerne is grazed at the hay stage, and then let recover. This would mean rotational grazing of ewes and lambs during the spring which is contrary to the normal practice. The lamb fattening qualities of lucerne however have been well demonstrated by McLean et.al.⁽⁷⁾

The place of lucerne on the light land farm has been the subject of considerable discussion. Its value as a grazing pasture has been demonstrated many times by farmers and others in recent years^{(8), (9), (10), (11), (12), (13)}.

(5) J.D. Stewart, (1963), op. cit.

(6) C.E. Iversen, (1964), op. cit.

(7) J.W. McLean, et.al., (1965), op. cit.

Currently a 30 acre farmlet trial is being conducted at Ashley Dene in order to study the possibility of, and the management problems associated with, the carrying of five ewes per acre over the whole farm when 80% of the area is in lucerne pastures. Theoretically, 7,500 lbs. of dry matter per acre should support five ewes. In the first year the five ewes have been carried with ease, lamb meat production per acre was 169 lbs. and wool production per acre, 50 lbs.

If the trial demonstrates a management system which can utilise the high dry matter production of lucerne in an efficient manner, and carrying capacities of the order of five ewes per acre are possible, then lucerne, utilised mainly as a pasture will undoubtedly be the key to further increases in production on the light land of Canterbury.

4.4.2 Increased Levels of Fertiliser and Lime Application. The Lismore, Eyre and Ghersey soils are naturally deficient in sulphur, phosphate, calcium and molybdenum. Fertiliser trials throughout the light land have proved conclusively that these elements are required in order to build up soil fertility and so allow greater pasture and crop production. Increased levels of fertiliser application are essential if pastures are to become higher producing and more persistent.

(a) Lime. Lime is effective in two ways: in reducing the soil acidity and in releasing molybdenum. Liberal quantities of lime have been used on the

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- (8) A.H. Flay, et.al., (1955), "Lucerne in the Farm Programme". Proc. 5th Lincoln Coll. Fmrs' Conf., pp. 61-79.
 - (9) A.H. Flay, (1956), "Potential Production on Light Plains Land". Proc. 6th Lincoln Coll. Fmrs' Conf., pp. 60-62.
 - (10) A.H. Flay, (1962), "The Place of Lucerne in Dry-Land Farming". Proc. 24th Conf. N.Z. Grassld Ass. pp. 104-114.
 - (11) David Watson, (1962), op. cit.
 - (12) D.E. Rankin, (1965), "Increasing Production on Light Land". Proc. 15th Lincoln Coll. Fmrs' Conf., pp. 43-47.
 - (13) E.C. Topp, (1965), "Lucerne in Practice". Proc. 15th Lincoln Coll. Fmrs' Conf., pp. 100-104.

light land of Canterbury in recent years and consequently soil acidity has been largely corrected. A pH of 6.0 - 6.2 appears to be adequate for satisfactory pasture growth on this class of soil.

This level of pH can be maintained by the application of 1 ton of lime on the fallowed ground prior to sowing new grass, followed by a further application of a ton every 6-8 years.

Lucerne, however, is much more responsive to lime. A high pH is necessary for good nodulation and for the development of the characteristic tap root system. While one ton of lime applied at sowing will allow good nodulation, the development of the tap root may be impeded by acid conditions lower in the soil profile. Because of this it is recommended that one ton of lime be applied with the crop preceding the lucerne, and maintenance dressings of one ton every 4-6 years are necessary to maintain a strong vigorous stand.

(b) Phosphate and Sulphur. Phosphate and sulphur are normally applied in combination as superphosphate. Only in recent years has the need for sulphur on the light land been recognised. Few areas in the light land give sulphur responses, but this is almost certainly due to the fact that considerable quantities of sulphur have been applied in the superphosphate used over the years.

Phosphate is sown at $1\frac{1}{2}$ -2 cwt. per acre with all brassica forage crops.

Lucerne is normally sown down with 2 cwt. of superphosphate, followed by annual maintenance dressings of at least 2 cwt. applied in the early spring. Recent work⁽¹⁴⁾ has shown that where heavy yields of lucerne are removed, with little being fed back on to the stand, potash reserves are depleted, and it may be necessary to topdress with muriate of potash occasionally to maintain a healthy stand.

The quantity of superphosphate sown with new grass has for many years been 1 cwt. per acre. Recently evidence suggests that $1\frac{1}{2}$ or even 2 cwt. of

(14) P.B. Harris and W.R. Lobb, (1964), op. cit.

superphosphate gives quicker and stronger establishment of clovers in the new pasture and so increased spring production. Where only limited amounts of superphosphate have been applied in the past, it may be necessary to increase initial dressings and to sow down with 3 cwt.

Annual maintenance dressings of superphosphate for high production on the light land should be $1\frac{1}{2}$ -2 cwt. per acre, applied in the autumn. There is no evidence to suggest that higher maintenance dressings of superphosphate are necessary on the light land, with present levels of production.

The application of D.D.T. superphosphate to protect pastures from grass grub and porina attack is essential if pastures are to be maintained in a productive state for any length of time. Under the existing regulations governing the use of D.D.T. on pastures, the optimum time of application of D.D.T. in the more common prill form appears to be in the spring. This gives up to three years protection of the pasture.

4.4.3 Increased Areas of Autumn Saved Pasture for High Quality Winter and Lambing Greenfeed. The last six weeks of pregnancy is the most critical period in the winter feeding of the ewe flock. High quality feeding then is essential in order to prevent pregnancy toxaemia and to allow increased lamb birth weight and milk production.

The cheapest and one of the highest quality feeds available at this time on the light land is undoubtedly autumn saved pasture (A.S.P.). This consists of good ryegrass-subterranean clover-white clover pasture closed in March after topdressing and saved through the winter to be ration grazed prior to lambing. A.S.P. is also invaluable as a supplementary greenfeed for the period immediately following lambing and before the beginning of the spring growth. Over recent years the trend to earlier lambing has increased the need for special greenfeed crops for this period. The equation of feed supply and demand immediately post-

lambling is usually difficult on the light land farm, and to this end A.S.P. is of immense value. As well as being high in energy and protein value⁽¹⁵⁾ A.S.P. is a relatively low cost form of supplementary feed. Because of this, the aim must be to save as much of the good pasture as is possible in this way.

In order to obtain satisfactory production from these pastures however, it is necessary to close them in early March, following a topdressing with 2 cwt. of superphosphate. Later closing of pastures on the light land e.g. April, cannot be relied upon to give a bulk of growth because of the uncertainty of the autumn rains and the possibility of early frosts.

Feed requirements are increased for a six week period of 'flushing' while mating takes place in the autumn. In the past the practice has been to 'save' good pasture in order to provide an improvement in nutrition at this period. While this is quite satisfactory at the time, it leaves a smaller area of pasture which can be saved for the late winter period.

One well proven method of overcoming this problem is to sow York Globe turnips in November for utilising in the autumn. This not only provides a special purpose crop which is ideal for flushing ewes, but by concentrating the flock on a small area over the autumn, it allows increased areas of pasture to be saved for late winter feeding.

4.4.4 Emphasis on Turnips for Early Winter Feed. In the past smaller areas of turnips and larger quantities of hay have been used for that period of early winter feeding of the ewe flock when requirements are for maintenance only. This has been encouraged by the increased pasture productivity and hence smaller areas under cultivation, and the increased mechanisation of hay making.

The use of hay as a winter feed where turnips are an alternative is not

(15) I.E. Coop, (1964), "Supplementary Feeds for Sheep". Canterbury Chamber of Commerce, Agricultural Bulletin, No.417.

regarded as being economically sound. Stewart and Taylor⁽¹⁶⁾ have shown that whereas the direct cost of wintering a ewe on turnips is only 1/10 per ewe per winter, the cost of wintering on lucerne hay alone (where the hay is made on the property) is 5/6. Additional to this is the opportunity - cost of the valuable spring feed which is converted to hay. Hay-making competes directly with sheep, for the available spring feed so that in order to provide winter feed in the form of hay, potential spring carrying capacity is sacrificed. Thus a low cost winter feeding system on the light land would place more emphasis on turnips than hay as a winter feed. There is still a need for a reserve of hay for the cold wet spell in winter, but this reserve, conserved in good seasons need not be large.

4.4.5 The Maintenance of Reserves for Periods of Feed Shortage. Feed reserves in the form of hay or grain are necessary on the light land especially where the level of stocking is high. Variation in pasture production between years is considerable. The effect of this can be minimised where reserves of hay conserved in years of a surplus of feed, are used as a buffer when drought conditions prevail.

Reserves usually consist of lucerne hay, threshed ryegrass straw, or feed barley. When drought conditions develop, the body weight of ewes can be maintained by confining ewes on rough pastures and feeding ryegrass straw or feed barley until pasture production improves. In the case of a prolonged drought, supplementary feeding may be necessary for two months prior to mating, and for a period following mating before winter feeding commences. Usually the summer and early autumn conditions are not so severe however, and supplementary feeding may only be necessary for 4-6 weeks over this period.

With the greater emphasis on turnips for winter feed, the need for reserves for the three month period is reduced. In general, turnip crops on the light land are reliable given reasonable standards of fertility and management, so that

(16) J.D. Stewart & N.W. Taylor, (1965), op. cit., pp.96-98.

lucerne hay or feed barley may only be necessary when conditions make the feeding of turnips, and later in the winter, autumn saved pasture, difficult.

On the light land, where pasture production is so variable, it is essential to conserve feed in years where there is a surplus, in order that this may be used as a buffer when summer drought conditions or unfavourable winter conditions make feeding of the ewe flock difficult. This becomes increasingly important as stocking rates are raised. While more efficient utilisation of the available feed is made, the need for feed reserves to maintain the flock through periods of low pasture production is likewise increased.

4.4.6 Flexibility in the Stock Policy. In an environment where the pattern of pasture production is so variable, the need for a flexible stock policy is evident. Only through such a policy can the feed supplies be equated with feed requirements throughout the year. This is especially important in the spring and early summer periods where the level of feed supply is subject to wide fluctuations, even where the lucerne pastures are dominant. (See Fig. 4.2.)

Wintering of stock on the light land is usually no real problem, for with adequate supplies of turnips, autumn saved pasture and new grass, ewes can be carried through to lambing in mid-August without fear of feed shortage, provided planning has been prudent.

From lambing on however, the feed supply is dependent entirely on the season's growth pattern. Where growth is adequate to meet stock requirements, the season is regarded as being very satisfactory. However where the early spring growth is slow because of cold conditions or dry weather prevents continued spring growth, stock management has to be adjusted accordingly, in order that the flock be maintained in satisfactory condition. In the former situation where growth is slow in spring, it may be necessary to sell a proportion of the ewes and lambs 'all counted' in order to equate feed supply and demand. Where dry conditions

occur in the spring and growth stops in October, early weaning, and drafting of light-weight lambs (provided high quality lamb fattening feed is available), relieves the situation and gives more efficient utilisation of the adequate feed. Over the summer period dry conditions can be expected to prevail on the light land, so that those stock policies which facilitate high stocking rates over the spring and early summer period, must allow considerable de-stocking over the summer, mainly through the sale of cull ewes at weaning. Feed supplies are at a minimum from December to February (see Fig. 4.1) and while the dry ewes' requirements are not high at this period, every effort must be made to lighten stock numbers. As pasture production increases in the autumn again, stock numbers are built up as replacement stock are bought into the flock.

The degree of flexibility required in a stock policy depends on the level of stocking on the particular farm and the level of feed reserves held. Where the stocking rate is high and feed reserves are limited, a high degree of flexibility is required in the stock policy.

The different stock replacement policies which are found on the light land fat lamb farms in Canterbury, incorporate varying degrees of flexibility and de-stocking over the summer months. These policies include:-

(a) Buying in Two-year Ewes. This involves the replacing of approximately a third to a half of the ewe flock with ewes culled from mainly hill country flocks. While the policy has the advantage of markedly reducing stock numbers over the summer, there are problems associated with buying in the numbers of ewes required for the larger flocks. This policy is common on the smaller properties however,

(b) Buying in Two-Tooth Ewes. This policy, where approximately one-fifth of the flock is bought in each year, does not allow a large reduction of stock numbers over the summer. The flock includes a proportion of younger sheep, and as a result, can withstand the hard summer feeding better, where this is necessary.

(c) **Buying in Ewe Lambs.** The system of buying ewe lambs in the early autumn has advantages in that the farmer can control the development of the ewe lambs up to maturity. However this necessitates the carrying of hoggets over the winter and spring, and the two-tooths over the following summer. While the ewe lambs are not bought in until late February the feeding of the replacement stock in the following spring and summer presents a problem, especially in dry years.

In the three policies described, ewes are generally mated to fat lamb sires.

(d) **Breeding Replacements.** On the larger properties, replacement ewes may be bred. This involves mating sufficient of the ewe flock to the Corriedale ram to give the required number of replacement stock, the remainder being mated to the fat lamb sire. It is difficult under this system to achieve high stocking rates per acre because of the replacement stock which must be carried through the winter, spring and summer periods (i.e. ewe lambs and two-tooths). An additional disadvantage of this system is the presence of Corriedale wether lambs, which are difficult to fatten. There is little flexibility in this system.

(e) **The "Two Flock" Crossbreeding Policy.** Where Border-Leicester X Corriedale (BL.C) ewes are used for fat lamb production, it is usually necessary to breed replacement ewes. Where Corriedale ewes are bought in, either as two-tooths or two-year ewes, and mated to the Border Leicester ram to give first cross replacement ewes for the fat lamb flock (which in turn is mated to Down type rams), the system is known as the "two flock system". Replacement stock have to be carried through the summer, and while their numbers in relation to total ewes carried are not high, flexibility is reduced by the "two flock" system.

(f) **The "Three Flock" Crossbreeding Policy.** Under this policy Corriedale replacements are bred for the Corriedale flock, which is crossed with the Border Leicester ram to produce BL.C replacements for the BL.C fat lamb flock. This

is one of the most unsuitable systems for light land fat lamb farms, for it involves the carrying of large numbers of replacement stock over the summer months (i.e. both Corriedale and BL.C ewe lambs and two-tooths), as well as producing the difficult to fatten Corriedale wether lambs. High carrying capacities are difficult to attain using this policy because of the high demands for late spring and summer feed. On the light land where BL.C are to be run, the "two flock system" is generally preferred to this one, because of the flexibility factor.

(g) Buffer Flock. The use of buffer flock on the light land, as an adjunct to any of the above policies is useful (especially at high stocking rates) as a means of introducing increased flexibility. This usually involves the mating of a small flock of aged or 'one-year' ewes which are wintered on the greenfeed and mated to lamb in late July or early August. When the feed supply is short in the spring, then these ewes and lambs may be sold 'all counted' or when feed is adequate, held through in the normal manner. This is normally a financially rewarding practice which enables more efficient utilisation of the available winter and spring feed.

(h) Wintering of Hoggets. Although not a common practice on the light land, the carrying of ewe and wether hoggets over the winter in conjunction with a basic replacement policy, does give increased flexibility in the stock feed requirement. When the spring feed is short, wether hoggets may be sold fat after shearing in late winter, and ewe hoggets sold as replacement stock. Where surplus feed exists in the spring, the hoggets may be carried on through the spring and sold later according to the feed supply.

4.4.7 A Management System on the Light Land Farm. The important management features of light land farming as described above, will, when integrated in a well organised system of management, enable the attainment of high per acre

output. (This has been well illustrated by the performances achieved by leading farmers in the area over recent years.)

Such a system involves the carrying of either a mixed age Corriedale or BL.C ewe flock, mated to a Dorset Down or Southdown for fat lamb production. Corriedale replacements are generally bought in as two-tooths, though on the smaller properties two-year ewes may be purchased. At high stocking rates, a buffer flock is often run to allow greater flexibility in feed requirements. A high proportion of the farm (60-70%) will generally be in the high producing ryegrass-white clover or lucerne based pastures if high output per acre is to be achieved.

An efficient method of flushing ewes, where pastures are dominantly lucerne based, is in the growing of York Globe turnips for the autumn. These are sown in November, and by confining ewes on a small area in the autumn, enable increased areas of A.S.P. to be closed up for late winter utilisation.

Following the 4-6 weeks flushing period in March the ewes are only fed at maintenance for the first two months of the winter when lamb development is slow. A low-cost system of feeding over this period involves the break feeding of York and Green Globe turnips and Italian ryegrass in conjunction with a run-off paddock. (A weed or grass infested lucerne stand is ideal for this purpose.) These turnips, sown in January provide the bulk of the winter feed for the ewe flock. Hay is only used when conditions preclude the feeding of turnips over this early winter period.

Only in the last 6-8 weeks of pregnancy does the lamb development affect the ewe. At this stage a progressively rising plane of nutrition is provided up to the time lambing commences. A.S.P. and new grass, ration grazed to the ewe flock, provides the high quality feed necessary over this period.

Where lambing is delayed until late August or early September, and where ewes are synchronised, the feed demands of the ewe flock are more compatible

with the growth pattern of the pasture production. This is most important, where greater emphasis is being placed on lucerne based pastures, which are later growing in the spring. (See Fig. 4.1.) In the past the practice has been to lamb in early August in order that lambs may be drafted before the onset of dry summer conditions. This places great strain on feed supplies in early August, as little pasture growth takes place before mid-August, even with subterranean clover pastures. To this end, early lambing has necessitated the sowing of special pre-lambing and lambing greenfeeds or A.S.P. to supplement feed supplies until pasture growth is sufficient to meet the rapidly increasing feed demand. Later lambing overcomes this problem for with new grass and large areas of A.S.P. available, the flock can be maintained at a satisfactory level of nutrition without the need for special greenfeeds over the pre-lambing period. Later lambing allows stock requirements to increase with the normal growth pattern of pasture production. This gives more efficient utilisation of spring feed especially where the stocking rate is such that a high proportion of the spring feed is utilised "in situ".

After lambing, a decision must be made as to whether or not the buffer flock is to be maintained. Should cold conditions reduce the early spring growth, then it may be necessary to sell the buffer flock 'all counted'.

Following docking, ewes and lambs are set stocked on subterranean clover-ryegrass-white clover or lucerne based pastures. Where maximum production is required from pure lucerne however, stock are rotationally grazed.

The commencement of drafting is dependent on the season and growth rate of lambs. Where Southdown or Dorset Down sires are used on Corriedale and BL.C ewes, light-weight lambs can be drafted at 8-10 weeks of age. One of the basic aims of the light land farmer is to draft a high percentage of lambs fat off the mothers before dry summer conditions commence. In a normal season up to 75% of the lambs may be sold by the time weaning takes place. When dry conditions

set in early in the spring, weaning may be necessary when lambs are only eight weeks old, in order to utilise the available feed more efficiently. This early weaning allows de-stocking through the sale of cull ewes immediately after weaning, and allows the remaining ewes to be fed at maintenance only. Weaning may still take place at no more than 10-12 weeks when feed is adequate, since more efficient utilisation of the available feed can be made by conserving this in the form of a hay reserve for possible summer, early autumn, or winter use.

At weaning the remaining lambs (which will be all Down-cross lambs where a buying in policy is employed), are drenched with thiobendazole and selenium and fattened on mature lucerne paddocks. The ewe flock which is shorn following weaning is fed at maintenance levels through until three weeks prior to mating, when flushing starts. At this stage all ewes are dosed with selenium.

Should conditions be such that pasture growth is negligible over the summer period, it may be necessary to supplement the pasture production with threshed ryegrass straw or grain in order to maintain body weight in the ewes. Pasture production is low during the post-weaning period hence the aim is to minimise stock requirements over this period.

Where a policy of breeding replacements is followed, flexibility is reduced. The hoggets are usually wintered on turnips and grass, but compete with ewes and lambs over the spring for available feed. This accentuates the problem of equating feed supply and demand over the spring and summer period in years when pasture production is low. Such a policy then has the effect of limiting stocking rate over this period.

Where a large percentage of the property is in lucerne pastures, and a BL.C two flock system (for which replacements are bought in) is employed for fat lamb production, high levels of output per acre are attainable. With emphasis on turnips and A.S.P. for winter feed, and with later lambing, more

efficient utilisation of the available feed is possible. The most critical feature in any management policy on the light land is the equation of feed supply and demand through the use of a flexible stock policy and adequate feed reserves.

4.5 The Uncertainty Associated with Light Land Farming

A system of management on light land as described in section 4.4.7 will, under average climate and price conditions, enable high levels of physical and financial performance to be attained. Unfortunately the environment both physical and economic, within which the light land farmer must operate, is characterised by a high degree of uncertainty. This uncertainty above all else, is the dominating factor which demands consideration in the planning and decision making of a programme, and in the evaluation of possible future outcomes on the farm. Because of this the farming system adopted must incorporate a high degree of flexibility in order to enable the management to be adjusted according to the changing conditions, with a minimum physical, financial and managerial input. Climatic uncertainty constitutes the major management problem faced by the light land farmer.

Yield uncertainty in forage crops is important on the light land because of the emphasis on livestock production. Yield uncertainty in relation to pasture production is undoubtedly one of the greatest problems encountered. While every effort is made to reduce the variability in production, the climate is such that large feed reserves, flexible stock policies, and more drought resistant pasture species are necessary to counter the wide fluctuations in the feed supply. Where a practice of feed conservation is not adopted, and the carrying capacity is restricted to the level which can be supported under drought conditions, the inefficient use of the available feed in the average year,

constitutes considerable loss of revenue to the farmer. At high carrying capacities, available feed is more efficiently used in the average year. However when severe drought conditions do occur, and feed reserves are inadequate and/or the stock policy is inflexible, financial losses incurred through the forced disposal of capital stock, can be high. Thus yield uncertainty in forage crops, and particularly pasture production, has led to the evolution of the management system already described. Only when such a system is implemented, is the uncertain nature of the climatic environment and resultant feed supply, successfully counteracted.

Price uncertainty is also important on the light land, since the range of products which it is possible to produce is extremely limited. The two major products are wool and fat lamb. The price received for wool (the bulk of which is sold at auction), is subject to marked fluctuations between and within seasons (see Table 5.8) as a result of changes in the world demand for wool. Similarly, the price received for fat lambs sold on a schedule (drawn up by the meat export companies and based on the prices received at Smithfield) varies again between and within seasons. This wide fluctuation in the income received, makes long term planning difficult, though very necessary. Unfortunately the opportunity to diversify output, and so hedge against price fluctuations, is limited by the soil type and climate of the area. It is conceivable however that as soil fertility is built up under good husbandry and management, that some limited cash cropping (e.g. wheat, barley peas) may be possible on the light land.

Thus the light land farmer is vulnerable to changes in the price of the two major products. This factor, along with the uncertainty of feed supplies, creates a decision making environment in which uncertainty has a real and significant influence. This undoubtedly tends to impede rapid increases in stocking rates, and development generally, on the light land.

4.6 Farm Size

While it is an important consideration in farm management and farm development, the optimum size of farm on any particular soil type is indeterminate. Farm size is linked in economic theory with scale relationships⁽¹⁷⁾ but because of the wide differences in technical efficiency of the farm operators the quantifying of these relationships is difficult.

The size of the farm which constitutes an "economic unit" will, with changing technology, vary considerably over time. In recent years the application of improved light land farming techniques and the evolution of a more intensive system of farming, has allowed greater output from a given area. As a result, the larger properties have been subdivided and this has led to increases in total output in any given area. From a social and national viewpoint this settlement of more families on a given area, producing increased output may well be highly desirable. In Stewart's 1963 survey⁽¹⁸⁾ 43 dry land farms ranged in size from 306 acres to 1,772 acres, with an average of 706 acres. While some of the farms of 1,000 acres or more were well developed, most were being farmed under a low stocking rate, low cost system and were capable of large increases in output. In many cases this potential could only be achieved by subdivision of the property into smaller units, or by some production incentive scheme⁽¹⁹⁾. Where farms of 400 to 600 acres are carrying 4-4½ ewes per acre, and adjacent to these, 1,000 to 1,500 acre properties carrying only 1-2 ewes per acre, the loss of potential production from a given area is significant, from the national viewpoint.

4.7 Summary

The variable nature of the climate and the soil conditions which exist on the light land of Canterbury, create an environment where the basic problem is

(17) E.O. Heady, (1952), "Economics of Agricultural Production and Resource Use". Prentice-Hall. Inc., Englewood Cliffs, N.J. Chapt. 12, pp. 349-381.

(18) J.D. Stewart, (1963), op. cit.

(19) W. Candler, (1964), "Incentives for Increased Output of Farm Products". Proc. 14th Lincoln Coll. Fmrs' Conf. pp. 10-19.

the equation of stock requirements and the variable feed supplies. The natural soil fertility is not high and so increased pasture production and persistency can only be achieved where the fertility has been improved through the use of subterranean clover and adequate lime and topdressing. Where this initial improvement has been made, the introduction of high producing lucerne based pastures, enables the carrying capacity of the light land to be further increased. This increase is possible particularly where the management system is adjusted to allow large areas of lucerne to be farmed.

The well established principles of light land farming enable high levels of output to be attained where a flexible stock policy is efficiently integrated with the variable feed supply. The production possibilities on light land are not wide when compared with other types of farming. Because of this, the risk and uncertainty associated with output in this variable environment is considerable. While feed reserves help to overcome the uncertainty of feed production little can be done to alleviate price uncertainty. Considerable advances have been made in the techniques of light land development in recent years, and the efficiency of these have been demonstrated by many farmers, especially those on smaller properties. A considerable portion of the light land of Canterbury is held in large units, and this has undoubtedly contributed to relatively slow development of farms in these areas.

CHAPTER V

A LINEAR PROGRAMMING STUDY OF A LIGHT LAND FARM

5.1 The Nature and Objective of the Study

The economics of light land farming, given assumptions about price and technical relationships involves:

- (i) The optimum combination of enterprises within a particular resource structure.
- (ii) The optimum resource use, given a range of production alternatives.

Ideally these problems must be answered at both the individual farm level, and for the area as a whole if economic efficiency is to be achieved.

The objective of this particular study has been defined as an investigation of the relative profitability of a range of different management systems possible on one light land property in relation to:

- (i) The maximum level of short term profits, subject to the maintenance of the asset.
- (ii) The compatibility of the programmed solution with the labour and management capacity, and personal preference of the owner.

5.2 Methodology

In this study linear programming has been used to explore and examine the relative profitability of the various production alternatives. While this technique is undoubtedly appropriate for the analysis of this type of problem generally, its application in the particular environment within which this study is made does expose some deficiencies. The light land farming system is characterised by widely fluctuating feed supplies and variable product prices between years. Under these conditions the use of a non-stochastic linear programming model (in which single valued expectations for these coefficients

have been incorporated) is not entirely satisfactory as an analysis technique. Other techniques (e.g. Monte Carlo simulation and drought models), which would have been suitable for the exploration of particular facets of the problem within a stochastic framework, were precluded by their rigorous data requirements. The wide range of alternatives being considered in this problem, and the nature of the input data available, favoured the use of linear programming. Since the programmed solutions, which are optimum under average or normal conditions, relate only to the given range of alternative activities and coefficients specified in the problem, care must be exercised in generalising from the results.

The generalised form of the linear programming model used in the study, may be expressed as follows:

The objective function is to:

- (i) Maximise $Z = \sum_{j=1}^n c_j x_j : j=1, 2, \dots, n.$
 (ii) Subject to $b_i \geq \sum r_{ij} x_j : i=1, 2, \dots, m.$
 (iii) and where $x_j \geq 0$

Where Z = programmed net revenue
 c_j = unit net revenue of the j th activity
 x_j = level of j th activity
 r_{ij} = the per unit requirement of the j th activity for the i th resource
 b_i = level of the i th resource
 n = number of activities
 m = number of resources

A case study approach has been adopted as the basis for this analysis. Maunder⁽¹⁾ has shown that the selection of a representative farm, based on the frequency distribution of certain characteristics of farms within the total population, is entirely satisfactory for farm management investigations. As an alternative

(1) A.M. Maunder, (1953), "A Note on the Representative Farm". J. agric. Econ., 10,4:363.

to random sampling, this purposive selection of a farm for case study has advantages in terms of time and money where the detailed nature of examination precludes the use of large numbers of farms. While the particular farm used in this study was selected basically because the owner was able to furnish the required data, it is representative of light land farms in the area. Climate and soil type are homogeneous over a large number of farms on the light land of Canterbury. Likewise the particular resource structure and pattern of farming of the case farm is similar to that found on many light land farms, with one notable exception, namely, the size of the farm. The case farm of 440 acres, is smaller than the average found in the area. An analysis of the 43 dry land farms in Stewart's⁽²⁾ survey shows the average farm to be of 706 acres, while the average of the 25 farms of 700 acres or less is only 510 acres. Thus the case farm is somewhat smaller than the average one man light land farm in the area. While the results obtained in the study refer specifically to the resource structure, management and location of the particular farm under study, they do have some application to light land farms in general.

5.3 The Farm Used for this Study

The 440 acre farm selected for this study is situated in the Ashburton County one mile west of Lauriston. The average rainfall is 23 inches and the climate is typical of the Canterbury plain (see section 2.3 for further details). The farm is on a Lismore soil, slightly more fertile than the bulk of the Lismore series. The effective area of the farm is 434 acres and the present policy is one of intensive fat lamb production with the occasional crop of wheat or barley.

The farmer, an energetic and competent manager, operates the property on his own, with casual labour hired only in December and January to assist with

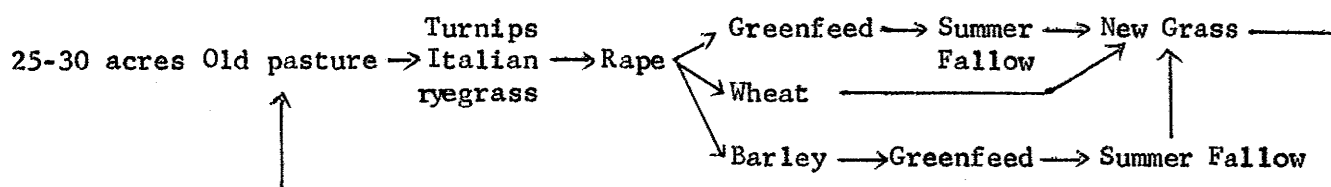
(2) J.D. Stewart, (1963), op. cit.

shearing and harvesting.

A mixed age Corriedale flock is run with all ewes mated to Border Leicester-Southdown cross rams for fat lamb production. Replacements are bought in as two-tooths in February or March. All the lambs are fattened and up to 70% are drafted fat off the mothers. Average stock numbers over the last three years (1963, 1964, 1965) have been:

| | | |
|-----------------|---|------|
| Corriedale ewes | : | 1300 |
| rams | : | 24 |

The bulk of the pastures are in good condition and consist of white clover and subterranean clover. Sixty acres of lucerne provide hay and grazing. The rotation generally followed is:



This has given an average land utilisation over the spring and summer of:

| | |
|-----------|--|
| 27 acres | wheat |
| 27 acres | turnips and Italian ryegrass |
| 27 acres | rape |
| 27 acres | greenfeed Italian ryegrass → summer fallow |
| 27 acres | 1 year grass |
| 60 acres | lucerne |
| 239 acres | grazing |
| <hr/> | |
| 434 acres | |

At least 1,000 bales of lucerne hay are made each year for use in late summer and early winter. The aim is to have a carry-over of 2,000 bales.

While the spring carrying capacity of 3.3 stock units per available acre is not high, it is near the average for the district⁽³⁾. A small amount of cereal cropping is practised, and although the farm is situated on one of the more

(3) *ibid.*, p.15.

fertile phases of the Lismore series, yields are not high enough to encourage the farmer to expand the area of cropping. In view of the yields being obtained, there may be good reason to discontinue this cereal cropping, as many farmers on the light land have in fact already done.

The property is subdivided into 15 paddocks of approximately 27 acres each. Fences, shelter belts and sheds are all in very good repair. Stock water is supplied from County races and reliable throughout the summer. The farm is equipped with an adequate range of plant and machinery for the current programme. Harvesting of wheat and barley is by contract.

5.4 The Construction of the Model

5.4.1 Labour. The incorporation of labour restrictions in a model comparing profitability of activities is obviously a vital consideration. This is especially important when the production alternatives considered vary in their labour requirements as is the case in most farming enterprises, e.g. dry sheep, store lambs, and an all breeding policy. Unfortunately information on labour inputs for various stock and crop activities on farms is extremely difficult to obtain. Ideally, this information should be obtained from the particular property being programmed because of the variation in labour efficiency between farms. The necessary detail however is seldom available for one farm.

Tyler⁽⁴⁾ in an attempt to overcome this problem, obtained estimates of labour inputs from a sample of farms within a population by survey interview. He suggested that while the figures from each farm may be subject to error, the average obtained from the survey would be reasonably representative of the sample average, and hence of the population average.

(4) G.J. Tyler, (1963), "Labour Requirements on Wheat Farms in the North Western Slope of New South Wales". Rev. Mktg. agric. Econ. 31.2:81-87.

In some of the more recent programming work applied to farm programmes in New Zealand, labour profiles have been included in the matrices^{(5) (6)}. However these studies were concerned more with crops than livestock activities. Holden⁽⁷⁾ assumed linearity in input-output coefficients for livestock activities in his model, using coefficients based on work diaries. Holden was only partially successful, and his results could be explained by the fact that economies of scale undoubtedly existed in the labour requirements for the stock activities concerned.⁽⁸⁾ Haslam⁽⁹⁾ investigated the problem of labour coefficients but because of the lack of precise information was forced to omit labour requirements from his model. He estimated the labour requirements of the programmed solutions on the basis of judgment.

Similar problems of lack of data were encountered in the present study. The farmer did not possess work diaries and when interviewed, was unable to provide accurate and precise information on labour requirements for the various activities included in the model. This lack of input data, and the existence of economies of scale in the labour use for stock activities (which comprise a major section of the model), forced the writer to exclude labour requirements from the model. The labour requirements for the programmed solutions are assessed ex poste.

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- ((5) D. Wesney, (1964), "A study of the Financial Returns to Process Pea Growers in Hawkes Bay". Unpublished thesis for M.Agr.Sc., Massey University, Manawatu.
 - (6) A.R. Frampton, (1964), "The Economics of Growing Sugar Beet on Farms in South Otago". Unpublished thesis for M.Agr.Sc., Massey University, Manawatu.
 - (7) J.S. Holden, (1963), "Studies in the Measurement of Farm Efficiency". Unpublished thesis for M.Agr.Sc., Lincoln College, University of Canterbury.
 - (8) G.J. Tyler, op. cit.
 - (9) D.A.R. Haslam, (1965), "A Management Study of Irrigation Farming in the Ashburton-Lyndhurst Scheme of Mid Canterbury". Unpublished theses for M.Agr. Sc., Lincoln College, University of Canterbury.

5.4.2 Pasture and Crop Activities. Because of the physical and biological interrelationships which exist between the various crops on the light land farm, it is often difficult and sometimes illogical to consider these enterprises independently. In many cases there are joint costs which cannot be ascribed to particular crops. Likewise in a rotation of pastures and crops, residual effects in respect of plant nutrient and cultivation requirements make it more desirable to study combinations of enterprises rather than individual enterprises.

A practical way of overcoming these interrelationships is by grouping these different enterprises in a feasible rotation. A series of feasible rotations for this class of property has been defined and included in this model. The rotations include a representative range from a dominantly lucerne grazing system to one including some cereal cropping.

5.4.3 Livestock Activities. Widely differing stock policies are found on the light land farms as indicated in Tables 3.3 and 3.4. All possible policies, from an intensive fat lamb system to one concentrating on wool production have been included. In addition to store lamb and dry sheep activities, policies for Corriedale and Border Leicester X Corriedale ewes have been included in order that the profitability of the two breeds could be compared.

5.4.4 The Expression of Feed Supply and Stock Requirements. All stocks have been converted to the stock unit (or ewe equivalent) basis, and feed provided by the various rotations, defined in the same terms. This system, as outlined by Coop⁽¹⁰⁾, is the most accurate available for expressing feed requirements and provisions in common terms and has been used in recent farm programming models in New Zealand. When expressed in stock units, the requirements for the main classes of stock can be regarded as giving an accurate interpretation of the true situation. The conversion ratios of some of the other classes of

(10) I.E. Coop, (1965), op. cit.

stock such as store lambs and dry sheep are subject to greater error. Estimation of feed provision from pasture and forage crops is based on the farmer's figures for stock actually carried, but adjusted where necessary to take account of more accurate figures on yields where these were available. An allowance is also made for the fact that the particular property concerned was slightly understocked.

For most classes of stock, requirements can be determined quite accurately. With feed provision however the estimates are likely to be less accurate because of the extreme variability of seasonal production and the resulting problem in defining the "average production".

5.5 The Model

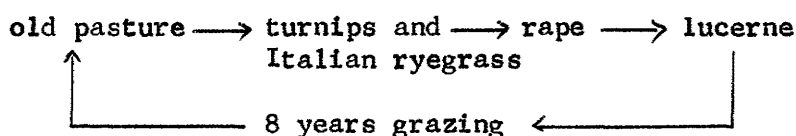
The model used in this study is given in full in Appendix F. A brief description of the activities and constraints is given here.

5.5.1 The Activities.

(a) Rotation activities $P_1 - P_9$

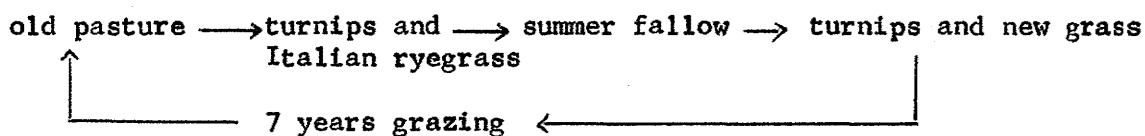
(i) Lucerne

P_1 Rotation A.

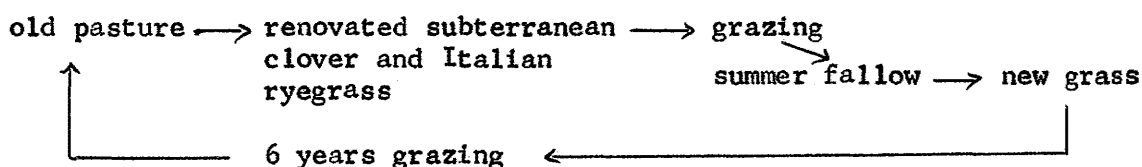


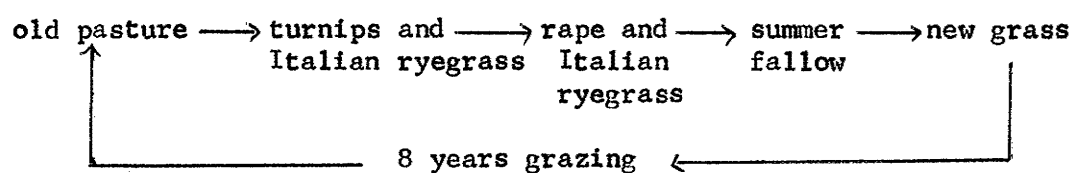
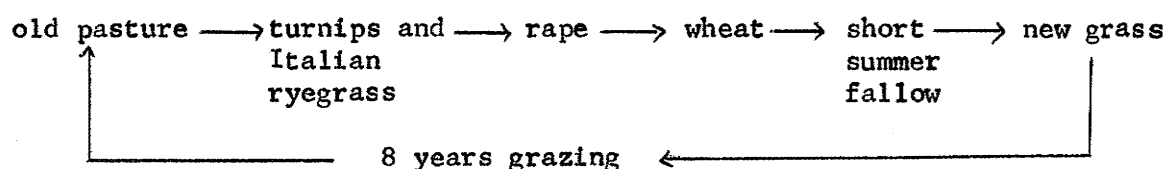
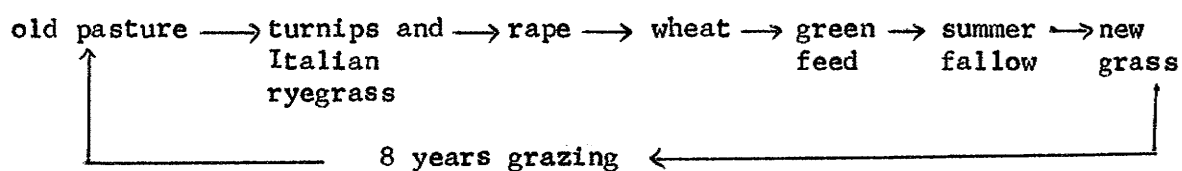
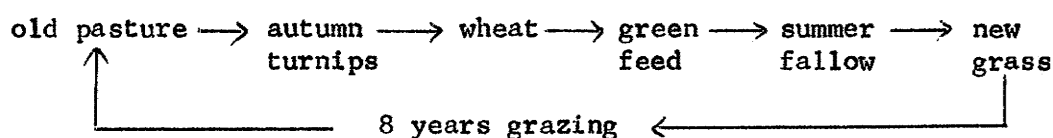
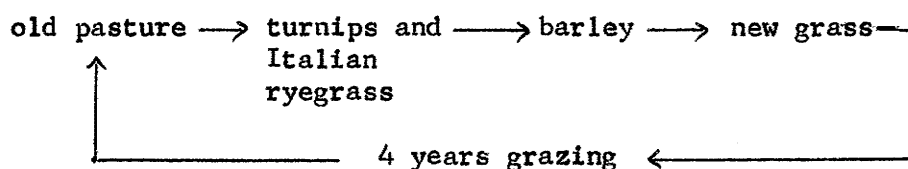
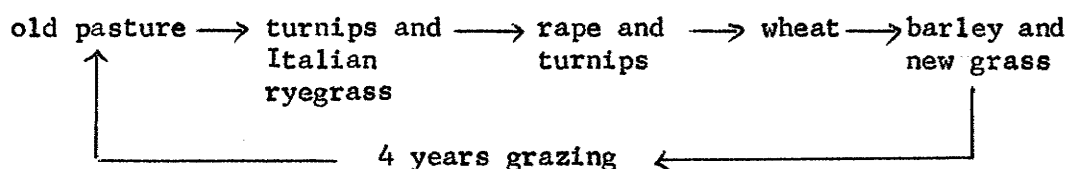
(ii) Forage Cropping

P_2 Rotation B.



P_3 Rotation C.



P₄ Rotation D.(iii) Cereal CroppingP₅ Rotation E.P₆ Rotation F.P₇ Rotation G.P₈ Rotation H.P₉ Rotation I(b) Feed transfer activities P₁₀ - P₁₈

Activities to allow feed to be transferred from one period to a second are included. (See section 5.6.1 (b) for further details.)

- P₁₀ Hay made in spring and winter fed.
- P₁₁ Hay made in autumn and winter fed.
- P₁₂ Hay made in spring and summer fed.
- P₁₃ Hay made in autumn and summer fed.
- P₁₄ Farm produced barley, winter fed.
- P₁₅ Farm produced barley, summer fed.
- P₁₆ Lamb fattening feed.
- P₁₇ Autumn saved pasture.
- P₁₈ Winter feed.

(c) Supplementary Winter feeding activities P₁₉ - P₂₂

Supplementary winter feed activities in which additional feed may be purchased are included.

- P₁₉ Buying lucerne hay.
- P₂₀ Buying perennial ryegrass straw.
- P₂₁ Buying short rotation ryegrass straw.
- P₂₂ Buying feed barley.

(d) Supplementary summer feeding activities P₂₃ - P₂₆

Supplementary summer feeding activities in which additional feed may be purchased are included.

- P₂₃ Buying lucerne hay.
- P₂₄ Buying perennial ryegrass straw.
- P₂₅ Buying short rotation ryegrass straw.
- P₂₆ Buying feed barley.

(e) Cereal crop selling activities P₂₇ - P₂₉

- P₂₇ Wheat.
- P₂₈ Malting barley.
- P₂₉ Feed barley.

(f) Stock activities P₃₀ - P₅₁

- P₃₀ Breeding ewe policy, mixed aged Corriedales, mated to Corriedale rams, surplus sold as ewe lambs or two-tooths.
- P₃₁ Selling surplus Corriedale ewe lambs (from P₃₀).
- P₃₂ Selling surplus Corriedale two-tooths (from P₃₀).
- P₃₃ Breeding ewe policy, mixed aged Corriedales, mated to Down rams.
Replacement bought in as ewe lambs or two-tooths.
- P₃₄ Buying in Corriedale ewe lambs (for P₃₃).
- P₃₅ Buying in Corriedale two-tooths (for P₃₃).
- P₃₆ Breeding ewe policy, mixed aged Corriedales, with one half of the flock mated to Corriedale rams for replacements and one half to Down rams for fat lamb production.
- P₃₇ Breeding ewe policy, two-year Corriedale ewes, mated to Down rams for fat lamb production. Replacements bought in as two-year ewes.
- P₃₈ Buying in two-year ewes (for P₃₇).
- P₃₉ Breeding ewe policy, mixed age Corriedale ewes, mated to Border Leicester rams. Surplus sold as ewe lambs or two-tooths (P₄₁ or P₄₂), or supplied to P₄₃.
- P₄₀ Breeding ewe policy, two-year Corriedale ewes, mated to Border Leicester rams. Replacements bought in as cast-for-age ewes. Surplus sold as ewe lambs or two-tooths (P₄₁ or P₄₂), or supplied to P₄₃.
- P₄₁ Selling surplus BL.C ewe lambs (from P₃₉ and P₄₀).
- P₄₂ Selling surplus BL.C two-tooths (from P₃₉ and P₄₀).
- P₄₃ Breeding ewe policy, mixed age BL.C ewes, mated to Down rams. Replacements are either bred (from P₃₉ or P₄₀, i.e. a "two flock" system), or bought in as ewe lambs or two-tooths.
- P₄₄ Buying in BL.C two-tooths (for P₄₃).

- P₄₅ Buying in BL.C ewe lambs (for P₄₃).
- P₄₆ BL.C ewe lambs (intermediate activity).
- P₄₇ Sell lambs fat off the mothers (F.O.M.) i.e. lambs fattened prior to weaning.
- P₄₈ Sell lambs fat off the feed (F.O.F.) i.e. lambs fattening post weaning.
- P₄₉ Store lamb policy, purchased in early autumn and sold fat before winter.
- P₅₀ Dry ewe policy, replacements bought in as dry two-tooths.
- P₅₁ Buying in dry two-tooths (for P₅₀).
- (g) Wool selling activities P₅₂ - P₅₃
- P₅₂ Sell Corriedale wool.
- P₅₃ Sell BL.C wool.

To summarise, the model includes the following activities:

| | | |
|----|--------------------------------------|-----------------------------------|
| 9 | Rotation activities | P ₁ - P ₉ |
| 9 | Feed transfer activities | P ₁₀ - P ₁₈ |
| 4 | Supplementary winter feed activities | P ₁₉ - P ₂₂ |
| 4 | Supplementary summer feed activities | P ₂₃ - P ₂₆ |
| 3 | Cereal Crop selling activities | P ₂₇ - P ₂₉ |
| 22 | Stock activities | P ₃₀ - P ₅₁ |
| 2 | Wool selling activities | P ₅₂ - P ₅₃ |
| 53 | Total | |

5.5.2 The Constraints. The model includes 27 constraints which are described below in detail. The range of machinery on the property has been assumed to be sufficient for the requirements of any programmed plan. Similarly operating capital has been assumed to be adequate to meet requirements.

The constraints, which are numbered according to the initial matrix given in Appendix F, are as follows:

(a) Land Constraint R_1

The 434 effective acres of the property are homogenous with respect to fertility and land use. This constraint reconciles the land available with the requirements for land by the rotations, $P_1 - P_9$. For example, one unit of rotation P_1 requires 11 acres of land.

(b) Feed reconciliation constraints $R_2 - R_{12}$

The feed reconciliation constraints included in the model are of the general form outlined below:

$$\sum_{k=1}^s r_{ik} x_k \geq \sum_{j=1}^n r_{ij} x_j$$

The expression on the left of the inequality represents the total quantity of feed generated in the programme from the rotations and other feed providing activities (e.g. feed transfer activities), where i = the per unit level of feed generated by the k th activity.

The expression on the right of the inequality represents the total quantity of feed required by the stock and other feed absorbing activities (e.g. hay making activities) where i = the per unit level of feed required by the j th activity.

The reconciliation constraints then, ensure that the supply of feed generated in the programme is adequate to meet the level of feed required by the stock and other feed demanding activities included.

Because of the seasonal nature of feed supplies and stock requirements on this class of farm, the year has been divided into six periods, i.e.

| | |
|----------------|----------------------------------|
| Autumn | March and April |
| Winter | May, June and July |
| Pre-lambing | August to mid-September |
| Spring | Mid-September to weaning |
| Lamb fattening | For lamb fattening, post weaning |

Summer

Weaning to end February

 R_2 Autumn Feed

This constraint reconciles the autumn feed supplied by the nine rotations, with the demand for autumn feed by the various stock activities, the A.S.P. transfer activities, and the demand by the autumn hay activity.

The feeding of the ewe flock in the autumn is important, especially prior to, and during, mating. Not only is the body weight itself important, but an adequate supply of feed is necessary to allow a "flushing" of the ewes. For example, one unit of stock activity P_{30} (consisting of 5 ewes and 1 ewe lamb) demands 5.8 stock units of autumn feed, and one unit of activity P_1 (11 acres) supplies 54 stock units of autumn feed.

 R_3 Winter feed

Over the three months of the winter, the ewe flock is fed at maintenance only. Winter feed may consist of brassica forage crops, A.S.P., lucerne hay, perennial and short rotation ryegrass straw, and grain. This constraint then reconciles the demand for winter feed by the various stock activities and the winter feed transfer activity, with the feed supplied by the rotations, and supplementary feed activities.

One unit of activity, P_9 for example, provides 19 stock units of winter feed and 1 acre of spring-made hay provides 12 stock units of winter feed, while 1 unit of stock activity P_{30} requires 5.4 stock units of feed. One unit of winter feed transfer activity P_{17} requires 7 units of winter feed.

 R_4 Pre-lambing feed

This 2-3 week period prior to and during lambing is the most critical period of the year for the ewe. Over this period the protein content of the feed must be high, with emphasis on A.S.P. and greenfeeds rather than hay and turnips. With early August lambing the problem of feed provision for this period is accentuated,

as little pasture growth takes place before the end of August. Thus special greenfeed crops are often grown on light land to provide for this period. This row reconciles the demand for feed in this period with the feed supplied by the various rotations and the winter feed transfer activity P_{26} .

R_5 Spring Feed

The overall carrying capacity of a light land property is generally limited by the supply of spring feed. This period of the year is also subject to wide between year fluctuations in the feed supply.

This constraint effects a reconciliation between the supply of feed by the 9 rotations and the demand for feed by the various stock and hay making activities.

R_6 Lamb Fattening Feed

Lamb fattening feed is provided by lucerne in activity P_1 and rape in P_4 , P_5 , P_6 and P_9 . In the case of lucerne allowance is made in P_{16} to save spring lucerne for use as lamb fattening feed. The practice of using lucerne for lamb fattening on light land has increased in recent years, with a reduction in the area of rape grown. While lamb growth rates are greater on rape than on lucerne, rape grown on light land is an unreliable crop.

This constraint reconciles the demand for lamb fattening feed by the stock activities with the supply of fattening feed in the form of lucerne or rape.

R_7 Summer Feed

During the summer (or post-weaning) period the ewe flock is fed at maintenance only. While pasture pickings provide adequate feed for the stock carried under most stock policies, the use of supplementary feed in the form of lucerne hay, ryegrass straw or grain, is necessary where particular stock policies are adopted.

The supply of feed in these forms, along with that available from pasture pickings is then equated with the stock activity requirements in this row.

In addition to these constraints, five other restrictions on feed are included.

R_8 Spring lucerne

A reconciliation of the spring lucerne is necessary to ensure that the area made into hay or saved for lamb fattening is no greater than the area available from rotation P_1 .

R_9 Autumn lucerne

As for the spring lucerne, the area of autumn lucerne made into hay must be reconciled with the area available.

R_{10} Maximum lucerne area

Because of the need for a limited amount of conventional pasture for autumn saved feed, an upper limit of 300 acres was imposed on the area of lucerne. The effect of a lower limit (50 acres) was also investigated.

R_{11} Feed Barley

This reconciliation row constrains the quantity of feed barley sold or fed out with the quantity produced.

R_{12} Maximum Barley Fed (see section 5.6.2 for further details.)

Because of the nutritional problems involved where barley is fed alone, the amount of barley entering the programme is kept in proportion to the quantity of hay or straws fed.

(c) Stock reconciliation constraints $R_{13} - R_{20}$

Techniques for the effective reconciliation of various stock activities within a linear programming model have been demonstrated in recent years. Townsley and Schroder⁽¹¹⁾, in comparing the profitability of various culling policies within a linear programming model, included stock reconciliation rows, to effectively "tie together" the various classes of stock and stock policies in their model.

(11) Robert Townsley and W.R. Schroder, (1964), "A Note on Breeding Flock Composition in Relation to Economic Criteria". Aust. J.agric.Econ. 8.1:66-73.

Stewart⁽¹²⁾, in programming a livestock policy on a specialised sheep farm, separated out the stock selling activities to facilitate the exploration of price variations on the programmed solutions. He then successfully used reconciliation rows to ensure that numbers of livestock sold, or transferred to a different class, through intermediate activities, did not exceed the numbers available from the various stock activities included in the model.

This method has been incorporated in the present model. Thus the general form of the stock reconciliation constraint is:

$$\sum_{k=1}^s r_{ik} x_k \gg \sum_{j=1}^n r_{ij} x_j$$

The expression on the left of the inequality represents the total number of stock available in the programme, for sale or transfer, where i = the per unit number of stock provided by the k th activity. The expression on the right of the inequality represents the total number of stock disposed of by selling or transference to other livestock classes within the programme, where i = the per unit level of livestock required by the j th activity.

R_{13} Lambs Fat-off-mothers (F.O.M.)

The number of lambs sold F.O.M. is of considerable significance to the light land farmer. In general a stock policy which enables a high percentage to be sold F.O.M. is preferred because of the problem of providing fattening feed for large numbers of lambs over the late spring and summer periods.

This constraint then, reconciles the numbers of lambs sold, with the numbers available F.O.M. from the breeding ewe activities.

R_{14} Lambs Fat-off-Feed (F.O.F.)

In this constraint the numbers of lambs sold fat-off-feed (i.e. off

(12) J.D. Stewart, (1961), "An Exploration of the Role of Linear Programming in Farm Management Analysis". Unpublished Ph.D Thesis, University of Reading.

lucerne or rape) is reconciled with the numbers of lambs available from the various breeding ewe activities.

R_{15} Corriedale Ewe Lambs

One means of providing Corriedale ewe replacements for the ewe flock is through carrying Corriedale ewe lambs. This row reconciles the numbers of lambs provided by the ewe activities breeding ewe lambs, with the numbers required as replacements and those required by the ewe lamb selling activity.

R_{16} Corriedale Two-Tooths

This row reconciles the surplus two-tooth ewes available from the breeding ewe activities and those bought in, with the requirements by the remaining ewe activities and the two-tooth selling activity.

R_{17} Corriedale Two-Year Ewes

The two-year ewes required for the two aged-ewe breeding policies are reconciled with the number bought in.

R_{18} Border Leicester X Corriedale Ewe Lambs

As with the Corriedale ewe lambs, this constraint reconciles the numbers available from the breeding ewe activities and those bought in, with the numbers required by the breeding ewe activities and those sold.

R_{19} Border Leicester X Corriedale Two-Tooths

This row reconciles the numbers of surplus BL.C two-tooths available from the breeding ewe activities and those bought in with the numbers required as replacement for the fat lamb policy (P_{43}), and the two-tooth selling activity.

R_{20} Dry Ewes

The number of dry ewes required for the dry ewe activity is reconciled with the number purchased.

(d) Stock Limit Constraints $R_{21} - R_{22}$

Two physical constraints, based on husbandry considerations have been imposed on stock activities.

R₂₁ Maximum Breeding Ewes

An upper limit of 1,700 ewes was imposed on the breeding ewes carried on the property. This was felt to be the maximum number which could be managed by the existing labour on the property.

R₂₂ Maximum Store Lambs

The maximum number of store lambs permitted in this programme was 750. The present owner considered a larger number would prove difficult to manage.

(e) Wool reconciliation constraints R₂₃ - R₂₄

Because of the price differential existing between BL.C wool and Corriedale wool, the two types were separated out in order to facilitate the investigation of price variations.

R₂₃ Corriedale Wool

This row reconciles the Corriedale wool available from the various stock activities with the wool sold.

R₂₄ Border Leicester X Corriedale Wool

The crossbred wool is reconciled with the wool sold in this row.

(f) Maximum Cropping constraint R₂₅

R₂₅ Maximum Cereal Crop

Based on husbandry considerations, a physical restriction has been placed on the area of cereal cropping. The maximum area of cereal crop allowed is 100 acres, or approximately 25% of the total area.

(g) Cereal Crop reconciliation constraints R₂₆ - R₂₇

R₂₆ Wheat

The quantity of wheat produced from the five cropping rotations is reconciled with the wheat sold.

R₂₇ Malting Barley

The quantity of malting barley produced is reconciled with the malting barley sold.

To summarise the model includes the following constraints:

| | | |
|-----------|--|-------------------|
| 1 | Land constraint | R_1 |
| 11 | Feed reconciliation constraints | $R_2 - R_{12}$ |
| 8 | Stock reconciliation constraints | $R_{13} - R_{20}$ |
| 2 | Stock Limit constraints | $R_{21} - R_{22}$ |
| 2 | Wool reconciliation constraints | $R_{23} - R_{24}$ |
| 1 | Maximum Cropping constraint | R_{25} |
| 2 | Cereal Crop reconciliation constraints | $R_{26} - R_{27}$ |
| <u>27</u> | <u>Total</u> | |

5.5.3 The Input-Output Coefficients. The input-output coefficients are based largely on information supplied by the farmer. After calculations these coefficients were checked against production performances on the particular farm and where necessary adjustments were made. The levels of stock and crop performance assumed are given in Appendix D.1.

5.5.4 The Unit Net Revenue. The unit net revenues of the various activities are calculated on the 1965/66 costs and prices. Examples of these are given in Appendix D.3.

5.6 Other Characteristics of the Model

5.6.1 The incorporation of Feed Transfer Activities.

(a) Lucerne hay activities. The expedient used in the handling of hay in recent farm programming models has varied considerably. Stewart⁽¹³⁾ and Holden⁽¹⁴⁾ considered different levels of hay making for rotations included in their models. Frampton⁽¹⁵⁾ also included a hay activity where a minimum quantity of hay was forced into the programme. A different approach was adopted by

(13) J.D. Stewart, (1961), op. cit.

(14) J.S. Holden, (1963), op. cit., p.106.

(15) A.R. Frampton, (1964), op. cit. p.82.

Haslam⁽¹⁶⁾. He incorporated hay making activities in which the level of hay made was determined endogenously.

Hay is relatively expensive form of supplementary feed on the light land farm, yet in recent years the tendency has been to make increased amounts of hay for use especially over the winter. The inclusion of predetermined levels of hay making introduces considerable inflexibility in the feed provision. Thus an adoption of the method used by Haslam, where the level of hay made was determined endogenously appeared to be a more realistic approach.

The method used is outlined^d in Table 5.1.

Rotation 2 includes lucerne, which can be saved for hay in either spring or autumn.

It is necessary to reconcile the quantity of spring and autumn hay made, with the area of spring and autumn lucerne available. The model then enables the programme to select the optimum level of hay making in order to satisfy the feed requirements over the summer and winter periods. Livestock activities compete with the hay making activities for spring and autumn feed. Because of this the possibility of buying in hay for the summer or winter should not be overlooked, and to this end, hay buying activities have been included.

(b) Autumn, winter and lamb fattening feed transfer. The transferring of feed from periods of over supply to periods of shortage is a vital consideration in the management of light land properties. Based on the method described in 5.6.1 (a), three feed transfer activities for the periods autumn to winter, winter to lambing, and spring to post weaning (for lamb fattening), have been included in the model. Table 5.2 indicates the method used.

(16) D.A.R. Haslam, (1965), op. cit., p.79.

TABLE 5.1
Model Allowing the Level of Hay to be Determined Endogenously⁽¹⁷⁾

| | | P ₁ Stock Policy | P ₂ Rot.1 | P ₃ Rot.2 (incl. lucerne) | P ₄ Spring Hay Winter Fed | P ₅ Autumn Hay Winter Fed | P ₆ Spring Hay Summer Fed | P ₇ Autumn Hay Summer Fed | P ₈ Bgt.Hay Summer Fed | P ₉ Bgt.Hay Winter Fed |
|-------------------------------|-----|-----------------------------------|-------------------------|---|--|--|--|--|--|--|
| Net Revenue | = | +C ₁ | -C ₂ | -C ₃ | -C ₄ | -C ₅ | -C ₆ | -C ₇ | -C ₈ | -C ₉ |
| R ₁ Autumn Feed | 0 > | +r _{1.1} | -r _{1.2} | -r _{1.3} | | +r _{1.5} | | | | |
| R ₂ Winter | 0 > | +r _{2.1} | -r _{2.2} | -r _{2.3} | -r _{2.4} | -r _{2.5} | | | | -r _{2.9} |
| R ₃ Spring | 0 > | +r _{3.1} | -r _{3.2} | -r _{3.3} | +r _{3.4} | | +r _{3.6} | | | |
| R ₄ Summer | 0 > | +r _{4.1} | -r _{4.2} | -r _{4.3} | | | -r _{4.6} | -r _{4.7} | -r _{4.8} | |
| R ₅ Autumn Lucerne | 0 > | | | -r _{5.3} | | +r _{5.5} | | +r _{5.7} | | |
| R ₆ Spring Lucerne | 0 > | | | -r _{6.3} | +r _{6.4} | | +r _{6.6} | | | |

(17) Hay made on the farm consists of lucerne hay only. Ryegrass-white clover hay has not been considered, mainly because of its lower quality and yield.

TABLE 5.2

Model Allowing the Endogenous Determination of Feed Transfer

| | | P ₁ Stock | P ₂ Rotation | P ₃ 1 A.S.P. Transfer | P ₄ Winter Feed Transfer | P ₅ Spring Feed Transfer |
|------------------------------------|-----|-------------------------|----------------------------|--|--|--|
| Net Revenue | = | +C ₁ | -C ₂ | 0 | 0 | 0 |
| R ₁ Autumn Feed | 0 > | +r _{1.1} | -r _{1.2} | +r _{1.3} | | |
| R ₂ Winter Feed | 0 > | +r _{2.1} | -r _{2.2} | -r _{2.3} | +r _{2.4} | |
| R ₃ Lambing Feed | 0 > | +r _{3.1} | -r _{3.2} | | -r _{3.4} | |
| R ₄ Spring Feed | 0 > | +r _{4.1} | -r _{4.2} | | | +r _{4.5} |
| R ₅ Lamb Fattening Feed | 0 > | +r _{5.1} | -r _{5.2} | | | -r _{5.5} |

Activities P₃, P₄, P₅ have no direct cash cost, so that the net revenues are zero.

The model permits the endogenous determination of the optimum level of feed transfer necessary through the three periods above, in order that feed demand and supply are equated.

5.6.2 The Hay-Barley Ratio. In recent years, increasing use has been made of grain as a supplementary feed for ewes over the summer and winter period. Grain is easy to store and feed out. The cheapest and most satisfactory grain appears to be barley. It is high in energy value but low in fibre and because of this it is inadvisable to feed ewes on barley alone over the winter. Coop⁽¹⁸⁾ has suggested that in order to provide a balanced diet, barley and hay should be fed in the ratio of no more than 2:1 by weight.

$$\begin{aligned} \text{i.e. (Weight of hay fed) } \times 2 &> \text{ weight of barley fed} \\ \therefore 0 &> \text{ weight of barley fed} - (\text{weight of hay fed}) \times 2 \end{aligned}$$

A barley feeding activity is incorporated in the model and a nutritional

(18) I.E. Coop, pers. comm.

restriction based on the weight of barley fed is included as shown in Table 5.3,

TABLE 5.3

Model Incorporating a Hay-Barley Ratio for Winter Feeding

| | | | | P_1 Stock | P_2 Rotation | P_3 Spring Hay Winter Feed | P_4 Barley Winter Feed |
|-----------------------|---|--------|--|----------------|-------------------|--|-----------------------------------|
| Unit Net Revenue | = | | | $+C_1$ | $+C_2$ | $-C_3$ | $-C_4$ |
| R_1 Winter Feed | 0 | \geq | | $+r_{1.1}$ | $-r_{1.2}$ | $-r_{1.3}$ | $-r_{1.4}$ |
| R_2 Spring Feed | 0 | \geq | | $+r_{2.1}$ | $-r_{2.2}$ | $+r_{2.3}$ | |
| R_3 Feed Barley | 0 | \geq | | | $-r_{3.2}$ | | $+r_{3.4}$ |
| R_4 Max. Barley Fed | 0 | \geq | | | | $-r_{4.3}$ | $+r_{4.4}$ |

where $-r_{4.3}$ represents the weight of one unit of $P_3 \times 2$, and $+r_{4.4}$ represents the weight of one unit of P_4 . The constraint, as set out in this form allows any quantity of hay to be fed over the winter, but when barley enters the programme, as a winter feed supplement, hay also enters at no less than half the level of barley by weight.

5.6.3 The Inclusion of Buying and Selling activities. The model includes a number of buying and selling activities through which price changes can be made conveniently. A series of reconciliation rows is used to link the intermediate products and resources with their relevant production and buying and selling activities.

A similar method was used by Haslam⁽¹⁹⁾ in an early model, but the size of his model and its associated computational problems forced him to discard the technique in favour of a more compact method.

(19) Haslam, (1960), op. cit., p.76.

Where a selling activity had no resource requirements other than for its reconciliation row, Haslam placed the cost coefficient c_j on the corresponding disposal activity. This method allowed a considerable reduction in the size of the model, and is thus more efficient in terms of memory space. However, in the present problem, memory space was not limiting. The buying and selling activities were treated as separate activities, thus allowing more convenient price changes and exposition. An example of a model including buying and selling activities is shown in Table 5.4.

The breeding ewe activity P_1 (e.g. Corriedale ewes mated to Southdown rams) produces lambs fat-off-mothers; and/or fat-off-feed; and wool, and requires two-tooth ewes for replacement purposes. These ewes may be purchased as two-tooths in the year required (through P_3) or bred from ewe lambs purchased in the previous year (P_2). The coefficient $r_{1,1}$ designates the requirement of P_1 for two-tooths, while $r_{1,2}$ represents the number of ewe lambs which must be purchased in order to supply one two-tooth for P_1 in the following year. (The coefficient $r_{1,2}$ makes allowance for deaths in the ewe lambs over the year.) The coefficient $r_{1,3}$ represents the provision of one unit of P_3 . The numbers of lambs sold fat-off-mothers from P_1 , are reconciled in row R_2 with the selling activity P_4 . Row R_4 reconciles the production of wool by activity P_1 (i.e. $r_{4,1}$) and P_2 (i.e. $r_{4,2}$) with the sale of wool from the selling activity, P_6 .

The negative cost coefficient C_1 of activity P_1 consists of the per unit running costs of the activity less the return from the sale of the cull ewe. The negative cost coefficients of the buying activities are equal to their per unit purchase costs. The cost coefficients for lambs sold F.O.M. and F.O.F., and for wool sold, are equal to their unit revenues. In the model variations in the price of ewe lambs, two-tooths, lambs sold F.O.M., and F.O.F., and wool can be explored quite conveniently.

TABLE 5.4

Model Incorporating a Technique for Reprogramming with Variable Prices

| | | P ₁ Breeding Ewes | P ₂ Buying Ewe Lambs | P ₃ Buying Two- Tooths | P ₄ Lambs Sold F.O.M. | P ₅ Lambs Sold F.O.F. | P ₆ Wool Selling |
|-----------------------------|-----|------------------------------------|--|--|---|---|-----------------------------------|
| Net Revenue | = | -C ₁ | -C ₂ | -C ₃ | +C ₄ | +C ₅ | +C ₆ |
| R ₁ Two-tooths | 0 > | +r _{1.1} | -r _{1.2} | -r _{1.3} | | | |
| R ₂ Lambs F.O.M. | 0 > | -r _{2.1} | | | +r _{2.4} | | |
| R ₃ Lambs F.O.F. | 0 > | -r _{3.1} | | | | +r _{3.5} | |
| R ₄ Wool | 0 > | -r _{4.1} | -r _{4.2} | | | | +r _{4.6} |

5.7 The Results from the Programming Study

5.7.1 Introduction. The basic model as given in Appendix F was used to obtain a range of programmed solutions under:

- (i) various management systems;
- (ii) various price regimes;
- (iii) varying levels of feed requirements for the Border Leicester-Corriedale stock policies.

While the programme used⁽²⁰⁾ provides considerable information with each solution, only those activities which are of direct interest in management are discussed, i.e. land utilisation, stock numbers, and winter and summer feeding systems.

The financial results of the programmed plans have been compared using Owner's surplus⁽²¹⁾ as a measure of profitability. The overhead expenses

(20) The solutions were obtained using I.B.M. Library Programme 10.1.002 on the I.B.M. 1620 Data Processing System, at the School of Engineering, University of Canterbury.

(21) Owner's surplus is defined as income less working expenses, depreciation, and interest at 6% on the total value of farm capital, and is the sum available to the farmer as a reward for his labour and management.

(as outlined in Appendix D 4.2), and interest at 6% on the total farm capital have been deducted from the net revenue, as determined in the programmed solutions. The results have also been compared with the present plan in operation on the farm.

5.7.2 The Different Management Systems Considered. The basic aim in programming this farm was to determine the most profitable system of farming from a range of feasible alternatives, and under a given level of costs and prices⁽²²⁾. Included in the model were five rotations in which a restricted amount of cereal cropping was carried out ($P_5 - P_9$) and four rotations which included only forage crops in a process of pasture renewal ($P_1 - P_4$). These two groups of rotations formed the basis of the management systems considered, i.e. fat lamb farming with light cereal cropping, and intensive fat lamb farming with no cereal cropping. Within each group two levels of lucerne were considered with the view of illustrating the impact of lucerne on the light land farm. The level at which the lower limit was imposed (50 acres) was based on the current level of lucerne being grown on light land farms in the Ashburton County, i.e. slightly more than 10% of the farm⁽²³⁾. The upper limit was set at 300 acres (or nearly 70% of the farm). Areas in excess of 70% may create problems in management and for this reason it was thought that 300 acres was a realistic constraint to impose on this farm. Thus the two constraints were imposed at levels which were thought to be restrictive in the case of the lower limit and unrestrictive in the case of the higher limit.

In effect four management systems have been considered, with the aim of determining the most profitable system, i.e. light cereal cropping, with and without the lower lucerne restriction, and intensive fat lamb farming, again with

(22) The 1965/66 costs and prices were used in this section of the study. The product prices are detailed in Table 5.8.

(23) This figure was determined by the writer in investigations on the original data of Stewart's 1963 Survey, op. cit.

and without the lower lucerne restriction. These four programmes are compared in detail in order that the farm manager could consider the relative merits of the plans with respect to labour requirements, management input, risk and uncertainty, as well as their profitability.

(a) The Results⁽²⁴⁾. In Table 5.5 the spring-summer land utilisation for the four programmed plans and for the current farm plan are presented. The level of feed transfers are also given.

Stock numbers carried in the programmed plans are given in Table 5.6 and again compared with numbers in the current plan. The carrying capacity has been calculated on stock units carried per acre of available spring grazing. An important feature of the analysis is that the policy of buying in Corriedale two-tooths for a mixed age ewe flock, and mated to Border Leicester rams, is common to all plans. This policy with the ewe lambs being sold for replacements appears to be superior to all the other stock policies considered. Dry ewes enter the two plans in which the lucerne area is restricted indicating that more efficient utilisation is made of the feed (provided mainly from conventional pasture), where some dry ewes are carried. Store lambs enter only one plan.

The importance of lucerne is evident from the results. In the two plans where the lucerne restriction is non-limiting, lucerne enters at 108 and 188 acres respectively while it enters at the maximum allowed (i.e. 50 acres) in the other two plans.

The financial results of the programmed plans (in terms of Owner's surplus) are compared with the present plan in Table 5.7. The items involved in the estimation of total farm capital and overhead costs are given in Appendix D 4.

(24) Ewe and hogget numbers are approximated to the nearest 10, rams to the nearest 1, hay to the nearest 10 bales, land use to the nearest acre, and financial figures to the nearest £10.

- (i) The Present Farm Plan. In order to compare the financial results of the programmed plans, the net revenue of the present plan has been calculated on the costs and prices used in the linear programming model. Since the input and output data used refers to past performances, the technical relationships of the present plan are not necessarily those of the programmed plans. As explained earlier, the input and output coefficients used in the linear programming model are based on the farmer's estimates amended to take account of more accurate information where this was available. For example, the numbers of stock carried in the programmed plans are generally higher than in the present plan.

This change in technical relationships does not decrease the value of the comparison of the programmed plans with the present plan. It implies an intensification of resource use as well as a reallocation of the available resources. This intensification of resource use may require a greater degree of management skill. For example the higher stock numbers require more efficient utilisation of the available feed and hence a more controlled grazing programme must be implemented.

The programmed plans then, can be compared with the present plan in terms of revenue (Table 5.7) subject to the feasibility of their different technical relationships. Every effort, including discussion with the farmer concerned, was made to check the feasibility of the various programmed plans.

- (ii) Plan 1. This plan represents the most profitable of the programmed solutions. It includes cereal cropping with a

considerable area of lucerne and a Corriedale mixed age ewe flock mated to the Border Leicester ram. The ewe flock is wintered on turnips, A.S.P. and a small amount of hay.

The main features of this plan are:

- (1) A relatively large area of cereal cropping (32 acres wheat, 32 acres barley, undersown with new grass), compared with the present plan.
- (2) A high level of forage cropping, including 32 acres of turnips and rape sown in December and fed in late autumn and early winter. As a result, an insignificant amount of hay is used over the winter (120 bales).
- (3) The use of A.S.P. for late winter and lambing feed.
- (4) A relatively large area of lucerne (108 acres).
- (5) A mixed age Corriedale ewe flock mated to the Border Leicester ram. The BL,C ewe lambs are sold as replacements at the end of January, and 65% of the wether lambs are sold F.O.M. The considerable area of rape grown is utilised by the ewe lambs and lambs sold F.O.F.

This is quite different from the current plan. The average spring carrying capacity is more than half a ewe higher than at present and the crop acreage is increased by 39 acres. As in the current plan, Corriedale two-tooths are bought in as replacements, but the ewe flock is mated to the Border Leicester ram instead of the Southdown, with the bulk of the lucerne being grazed "in situ" in the spring.

The owner's surplus in this plan, some £1,010 higher than in the present plan, is the result of not only a reallocation of resources, but an intensification of their use (i.e. higher carrying capacity and increased cropping).

- (iii) Plan 2. This plan is similar in many respects to plan 1, having the same level of cereal cropping and basic stock policy. The ewe flock, consisting of 1400 Corriedale breeding ewes is supplemented by 160 dry ewes. Replacements for the ewe flock are bought in as two-tooths (320), and the 770 BL.C ewe lambs are sold as replacement stock. Dry two-tooths are bought in as replacements for the dry ewe flock. The spring carrying capacity is raised to 3.8 stock units. Feed is limiting in all periods. A feature of the plan is that the lucerne rotation is included at the maximum allowed (i.e. 50 acres). However the restricted area of lucerne and the large area of crop, reduces the area of summer grazing with the result that supplementary feed in the form of perennial ryegrass straw (1010 bales) is bought in and fed over this period.

The ewes are wintered on turnips, A.S.P. and pasture pickings.

No hay is made.

As in plan 1, a large area of rape is used for lamb fattening and for the ewe lambs.

The owner's surplus in this plan, while some £230 lower than plan 1, is still £780 better than the present plan.

- (iv) Plan 3. This plan from which cereal cropping is excluded, involves the carrying of maximum numbers of ewes under the same policy as in plans 1 and 2 (i.e. Corriedale mixed ewes mated to

the Border Leicester ram). A large area of lucerne is included in the plan. (At 189 acres this is approximately three times the present area of lucerne.) The spring carrying capacity, the highest of the four plans, is 0.7 stock units higher than in the present plan.

A feature of the feed provision under this plan is the complete absence of hay in spite of the large area of lucerne. Ewes are wintered on 44 acres of turnips and Italian ryegrass.

The feed transfers are significant in this plan with 75 acres of A.S.P. of which 50 acres is utilised at lambing. With a lower acreage of rape in the plan, 42 acres of spring lucerne are saved for weaned lambs, both fattening and ewe lambs. Feed is scarce in all periods except summer, when the large area of lucerne provides more than sufficient feed for the ewe flock.

This plan provides an owner's surplus of £1,790 which is £850 higher than the present plan though £160 less than plan 1.

- (v) Plan 4. In this plan, with restricted lucerne, the spring carrying capacity is the lowest of the four plans. At 3.6 S.U. per available acre it is only 0.3 S.U. higher than the present plan. The basic stock policy is the same as in the previous plans, but is supplemented by a dry sheep flock.

The ewe flock of 1,520 Corriedale ewes is wintered on 39 acres of turnips and Italian and 63 acres of A.S.P. No hay is made. With the reduced area of lucerne available, 39 acres of rape and Italian are used as a lamb fattening crop. 33 acres are sown to new grass each year.

Spring and lamb fattening feed is limiting with the result that breeding ewe numbers are lower than in plan 3, and 186 dry ewes

are included.

Replacements for the main flock are bought in as two-tooths (350), while 840 BL.C ewe lambs are sold as replacement stock.

Of the BL.C wether lambs, 65% are sold F.O.M.

The profit from this plan at £1,440, is £500 more than the present programme but £350 less than plan 3 where lucerne is unlimited.

(b) Summary. All four plans described above have higher owner's surpluses than the present plan, with the highest profit plan (plan 1) including cropping rotations and unlimited lucerne.

The four plans not only differ in their resource allocation when compared with the present plan, but involve more intensive use of the given resources. These changed plans were considered by the farmer to be attainable.

The dominant feature of the comparison is undoubtedly the basic stock policy which is common to all plans, but different from the present plan. This policy of mating Corriedale ewes with the Border Leicester ram, and selling the BL.C ewe lambs as replacements, allows a considerable degree of destocking over the summer period. In the plans ewe lambs are sold as replacement stock but in practice, should lamb fattening feed be limited, or the fat lamb price be more favourable, then these BL.C ewe lambs may be sold as export fat lambs. While this flexibility in this stock policy is not reflected in a static analysis such as this, in practice it is of considerable value where feed supply and stock prices tend to fluctuate. This flexibility is increased even further in plans 2 and 4 by the addition of a dry ewe flock. With an increasing demand for BL.C ewes in recent years, the policy as described above, has become more popular on the light land, especially when the ewe lambs can be sold immediately post-weaning.

The effect of limiting the area of lucerne to the 50 acres in plans 2 and

4 not only lowers the spring carrying capacity when compared with plans 1 and 3 (where lucerne is non-limiting), but has the effect of reducing the owner's surplus by £230 and £350 respectively.

Similarly the cropping in plans 1 and 2 confer higher owner's surplus when compared with the noncropping plans, 3 and 4. While this cropping allows higher profits in the short run, it is doubtful if long term profits would be increased, in view of the uncertainty of yields and loss of fertility through cereal cropping on the light land. Unfortunately these aspects are difficult to account for in a static analysis such as this.

Emphasis on winter forage cropping is increased, at the expense of hay making. This tends to support the system of winter feeding suggested by Stewart and Taylor⁽²⁵⁾. Likewise the area of lamb fattening crops is increased, especially where the area of lucerne is limited.

In all plans lucerne is used as the basic pasture, and only where the level is limited to 50 acres, is the area less than in the current plan.

This reallocation of resources does illustrate two interesting developments in light land farming. Firstly, the results indicate quite conclusively that forage cropping is a lower cost form in which to provide winter feed (c/f hay). Secondly, the results tend to suggest that there are advantages to be gained where farmers increase their area of lucerne over the present average of 10% of the farm.

As well as a reallocation of resources, a more intensive use of the given resources is assumed, so that the carrying capacity of all four plans is higher than from the present plan.

5.7.3 The Effect of Price Variation on Two Management Systems. The effect of price variation in the major products on the programmed plans is of importance

(25) J.D. Stewart and N.W. Taylor, (1965), op. cit., pp.96-98.

TABLE 5.5

Land Utilisation for Programmed Plans

| | | Plan 1 | Plan 2 | Plan 3 | Plan 4 | Current Plan |
|--|---------|--|--|--|--|--------------|
| Management System | | Cereal Cropping Lucerne Unrestricted | Cereal Cropping Lucerne Restricted | No Cereal Cropping Lucerne Unrestricted | No Cereal Cropping Lucerne Restricted | |
| Basic Rotations | | P ₁ and P ₉ | P ₁ and P ₉ | P ₁ and P ₂ | P ₁ and P ₄ | |
| 1. <u>Spring Land Utilisation</u> (acres) | | | | | | |
| (a) Wheat | | 32 | 35 | - | - | 25 |
| (b) Barley and New Grass | | 32 | 35 | - | - | - |
| (c) Oats → Turnips and Italian | | 44 | 42 | 44 | 39 | 37 |
| (d) Rape and Italian (or turnips) | | 32 | 35 | - | 33 | - |
| (e) Rape | | 12 | 7 | 21 | 6 | - |
| (f) Renovated Sub.clover | | - | 9 | - | - | - |
| (g) Summer fallow → New Grass | | - | 9 | 23 | 33 | 25 |
| (h) Lucerne | | 96 | 50 | 168 | 50 | 60 |
| (i) → New Lucerne | | 12 | 7 | 21 | 6 | 12 |
| (j) Pasture | | 174 | 205 | 157 | 266 | 250 |
| 2. <u>Feed Transfer</u> | | | | | | |
| (a) A.S.P. | (acres) | 69 | 45 | 75 | 63 | 100 |
| (b) Winter → lambing | " | 44 | 16 | 50 | - | - |
| (c) Spring → lamb fattening | " | - | - | 42 | - | - |
| (d) Hay → winter fed | (bales) | 120 | - | - | - | 1000 |
| (e) Hay → summer fed | " | - | - | - | - | - |
| (f) Straw → winter fed | " | - | - | - | - | - |
| (g) Straw → summer fed | " | - | 1010 | - | - | - |

TABLE 5.6
Livestock Numbers for Programmed Plans

| | Plan 1 | Plan 2 | Plan 3 | Plan 4 | Current Plan |
|---|--|--|---|---|-------------------------------------|
| Management System | Cereal Cropping Lucerne Unrestricted | Cereal Cropping Lucerne Restricted | No Cereal Cropping Lucerne Unrestricted | No Cereal Cropping Lucerne Restricted | |
| Basic Stock Policy | Corriedale M.A. Ewes x B.L. ram | Corriedale M.A. Ewes x B.L. ram | Corriedale M.A. Ewes x B.L. ram | Corriedale M.A. Ewes x B.L. ram | Corriedale M.A. Ewes x Dn ram |
| 1. <u>Class of Stock</u> | | | | | |
| (a) Corriedale | | | | | |
| (i) Mixed age breeding ewes | 1,540 | 1,400 | 1,700 | 1,520 | 1,300 |
| (ii) Two-tooths bought | 350 | 320 | 390 | 350 | 280 |
| (b) BL.C | | | | | |
| Ewe lambs sold | 840 | 770 | 930 | 840 | |
| (c) Rams | 31 | 28 | 34 | 31 | 20 |
| (d) Store lambs fattened | | | 40 | | |
| (e) Dry ewes | | 160 | | 190 | |
| (f) Lambs - F.O.M. | 550 | 500 | 610 | 540 | 1,000 |
| Lambs - F.O.F. | 300 | 270 | 330 | 290 | 430 |
| 2. <u>Stock Units per Available Acre</u> | 3.9 | 3.8 | 4.0 | 3.6 | 3.3 |

TABLE 5.7

Financial Results from Programmed Plans

| | Plan 1 | Plan 2 | Plan 3 | Plan 4 | Current Plan |
|----------------------------------|--|--|---|---|-----------------|
| Management System | Cereal Cropping Lucerne Unrestricted | Cereal Cropping Lucerne Restricted | No Cereal Cropping Lucerne Unrestricted | No Cereal Cropping Lucerne Restricted | |
| 1. <u>Farm Capital</u> | | | | | |
| (a) Land and Buildings | 33,000 | 33,000 | 33,000 | 33,000 | 33,000 |
| (b) Stock | 4,760 | 4,700 | 5,270 | 5,130 | 4,020 |
| (c) Plant | 2,500 | 2,500 | 2,500 | 2,500 | 2,500 |
| (d) Working Capital | 2,020 | 2,010 | 2,040 | 2,030 | 1,980 |
| (e) Total Farm Capital | 42,280 | 42,210 | 42,810 | 42,660 | 41,500 |
| 2. <u>Programmed Net Revenue</u> | 5,710 | 5,470 | 5,580 | 5,220 | 4,650 |
| 3. <u>Overhead Costs</u> | 1,220 | 1,220 | 1,220 | 1,220 | 1,220 |
| 4. <u>Interest on T.F.C. 6%</u> | 2,540 | 2,530 | 2,570 | 2,560 | 2,490 |
| 5. <u>Owner's Surplus</u> | 1,950 | 1,720 | 1,790 | 1,440 | 940 |

to the light land farmer whose range of alternate products is generally limited. In order to study these effects, a series of price combinations was used.

Although the library programme used gave price stability limits for the basic activities, the limits for any one activity only apply if the prices of all others remain unchanged. These stability ranges then are of limited value in programming whole farm situations because of the sympathetic movement of product prices which are typical in this system of farming.

In recent programming work Holden⁽²⁶⁾ based his price movements on the assumption that changes in stock prices followed changes in wool prices. Not only is the validity of this assumption debatable, but these movements are difficult to estimate. Thus the approach adopted by Haslam⁽²⁷⁾ may be more realistic. He used two historical price regimes, which, while unlikely to reoccur in the future, at least represent an actual combination of prices that has occurred. This approach has been used in the present study. The two price regimes selected represent wide fluctuations in product price.

Information on product prices was assembled for the period 1954/55 to 1965/66⁽²⁸⁾. These were then corrected to 1965/66 values using a Farm Costs Index⁽²⁹⁾.

(26) J.S. Holden, (1963), op. cit., p.135.

(27) D.A.R. Haslam, (1965), op. cit., p.100.

(28) Data was collected from the following sources:

(1) N.Z. Wool Commission Report "Annual Review of Sheep Industry", N.Z. Meat and Wool Boards' Economic Service for Wool prices.

(2) "Annual Review of Sheep Industry", N.Z. Meat and Wool Board's Economic Service for two-tooth ewes, two-year ewes, and fat lamb prices.

(3) Stock sale reports in the "Christchurch Press" for ewe lamb and store lamb prices.

(29) B.P. Philpott, (1963), "Cost Price Squeeze in Farming", Canterbury Chamber of Commerce Bulletin No.408, Table 1. This was extended over the 1962/63, 63/64 and 64/65 seasons, using index numbers in "Annual Review of the Sheep Industry".

Since the aim of the study was to analyse the effect of price changes in the major products, two price regimes which included wide fluctuations in product prices were selected. These were the 1956/57 and 1961/62 regimes which are shown in Table 5.8 with the prices for the 1965/66 season.

In the analysis of the effect of price changes on the programmed plans, only the more common management systems have been considered, viz., those excluding cereal cropping. Both plans 3 and 4 have been included in order that the impact of lucerne on light land be analysed further.

(a) A comparison between Fixed and Variable Plans. Because of the time factor in farming a farmer cannot rapidly alter his production patterns in response to changing product prices. Haslam⁽³⁰⁾ has calculated the "cost of inflexibility", as the difference between owner's surplus of an optimum plan under one price regime, and the owner's surplus of the same plan under a different price regime, where it is sub-optimal.

Farmers do tend, however, to modify their pattern of output in response to changing product prices, year by year, with the aim of reaching the optimum pattern of output. While these changes will in general be small, Haslam's "cost of inflexibility" may oversimplify the real situation and in fact the farmer may never reach the optimum under a given price regime.

In this study the programmed plans 3 and 4 which were obtained under 1965/66 prices have been reworked at 1956/57 and 1961/62 prices, and their owner's surplus compared. These plans have been termed "fixed", i.e. prices apart, they are in no way different from the optimum plans obtained under 1965/66 prices.

As well however, these two plans, 3 and 4, have been reprogrammed under 1956/57 and 1961/62 price regimes and the effect on the optimum combination of activities observed. These plans in which complete reallocation of resources

(30) D.A.R. Haslam, (1965) op. cit., p.105.

in response to the changed prices is allowed, are termed "variable" plans.

The results of the analysis are presented in Table 5.9. The cost of maintaining the original plan under price regime II is small, both for plans 3 and 4, where gains of only £60 and £10 are made respectively, by reprogramming. Under the price regime III, the gains are considerably higher at £190 and £250 for plans 3 and 4 respectively.

While replacements are bought in for both policies, it is not suggested that the basic flock be changed from Corriedale ewes to BL.C ewes or vice-versa in one season. The analysis is intended to indicate what basic stock policy and land utilisation is optimum under the given price regimes.

(b) The Vulnerability of Selected Plans to Price Changes. The price regimes studied have a significant effect on the relative profitability of the two plans. Under price regime I, plan 3, with a high level of lucerne is more profitable than plan 4, and this position remains unchanged under price regimes II and III. Not only is the owner's surplus higher under plan 3 for each price regime (see Table 5.9), but the variation in owner's surplus is less as prices are changed. Expressed as a percentage of owner's surplus at price regime I, owner's surplus in plan 3 varies from -50% to +12% and in plan 4 -65% to +14% at the price regimes III and II respectively.

Under price regimes I and II, plan 3 includes 1700 mixed age Corriedale ewes mated to B.L. rams and plan 4, 1520 Corriedale ewes. In plan 3 and at price regime III 1700 BL.C ewes are carried, and in plan 4, 1560 BL.C ewes. Thus except for those periods when low prices are obtained for the major products, a mixed age Corriedale ewe flock mated to Border Leicester rams appears to be the most suitable under the management systems of plans 3 and 4. Where prices are low, e.g. regime III, a policy of BL.C ewes mated to Down type rams gives the highest profit.

TABLE 5.8

Indexed Price Regimes used in the Programming Study

| Price Regime | | Unit | I (1965/66) | II (1956/57) | III (1961/62) |
|---|------------|----------------------|----------------|-----------------|------------------|
| | | | £ | £ | £ |
| <u>Livestock Products</u> | | | | | |
| Fat Lambs: | F.O.M. | 1 lamb | 2.40 | 2.90 | 2.00 |
| | F.O.F. | 1 lamb | 2.60 | 3.80 | 2.20 |
| Ewe Lambs: | Corriedale | 1 lamb | 2.75 | 3.50 | 2.00 |
| | BL.C | 1 lamb | 2.75 | 3.45 | 2.15 |
| Two-Tooth Ewes: | Corriedale | 1 ewe | 4.00 | 4.48 | 2.72 |
| | BL.C | 1 ewe | 4.00 | 4.90 | 3.05 |
| Two-Year Ewes: | Corriedale | 1 ewe | 2.70 | 3.37 | 1.67 |
| Dry ewes: | Corriedale | 1 ewe | 2.75 | 3.50 | 2.00 |
| Store Lambs: | Corriedale | net gain per lamb | 1.00 | 1.30 | 1.06 |
| | | | d. | d. | d. |
| Wool: | Corriedale | 1 lb. | 46 | 61 | 38 |
| | BL.C | 1 lb. | 41 | 47 | 37 |
| <u>Crop Products</u> | | | | | |
| | | | £ s. d. | £ s. d. | £ s. d. |
| Wheat | | 1 bu. | 13.6 | 12.5 | 13.6 |
| Malting Barley | | 1 bu. | 8.10½ | 9.6 | 8.11 |
| Feed Barley | | 1 bu. | 8.0 | 9.0 | 8.5 |
| <u>Supplementary Feed</u> ⁽³¹⁾ | | | | | |
| Feed Barley | | 1 bu. | 10.0 | 10.4 | 10.2 |
| Lucerne Hay | | 1 bale | 5.9 | 5.0 | 6.6 |
| Perennial Ryegrass Straw | | 1 bale | 1.6 | 1.0 | 2.0 |
| H.1 Ryegrass Straw | | 1 bale | 2.0 | 1.6 | 2.6 |

(31) Extremely dry conditions prevailed in the 1961/62 season and this accounted for the relatively high costs of supplementary feed over this period.

TABLE 5.9

The Effect of Price Changes on Two Management Systems

| Management Systems | Plan 3 | | | Plan 4 | | |
|--|---|------------------------|-----------|---|------------------------|-----------|
| | No Cereal Cropping - Lucerne Unrestricted | | | No Cereal Cropping - Lucerne Restricted | | |
| | I | II | III | I | II | III |
| Price Regime | | | | | | |
| 1. <u>Stock Policy</u> | Corrie.M.A. x B.L. | Corrie. M.A. x B.L. | BL.C x Dn | Corrie. M.A. x B.L. | Corrie. M.A. x B.L. | BL.C x Dn |
| 2. <u>Land Use</u> | | | | | | |
| Fixed | See TABLE 5.5 | | | | | |
| Variable - Lucerne | 168 | 300 | 280 | 50 | 50 | 50 |
| - Grass | 157 | - | 49 | 266 | 265 | 271 |
| - Turnips | 44 | 45 | 35 | 39 | 40 | 42 |
| - Rape | 21 | 45 | 35 | 39 | 40 | 28 |
| 3. <u>Stock Numbers</u> | | | | | | |
| Fixed | See TABLE 5.6 | | | | | |
| Variable - Corriedale ewes | 1,700 | 1,700 | 1,700 | 1,520 | 1,520 | 1,560 |
| - BL.C ewe lambs sold | 940 | 940 | - | 840 | 840 | - |
| - Corriedale two-tooths bought | 390 | 390 | - | 350 | 350 | - |
| - BL.C two-tooths bought | - | - | 390 | - | - | 360 |
| - Store lambs | 40 | 270 | 130 | - | - | - |
| - Dry Sheep | - | - | - | 190 | 190 | - |
| - Lambs F.O.M. | 610 | 610 | 1,720 | 550 | 550 | 1,560 |
| - Lambs F.O.F. | 330 | 330 | 430 | 290 | 290 | 390 |
| 4. <u>Total Farm Capital</u> - Fixed | 42,810 | 42,810 | 42,810 | 42,660 | 42,660 | 42,660 |
| - Variable | 42,810 | 42,950 | 42,840 | 42,660 | 42,660 | 42,760 |
| 5. <u>Programmed Net Revenue</u> - Fixed | 5,580 | 7,860 | 4,570 | 5,220 | 7,360 | 4,290 |
| - Variable | 5,580 | 7,930 | 4,760 | 5,220 | 7,360 | 4,550 |
| 6. <u>Owner's Surplus</u> - Fixed | 1,790 | 4,070 | 780 | 1,440 | 3,570 | 510 |
| - Variable | 1,790 | 4,130 | 970 | 1,440 | 3,580 | 760 |

These results indicate that of the two basic plans studies, plan 3 is superior to plan 4. It enables a considerably higher owner's surplus to be obtained under each price regime investigated. Where prices fluctuate widely (for example, from price regime II to regime III), plan 3 exhibits less variability in owner's surplus. Only at extremely low prices (i.e. regime III) is there any significant change within the management system. This change in the basic ewe policy (from Corriedale ewes mated to B.L. rams, to BL.C mated to Down type rams) is common to both plans 3 and 4.

5.7.4 The Effect of Varying the Level of Feed Requirements for the Border Leicester X Corriedale Stock Policies.

(a) The Objective. The objective of this particular study was to compare profitability of the BL.C policies with similar Corriedale policies on light land. Coop⁽³²⁾ has demonstrated and farmers have confirmed in practice that the BL.C ewe is consistently a more prolific breeder than the Corriedale ewe. This has given rise to a gradual increase in the number of BL.C ewe flocks carried on light land in recent years. Overall wool production per head is higher from the larger crossbred ewes, but this decreases from approximately 1 lb. per head more as two-tooths to approximately the same as Corriedales when five year old. Prices realised for BL.C wool are generally 2' - 3' per lb. lower than Corriedale wool, so that the total return per head from wool is approximately the same for both breeds.

The BL.C ewe however has a 15-20 lb. higher body weight than the Corriedale, and since intake of a sheep increases with body weight to the power of 0.73⁽³³⁾, the feed requirement for the BL.C ewe is higher. Hence the relative carrying capacities of the BL.C are lower than for the Corriedale. There has been considerable discussion and divergence of opinion by farmers and scientists

(32) I.E. Coop, (1957), op. cit.

(33) I.E. Coop and M.K. Hill, (1962), op. cit.

alike as to this difference, but there is little evidence to support any exact figure. As well as a higher feed requirement, the BL.C appear to have slightly higher dentitional wear, resulting in a lowering of the useful life of the ewe.

In this study of the relative profitability of the two breeds, the feed requirements of the BL.C ewes have been parametised in order to determine the break-even point at which the effect of the increased productivity of the BL.C ewes is nullified by the higher feed requirements, and consequent lower carrying capacity. At this point the returns per acre for a given stock policy are the same for both Corriedale and BL.C ewes.

(b) Methodology. In the solutions obtained in sections 5.7.2 and 5.7.3 the feed requirement for the BL.C stock policies was 5% higher than for similar Corriedale policies. These solutions were reprogrammed with progressively higher feed requirements for the BL.C stock policies. The method used is shown in Table 5.10.

TABLE 5.10

Model Allowing Exploration of Feed Requirements for Various Stock Policies

| | | P_1 Rotation | P_2 Corriedale Ewes | P_3 BL.C Ewes | P_3^1 | P_3^{11} |
|-------------------|---------|-------------------|-----------------------------|-----------------------|--------------|-----------------|
| Net Revenue | = | $-C_1$ | $+C_2$ | $+C_3$ | $+C_3$ | $+C_3$ |
| R_1 Autumn Feed | $0 \gg$ | $-r_{1.1}$ | $+r_{1.2}$ | $+r_{1.3}$ | $+r_{1.3}^1$ | $+r_{1.3}^{11}$ |
| R_2 Winter Feed | $0 \gg$ | $-r_{2.1}$ | $+r_{2.2}$ | $+r_{2.3}$ | $+r_{2.3}^1$ | $+r_{2.3}^{11}$ |

In the original programming $r_{1.3} > r_{1.2}$ by 5%. When reprogrammed $r_{1.3}$ was increased further to 10% and 15% $> r_{1.2}$ i.e. $r_{1.3}^1$ and $r_{1.3}^{11}$ respectively.

(c) Results. Of the four plans analysed in Tables 5.5-5.9, only plan 3 (no cereal cropping and lucerne unrestricted) was reprogrammed in this study. A BL.C stock policy appeared in this plan only at price regime III (1961/62 prices). While this may be surprising in view of the higher productivity of the crossbred ewe, the absence of BL.C policies in plan 3 at price regimes I and II, can be explained largely by the price differential between BL.C wool and Corriedale wool in these years. In price regime II (1956/57 prices) the prices realised for BL.C wool was some 15' per lb. less than Corriedale wool. Although large, this difference is typical of the price differences over that period. In price regime I (1965/66 prices) the price difference was 5' per lb. Over the 8 year period from 1956/57 to 1965/66 however the average price differential has only been 2' per lb. Thus the price regime III (1961/62 prices) where the difference in prices realised was only 1' per lb. is more representative of the current situation.

At price regime III plan 3 includes a BL.C mixed age ewe flock mated to Down type rams for fat lamb production (see Table 5.9). In the reprogramming, where the feed requirements for the BL.C policies were increased to 10% higher than that for Corriedales, a change in stock policy occurred. The mixed age BL.C ewe policy was completely displaced by a Corriedale policy consisting of mixed age ewes mated to BL. rams. BL.C ewe lambs were sold off as replacement stock. As would be expected, the programmed net revenue of the second solution (with BL.C ewes requiring 10% higher feed intake) was lower than in the original solution.

The results of this comparison are summarised in Table 5.11.

An earlier model constructed by the writer and used to investigate this problem has shown that as BL.C feed requirements were increased from 5% higher than Corriedales to 10% higher, the BL.C policies were progressively displaced by

Corriedale policies, until at 10% only a Corriedale policy entered the solution. (This result was confirmed in the present analysis) At the 8% level Corriedales comprised more than half of the ewe flock.

TABLE 5.11

Comparison of BL.C and Corriedale Stock Policies under Changing BL.C Feed Requirements at Price Regime III

| Basic Policy | Feed Requirement of BL.C Policies | |
|------------------------|--|--|
| | 5% > Corriedales Mixed age BL.C X Dn. | 10% > Corriedales Mixed age Corriedale X B.L. |
| No. of Ewes Carried | 1765 | 1820 |
| Lambs Sold F.O.M. | 1765 | 652 |
| Lambs Sold F.O.F. | 441 | 349 |
| Ewe Lambs Sold | - | 1001 |
| Programmed Net Revenue | £4,787 | £4,600 |

Coop⁽³⁴⁾ suggested that the BL.C ewe requires between 5 + 10% more feed than the Corriedale. The results of the present analysis suggest that while BL.C feed requirements were no more than 8% higher than for Corriedales, a BL.C policy is more profitable on a per acre basis than a similar Corriedale policy, given the particular price relationships considered.

As mentioned earlier, the wool price is the critical factor in the comparison. Should the price for BL.C wool increase relative to Corriedale wool, then BL.C policies would undoubtedly be more remunerative than similar Corriedale policies.

(34) I.E. Coop, (1962), "Experiments on Sheep Fertility at Lincoln College". Proc. 12th Lincoln Coll. Fmrs' Conf. p.52.

5.8 Conclusions

This analysis has demonstrated that for the particular farm studied, a cropping programme in conjunction with unrestricted areas of lucerne, and a stock policy involving mixed age Corriedale ewes mated to a BL ram (plan 1), generates a higher owner's surplus than any of the three other basic management systems compared and the current plan. The owner's surplus of this system is £160 higher than that of one including no cereal cropping and unrestricted lucerne (plan 3). This difference was considered by the farmer to be insufficient to ensure increased profits in the long run, because of the considerable uncertainty of yields and probable lowering of fertility, where cereal cropping is carried out on light land.

In the light of these considerations, plan 3 appeared to be the most desirable programme for this farm. This plan when compared with plan 4 (no cereal cropping and restricted lucerne), was superior both when different price regimes were assumed and when a flexible system was compared with an inflexible system.

In the original analysis restricting the area of lucerne on both cereal cropping and non cereal cropping systems, reduced owner's surplus considerably, especially under the non cropping system. When plan 3 was compared with plan 4 under widely differing price regimes, the effect of restricting the lucerne area was again quite pronounced in terms of owner's surplus.

The dominant feature of the analysis is the basic stock policy of mating mixed age Corriedale ewes to BL. rams which is common to all systems. Replacements are bought in as two-tooths. The purchase of a small number of store lambs for fattening over the autumn, appears in only one plan and dry ewes in only two plans.

Another significant feature of the programmed plans is the almost complete

absence of hay as a winter feed. (Likewise ryegrass straw is utilised as a summer supplement in only one plan.) This is contrary to district practice, and while hay (conserved in periods of surplus feed) is necessary as a reserve for use under unfavourable weather conditions, or when root crops fail, the programmed plans suggest that under average seasonal conditions greater emphasis be placed on root crops and A.S.P. for the bulk of the winter feeding.

It must be emphasised that although all four plans considered had a higher owner's surplus than the current plan this is brought about not only by a reallocation of resources, but also by an intensification of use. This is especially significant in plans 1, 2 and 3 where the level of production is considerably higher than in the current plan.

In comparing the financial performance of the four programmed plans, the question arises as to the significance or otherwise of the difference in owner's surplus. Should the difference in owner's surplus of £160 between plans 1 and 3 be considered insignificant, the results would support the contention that within the given resource structure of a particular farm, there may be several different patterns of production (or positions on the production surface) which generate comparable financial results, and that financial success is more dependant on the managerial input, and particularly the execution of a given programme⁽³⁵⁾.

When BL.C stock policies were compared with similar Corriedale policies the higher productivity of the BL.C ewe gave increased returns per acre, provided the additional feed requirement for BL.C (and consequent lower carrying capacity) was no more than approximately 8% higher than for Corriedales. Obviously the level of performance and prices used in such a comparison are critical and the results must be interpreted in the light of the coefficients used.

(35) This theory is supported by findings of the writer when researching the original data on the 43 light land farms in Stewart's (1963) survey, op. cit. There was no significant correlation between financial success in farming and any particular farming system.

5.9 An Evaluation of Linear Programming as used in this Study

In a study where the objective is to investigate the relative profitability of a wide range of different management systems, linear programming is generally the appropriate tool of analysis. Its capacity to explore a wide range of alternatives simultaneously and to produce one unique combination of activities which maximises the objective function, gives it a distinct advantage over the more conventional techniques (e.g. comparative budgeting). Although linear programming has been used in this particular study (for these and other reasons already outlined), the environment in which the case farm is situated, does reduce the effectiveness of the programmed results. Because of this it is thought necessary to look more critically at linear programming as applied to this and similar problems.

The particular farming system which has been studied, is characterised by a high degree of uncertainty in respect to both yield and price. Thus a static linear programming model which incorporates single valued expectations for the yield and price coefficients, does not accurately represent the situation facing the light land farmer. His problem, that of maximising profits in the short run, in an environment where widely fluctuating feed supplies and changing product prices are typical, is extremely complex. Hence a flexible, yet rigorous technique is required to simulate and analyse this particular problem. The inability of a static linear programming model (as used in this study) to incorporate the seasonal variation in feed supplies is undoubtedly the major weakness of this technique, when applied to problems of this particular farming type. A stochastic model in which probability distributions could be incorporated (provided accurate and adequate input data was available) would be ideally suited to the analysis of farm problems in this particular environment. (For an environment where the degree of uncertainty is less significant and where single

valued expectations for price and yield are included, the value of a static linear programming analysis is increased accordingly.)

In the present study feed provision coefficients relating only to the average (or 'normal') season have been used. Consequently the programmed results are correct for the average season, but do not necessarily indicate the most profitable enterprise combination under different feed provision situations. For example, in all the programmed plans, there is virtually a complete absence of hay as a winter feed, with emphasis on turnips and A.S.P. While this is acceptable under average seasonal conditions, it is inconceivable to suggest that the light land farmer could equate feed supply and demand over a period of years and maximise profits, without the inclusion of a hay reserve in his programme. Obviously feed will be conserved in the form of hay when a surplus exists, and utilised in those periods when the feed supply is inadequate. This situation which is not depicted in the linear programming model as used in this study, highlights the importance of the interpretation of these results and the generalisations which are made from a particular study.

This limitation, which reduces the usefulness of the programmed results in this particular study, is less significant in a more reliable farming environment, where the between year fluctuations about the normal are small. To a limited extent the problem can be overcome by reprogramming with changed input coefficients in order to simulate the actual range of uncertainty encountered. Unfortunately data on yield variability was not available for this study, however, the effect of product price changes on the selected programmes was investigated.

In this particular study, where a large number of rotations and different stock policies have been compared, the linear programming model has been used to narrow down the wide range of alternatives facing the farmer (on a profitability

basis). However, since the model does not allow the endogenous consideration of the labour requirement, management input, and risk and uncertainty, the farmer is still left with the more difficult decisions to make before committing himself to a particular course of action.

In view of this, in addition to the difficulties experienced in obtaining reliable input data and of accurately specifying the problem which faces the light land farmer, the question arises as to whether the time and effort required to construct a linear programming model is justified by the results achieved.

Provided the input coefficients relating to yield and price accurately represent the average or normal situation, the programmed results are of value to the farmer, his advisor, and the research worker. (They are considerably more valuable where additional information makes possible an exploration of variations in some of the more critical input coefficients.) In this static study, the programmed results provide the farmer with a definite guide in his search for the most acceptable combination of enterprises. The programmed solutions, compared in terms of profitability under average conditions, form the basis on which the farmer makes his final decision after considering the labour requirement, management input and, of crucial importance on light land, the risk and uncertainty associated with each solution. The linear programming model then provides a basis for more rational decision-making by the farmer. In addition it provides the advisor and research worker with the facilities to analyse the effect of changes in product prices on a given solution, or the effect of changes in technical relationships in one enterprise (e.g. the BL.C and Corriedale comparison) on a given solution.

A static linear programming model, when used for the analysis of a problem of this particular type and in this environment has considerable deficiencies and limitations. Provided these are appreciated however, and care is exercised

in the generalisations made from the particular solutions obtained, the technique does provide some useful information as an aid to more rational decision making on the farm.

5.10 Summary

In this chapter, the technique of linear programming has been used to compare alternative management systems on a light land farm in Canterbury. The model includes a wide range of alternative activities, and available resources. Some special features of the model include a feed transfer system for winter, spring and summer, a hay:barley ratio, and a comparison of BL.C and Corriedale stock activities over a range of differing feed requirements for the BL.C.

The results of the programming study have been presented and discussed in some detail. The study includes an analysis of:

- (1) The relative profitability of various management systems.
- (2) The effect of price variations on two management systems.
- (3) The effect of varying the level of feed requirement for BL.C stock policies.

The study has shown that while a reasonably intensive cereal cropping system of management generates a slightly higher owner's surplus, when fertility and the uncertainty of yields are considered, the more reliable all-sheep system incorporating an increased area of lucerne, and a mixed age Corriedale ewe flock mated to the BL. ram, appears to be the most suitable for the farm concerned. The higher productivity of the BL.C ewes is reduced by a higher feed requirement and consequent lower carrying capacity, until at 8% higher feed requirement, the productivity per acre is the same for similar Corriedale and BL.C policies. In an evaluation of linear programming as used in this analysis it is concluded that while the technique does provide useful information as an aid to decision making, the inability of the static linear programming model to incorporate

price and yield uncertainty (which are characteristic features of this particular farming environment), seriously reduces the usefulness of the programmed results.

CHAPTER VI

THE DEVELOPMENT OF LIGHT LAND

6.1 The Nature and Scope of the Problem

In the previous chapter a static linear programming model was used to demonstrate the benefits which accrue from a reallocation of resources on one well developed farm. This chapter is devoted to a study of a comprehensive development programme of one light land farm over time.

The objective is to explore the physical and economic problems associated with the development of light land in Canterbury. In part I the general principles of development are discussed (with reference to light land); this is followed in part II by a study of development over time on one case farm. The analysis is made from the individual farmer's viewpoint, and the particular effect of varying the rate of development is investigated.

The principles and techniques involved in developing light land are well established. Briefly these involve a raising of the soil fertility through the use of subterranean and white clovers and fertiliser, and the replacement of low producing pasture species with ryegrass and white clover in association with large areas of lucerne. The additional pasture production which results, enables stock numbers to be increased quite rapidly, while ensuring the build up of a fodder reserve, usually in the form of hay. The rate at which stock numbers can be increased determines very largely the level of economic success achieved in a development programme. To this end, the careful planning of a balanced programme of development is vital. As well as balancing of the feed supply and demand, subdivision, water supplies, and major capital items must be accounted for within the overall physical and financial plan.

The financial resources of the farmer determine very largely the speed at which a development programme can proceed. Finance for a development programme must be provided either out of current income or from additional borrowing. Forward planning ensures that this scarce resource is used to maximum advantage over the development period being considered. The outcome of alternative methods can be calculated with reasonable accuracy, and periods of difficulty within a given programme (e.g. feed shortages, acute liquidity problems) predicted well in advance.

In the second part of this study in which forward budgeting has been used, the first step was to construct a pre-development budget for the farm, using the same costs and prices as in the development programme. This was followed by a series of annual development budgets, based on a carefully phased physical programme, which, when adjusted according to the unfolding financial situation, produced a balanced programme of development. Taxation commitments cannot be overlooked, and indeed become an important item of expenditure towards the conclusion of a development programme. To account for this, the farmer's cash and tax position was calculated annually throughout the programme. A stable post-development budget (based on the costs and prices used in the development budgets) was drawn up to indicate the increased level of income which results from the earlier development programme. Two rates of development have been budgeted for this farm, with the post-development budgets being drawn up when the carrying capacity reached 3 ewe equivalents per acre.

A development programme of this form provides a considerable amount of useful information. As an aid in decision making this information is invaluable. The individual farmer can determine the effect of a given development programme on his income position both before and after tax, the change in condition of the property and his net capital situation after development, and the ability of the

farm to withstand fluctuations in product prices following development.

Part I of this chapter then, outlines the general principles of development, with reference to the problems of light land. Part II is devoted to a case farm study of development.

PART I

THE BASIC PRINCIPLES OF DEVELOPMENT

6.2 Introduction

Balanced development implies the use of the three factors of production, land, labour and capital over time in order that the farmer's objective function be maximised. On a light land property, development involves pasture improvement, stock increases, establishment of feed reserves, and often improvement in fencing, water supplies and essential buildings. Both labour and working capital are necessary to implement such a planned programme, so that it must be planned according to their availability.

In planning development several fundamental aspects must be considered.

6.3 The Farmer's Objectives

Before commencing any development planning, the farmer's objectives must be determined. Each individual has different objectives, and these dictate largely the type of development planned. In this discussion it is assumed that the objective is to maximise profits by an intensification and expansion in the use of the factors of production so that farm output is increased and profits lifted.

6.4 The Components of Farm Development

The basic problem in farm development is that of deciding between the wide range of alternative courses of action open to the farmer, both in the planning and execution of a programme. Ideally the criterion to use in the evaluation of these different courses of action is the marginal return to the most limiting factor of production, whether it be land, labour, or as is more general, capital. Balanced farm development then implies the application of the basic production economics principle of equi-marginal returns over time.

In the New Zealand economy, farm development generally involves the application of capital (in the form of stock, fertiliser, lime, pasture establishment, fencing, water supplies, plant and buildings), and labour to a fixed area of land over time. The basic problem confronting the farmer, is the establishment of priorities for the allocation of his scarce resources. If farm development is to be efficient, the labour and capital available should be invested first in those areas which generate the highest marginal return. Components of development in this category include for example, extra stock, although items such as pasture establishment, fertiliser, fencing and water supply produce high marginal rates but indirectly. Items of expenditure including non-essential buildings or fence renewal, and non-essential plant which have low marginal returns should be left until the end of a development programme.

Unfortunately the specification of priorities is often difficult in practice. Thus the allocation of scarce resources over time so as to achieve balanced development, and at the same time satisfy the principle of equi-marginal returns, is not always possible.

Frequently however, the success of a development programme is found to be largely dependant on the rate at which stock numbers can be increased, especially where development is being financed out of farm income. Because of this high priority is given to the financing of pasture improvement, and where necessary, the purchase of additional stock. As the central component of most development programmes in New Zealand, this particular aspect of increasing the feed supply and demand requires major consideration.

On light land the replacement of browntop dominant swards (capable of carrying only $1\frac{1}{2}$ stock units per acre) with high producing ryegrass - white clover and lucerne pastures (capable of supporting 4-6 stock units per acre),

makes possible rapid increases in the feed supply. However, the dominant characteristic of light land farming is the variable herbage production both within and between years. These fluctuations make the equation of feed supply and feed demand by stock throughout a development programme difficult.

During a development programme on light land where the aim is to increase the area of improved pasture as rapidly as is feasible, a surplus of winter feed is generally generated. The most critical time of the year, especially in the early stages of a development programme is the early spring period. Over this period the quantity of feed available is considerably less than over the winter. In order to reduce this imbalance in the feed supply, grazing may be sold over the winter or special temporary greenfeed crops grown for the early spring period. As development progresses and the area of improved pasture increases, more A.S.P. can be saved, and the deficiencies over this period reduced.

To this end the rate of development is increased when, as well as improving total pasture production, a balanced programme of feed production throughout the season is achieved.

The rate of stock increase is governed largely by the level of feed supply over the spring period. In the early stages of a development programme all available spring feed should be utilised by the most profitable stock unit, the breeding ewe. While a policy of breeding replacements is preferable on a partly or fully developed property (where adequate spring and summer feed is available), the buying in of replacements is generally more suitable in the early stages of a development programme, particularly on small properties. All available spring feed is utilised by the breeding ewe and considerable destocking over the summer is made possible, especially where two-year ewes are bought.

The breeding of hoggets in the early stages of a development programme not only reduces the capacity to destock over the late spring and summer, but also

introduces a degree of inflexibility in the stock policy. Ideally, this should be avoided, until the property is fully developed. Clearly, factors other than flexibility must be considered in relation to the replacement policy adopted. Where the risk of introducing footrot is high for example, or where large numbers of replacement stock are required, a breeding flock may be established early in the development of a property. The farmer's personal preferences and stock prices are also factors to be considered before adopting a given policy.

In the initial stages of a development programme, stock numbers are generally increased by the purchase of two-tooth or two-year ewes, at a rate consistent with the increase in available spring feed. As development progresses however, and pasture improvement is effected, a gradual change to an all breeding policy should be adopted.

Flexibility in the stock policy assists in the equation of feed supply and demand, but it is even more important during development to build and maintain an adequate fodder reserve. Periods of feed shortage which are accentuated as the stocking rates increases, may occur at irregular intervals during summer and winter. A fodder reserve in the form of hay or grain (usually barley), which can be used over these periods to supplement pasture production, is essential if the effects of periods of feed shortage are to be minimised.

During each phase of the development the physical programme and its financial elements must be reconciled with the working capital available to the farmer. Movements in the level of fixed and working capital over the planning period must be predicted. With working capital this is necessary because of the marked fluctuations which occur during development, as a result of the timing of income and expenditure. These fluctuations in working capital requirements are particularly evident during light land development. The timing of expenditure on large capital items (e.g. tractors, woolsheds) is

especially important, and necessitates planning where working capital is restricted. The anticipation of heavy expenditure on additional stock, water supplies and fencing allows more efficient planning and utilisation of the available working capital.

The level of fixed capital on a developing farm is subject to considerable increment as the value of the improvements increase. This increment often proves useful as a means of refinancing where the demands on working capital are high, or where restrictions on the level of working capital are imposed by the stock firm or bank.

The rate of development is often dependant on the level of working capital available throughout the programme, and here judicious planning, particularly in the timing of expenditure on large items, is necessary if a balanced programme is to be implemented.

In the planning of a development programme, the labour complement required during each phase must be assessed. It must be considered both in terms of the permanent and casual complements. Clearly the requirement for labour must be consistent with the availability of labour if the projected programme is to be implemented effectively. Because of a scarcity of farm labour in New Zealand, it is vital that any development programme be planned to ensure efficient utilisation of the available labour force.

As with the timing of expenditure on major capital items, the introduction of additional labour units during a development programme has a significant influence on the financial results achieved. Labour is a costly item in farm development in New Zealand. This, in association with the indivisibility characteristic of labour, makes the planning of the labour requirement an important aspect of a development programme. As the labour requirement increases during development, it becomes necessary to explore fully the economics of the

additional labour input. The use of labour substitution techniques (e.g. contract work), or low labour demanding activities (e.g. dry sheep), may be necessary to bridge the gap between one labour unit and a second. Only by careful planning is it possible to equate the available labour with the demand during a development programme.

Balanced farm development implies the use of the land, labour and capital available to the farmer in a combination which allows the farmer's objectives to be realised. The ability of a manager to make rational decisions during the planning and execution of a development programme is vital if the programme is to be successful. Many decisions have important and often far reaching effects on the subsequent results and management of a property and which, if not fully appreciated at the outset, may result in an imbalance in the development programme, inefficiency, and/or a reduced rate of achievement of the stated objectives.

6.5 Risk and Uncertainty in Development

In the planning of a development programme allowance should always be made for risk and uncertainty. This is necessary because of the economic nature of farming and of the environment in which the farmer has to operate.

The uncertainty associated with the environment is most important. In livestock farming, where the animal relies mainly on pasture production, the feed supply varies according to the season. Management systems involving the transfer of surplus feed from one season to a second, the building of feed reserves, and the manipulation of feed demand through variation in stock numbers are necessary to take account of this normal variation. In areas where wide fluctuations in seasonal feed production occur at irregular intervals increased flexibility must be incorporated within the management system. A buffer flock may be carried to utilise any excess feed, and large reserves (at least two

seasons' requirements) built up in advance of stock numbers for use in adverse seasons. It is imperative, especially in grassland farming, to make adequate allowance for environmental uncertainty during a development programme. Where this is practised, the effect of an abnormal season on the development programme, and its subsequent management, is minimised.

Financial uncertainty is always present during a development programme. Product price fluctuations which are characteristic of most farming types, are particularly serious in sheep farming because of the limited diversification possible. While the net worth of the farmer increases as development proceeds, working capital is often still restricting after several years of development. In a period of credit restrictions, bank or stock firm pressure may have a detrimental effect on development. This can be eased by refinancing, and converting a portion of the farmer's increased net worth into working capital. Where adequate working capital is available, the farmer can use this as a buffer against fluctuating product prices during development.

In addition to financial and environmental uncertainty, there is a degree of risk associated with the application of new technology. The committing of scarce resources during development to an untried technique, carries a high element of risk. Should the technique prove unsuccessful, the financial loss may be high, especially where capital has been invested in a non-recoverable form (e.g. fertiliser).

Incorrect planning, or assessment of the personal factor may introduce an element of personal risk. In planning the development programme, the farmer's managerial and physical ability must be assessed, and reviewed according to the changing situations during the development. Care must be taken in the planning to minimise environmental and financial uncertainty and technical risk, and so remove any unnecessary strain on the personal element involved. As the programme

evolves it is essential to adjust the labour force according to the physical load imposed on the farmer, and make allowance for the additional management input necessary.

The success of a development programme is very dependant on the personal factor involved. To this end a continual review of the labour and management input required is necessary if the risk of ill-health and consequent curtailment of the development is to be minimised.

6.6 Financial Control in Development

In order to ensure that balanced development is achieved, stringent physical and financial control of the planned programme is necessary. This is particularly the case where rapid rates of development or credit restrictions impose strains on the supply of working capital. In this dynamic state, the programme must be controlled to ensure that adequate capital is available at strategic points during the programme, if it is to be maintained in balance. Where insufficient capital is available to buy extra stock for example, and so exploit earlier investment in fertiliser and seed, imbalance may occur and profitability and rate of development may be reduced quite significantly.

Taxation commitments assessed under the P.A.Y.E. system, require that provisional tax be paid in September based on an estimate of income for the year (using the previous year's assessment), followed by terminal tax in March of the following year. This can cause the farmer considerable financial embarrassment towards the conclusion of a development programme. During development, taxation commitments are low; immediately development expenditure is reduced however, the taxable income increases markedly, with the result that the taxation commitments in that first year may impose severe strains on the farmer's working capital position. A comprehensive financial appraisal of the development programme and a forecast of its taxation implications is vital, especially towards the completion

of a development programme.

The problem of imbalance during development can often be alleviated by sound financial control. A system involving comparison of the actual income and expenditure with the predicted budget position at regular intervals (e.g. monthly) during the year, allows firm control of the farm's financial structure. The development plans and budgets used in this control must be reviewed and adjusted periodically in response to the changing economic, human and technical environment. Only when this is carried out carefully does the control of a given development plan become an effective and integral part of the development process.

In summary, balanced development requires that the physical and financial components of a development programme be carefully related over time, so that some specified objectives are realised. Capital and labour requirements must be consistent with the available supplies, while the equation of feed demand and supply is central to the whole programme, especially under light land farming conditions. The development plan must be designed to include sufficient flexibility in the physical and financial plan to allow for the element of risk and uncertainty inherent in such a plan. Increased rates and efficiency of development are facilitated by sound financial control during the development programme and in financial planning and organisation following development.

PART II

A CASE FARM STUDY OF DEVELOPMENT

6.7 Budgeting Methodology

The technique of forward budgeting used in this case farm study requires that a pre-development budget be drawn up to indicate the costs and returns of the property prior to the initiation of development. The costs and prices in this budget should be representative of those which are likely to occur during the development programme. For each year of the programme, a carefully phased physical plan, involving a complete land utilisation, stock and feed reconciliation is drawn up in detail. A series of annual budgets based on this programme is then compiled, using the same costs and prices as in the pre-development budget. (The coefficients used in these plans and annual budgets are detailed in Appendix E.) Both the cash and tax situations are calculated so as to ensure that the proposed development is in fact possible. This is especially important where development is financed out of income or where finance for development is restrictive. When the development programme has been completed a post-development budget is drawn up based on the stable physical programme for the farm at that point, and indicating the new level of income which results from the development.

A development programme outlined in this manner provides the farmer, his adviser, and the lending institution with valuable information. The individual farmer can evaluate the effect of the programme on his income both pre- and post-taxation, the effect on management input required, and the changes in his net capital position. As an aid in decision making, this technique is invaluable to the farm adviser, particularly where alternative methods of development are possible. It is of interest to lending institutions who are generally more favourably inclined towards financing development when the development plan is

carefully budgeted out, and the likely return calculated.

The forward budgeting approach to farm development has several important advantages not found in the analysis of past development. The one main advantage is that in planning the development forward over time, a more rational allocation of the scarce resources is possible. This applies particularly to the timing of expenditure on large capital items. The development programme may be parametised, in order to analyse the effect of different factors such as prices, yields and technology on the result. Forward analysis of this type is of greatest value when it enables the farmer or adviser to choose between different development programmes involving differing rates and methods of development. Because the particular set of circumstances which existed while past development was achieved may never occur again, the analysis of this development may be of limited value as a guide for future planning. In discussing forward planning Frengley et. al.⁽¹⁾ state:

"In general the future cannot be predicted with great accuracy, but forward budgeting ... makes the best use of the available information ... and provides a year to year basis of budgeting control for farm advisers and credit institutions".

6.8 The Case Farm Pre-Development

6.8.1 The Property. The property of 950 acres is situated on the north bank of the Selwyn river at Norwood, 22 miles south from Christchurch.

The climate is typical of the Canterbury Plains (see section 2.3 for details), with an annual rainfall of 22-26". The farm is exposed to the north-west but pine plantations provide some shelter from the south-west. Little growth occurs over the winter and special consideration is given to the provision of high quality feed over the critical late July-August period. Lucerne hay and turnips provide the bulk of the early winter supplementary feeding, followed by

(1) G.A.G. Frengley, R.H.B. Tonkin, R.W.M. Johnson, (1966), "Programming Farm Development." Ag. Econ. Res. Unit. Lincoln College, Publication No.35,p.4.

A.S.P. prior to and during lambing in early August.

Although most of the farm appeared to have been cultivated at some earlier period, the greater part of the property had gradually reverted to browntop (Agrostis tenuis), sweet vernal (Anthoxanthum odoratum), danthonia (Danthonia pilosa), and other low producing species. The cover in the year immediately preceding the initiation of development consisted of:

50 acres Turnips
 60 acres Greenfeed oats
 50 acres Lucerne
 40 acres New Grass
 130 acres Improved pastures (fair quality only)
 610 acres Browntop dominant pasture
10 acres House and Yards, trees etc.
950 acres

This property is divided by a road into two blocks of 710 acres, and 240 acres. The house and main buildings are located on the smaller block. Soils on the property are classified as Eyre stony silt loam, and respond well to phosphate and lime. The property is approximately 220' a.s.l.

Apart from the main homestead (8 yr. old brick), and married couple's cottage (40 yr. old wooden), which were both in good condition, the improvements on the property were of a low standard. The farm was inadequately subdivided into only 18 paddocks. Fences, mainly gorse, were of low standard. The water supply consisted of two County water races, which watered 12 of the 18 paddocks. This system as it existed, was inadequate for further subdivision. The woolshed, (without electricity), and sheepyards, were poorly situated (being some 1½ miles from the house and other buildings) and were in poor repair, necessitating considerable expenditure on improvement. Other farm buildings were of only

fair condition. There were no hay barns on the property.

Access within the property is facilitated by two County roads, one of which divides the farm, and the second which bounds the larger of the two blocks.

6.8.2 The Farmer. The farmer is 40 years old, with four children, two of whom are at boarding school. He purchased this property after having successfully farmed two smaller heavy land units on his own account in another district. Realising the potential of this light land property, the farmer immediately decided to embark on a substantial programme of development, with the object of increasing stock numbers as rapidly as was possible, taking into account personal and financial considerations.

The farmer is an energetic, conscientious and skilled farm manager.

6.8.3 Production and Income. In the winter prior to the commencement of development, the property carried 1400 light-weight Corriedale ewes, and 20 Southdown rams, or approximately 1.3 stock units per acre. Ewe numbers had been constant for several years, and production from the flock was not high. The lambing percentage was estimated at 100% (survival to sale), and wool weights at 8 lbs. per ewe. Replacements for the flock were bought in as two-tooths and cull ewes were sold to the freezing works.

Winter feed consisted of turnips and greenfeed oats, with a minimum amount of hay being fed out. The low stocking rate enabled ewes and lambs to be carried through the spring period without the need for special lambing greenfeeds or saved pasture.

Rape was sown with the new grass to provide fattening feed for lambs in the early autumn.

The gross farm income in the pre-development budget was estimated at £5,630 or £6.0 per acre. This was made up of 60% sheep sales (£3.6/acre), and 40% wool (or £2.4/acre).

The taxable gross income left after meeting the £4,735 non taxable expenditure was only £895. When wages of management, life insurance and tax were allowed for, there was no surplus available for farm development or disposition off the farm. This critical situation was attributable to two factors. Firstly, high interest commitments, and secondly, extremely low output, as a result of the low carrying capacity.

6.8.4 Capital Position. One of the first and most important factors to be assessed when contemplating development on a farm is the farmer's capital position. In this case study, the farmer's position prior to development can be summarised as follows:-

ASSETS

| | | |
|--------------------|---------------|---------|
| Stock | 3,640 | |
| Plant | 2,655 | |
| Land and Buildings | <u>41,475</u> | £47,770 |

LIABILITIES

| | | |
|-------------------------------|-----------------------------|----------------|
| Current: Stock Firm Overdraft | 3,500 | |
| Long Term: Private Loan | 1,085 | |
| 1st Mortgage | <u>22,000</u> <u>23,085</u> | £26,585 |
| ∴ Farmer's Net Worth = | | <u>£21,185</u> |

The assets are valued at fair sale value as at 30 May, 1964. Current liabilities consist of an unsecured stock firm overdraft which is used basically as a source of working capital. A first mortgage of £22,000 is secured on the land. This five year flat mortgage at an interest rate of 6% is due for repayment or renewal in 1969.

6.9 The Development Programmes

Two development programmes have been drawn up to illustrate the effect on the rate of development when finance is available firstly out of income, and secondly, through refinancing. While programme A is financed out of income, working capital is available throughout the season from the stock firm, with a maximum overdraft of £5,000 at any one period. No mortgage principle repayments are made during the development period.

Programme B includes a reorganisation of the development capital with the raising of a medium term development loan of £5,000. This not only increases the cash available for development, but also reduces the reliance on the stock firm with its associated risks.

In both development programmes, the carrying capacity is increased from 1.3 stock units per acre to 3.0 stock units per acre.

6.9.1 Development out of Income : Programme A.

(a) Finance: The rates of development are likely to be considerably reduced where finance is restricted to the cash surplus available (after paying mortgage interest, taxes, and wages of management) plus the normal seasonal finance from the stock firm. This is the situation in the present programme. Prior to the commencement of this development programme, the estimated annual cash surplus was zero. This was a reflection basically of the low carrying capacity, and was insufficient to initiate any development. The initial problem in the development programme then was to increase turnover through a balanced programme of increased stock numbers following improved feed provision. The rate of progress of this programme was determined initially by the stock firm finance available. While gross output was increased by over £2,500 by the third year, the overdraft level had also increased to a point approaching the upper limit set by the stock firm.

(b) Pasture Improvement: The aim in the pasture improvement programme is to replace the browntop dominant sward with high producing pastures. Two methods are used. Firstly, where subterranean clover is present, the area is surface cultivated during the summer and followed by the sowing of $\frac{1}{2}$ bushel of Italian ryegrass. This has a two-fold effect of firstly reducing the browntop, and secondly of providing a high quality greenfeed suitable for the late winter. This paddock is then sown to turnips for the following winter after which it is either sown to new lucerne in the spring or summer-fallowed to new grass. The second method used is especially effective where a heavy turf of browntop exists and/or there is no subterranean clover. This consists of deep ploughing and rolling the area in the winter, thus effectively smothering the browntop. Turnips are sown on this for the following winter and a second crop of turnips sown one year later. Following this treatment the area is sown to new lucerne in the spring or new grass after a summer fallow. Where effective control is achieved with one crop of turnips, the lucerne may be sown in the spring following the turnip crop.

These two simple rotations allow the establishment of high producing lucerne or ryegrass - white clover pastures (capable of supporting 4-6 stock units per acre), in place of the low producing browntop swards supporting only $1\frac{1}{2}$ stock units per acre.

(c) Topdressing: New grass pastures are sown down with two cwt. per acre each autumn. Lucerne is sown with two cwt. of reverted superphosphate, and topdressed at two cwt. in the spring. The turnip crops preceding lucerne and new grass are sown with one ton of lime per acre while both the new grass and lucerne are sown down with a second ton. This is necessary in view of the low pH level found under the browntop swards.

(d) Stock: The immediate requirement at the initiation of the development is to increase stock numbers as rapidly as finance will allow. This has to be achieved while maintaining a high degree of flexibility in the stock feed requirement especially over the critical spring period.

For the first three years of development two-year ewes are purchased as replacements for the ewe flock after which replacements are bred. Throughout the development programme, a buffer flock consisting of cull ewes is maintained and sold with lambs 'all-counted' in the spring when the feed situation dictates. This, along with the practice of wintering some wether hoggets in the early stages of development makes full use of the surplus winter feed while at the same time incorporating considerable flexibility into the stock feed requirements.

The replacement policy involves the mating of half the ewe flock to Corriedale rams and half the flock to fat lamb sires. On a property of this size, it is preferable to breed replacements even though flexibility is reduced by the carrying of ewe hoggets over the spring-summer period. In addition, this particular replacement policy involves the carrying of large numbers of Corriedale wether lambs which are generally slower in fattening than Down-cross lambs.

The carrying capacity rises from 1.3 to 3.0 stock units per acre during the development programme. At this level it would be stocked at a rate similar to other properties of comparable size in the area ⁽²⁾. Wool output rises from 12 lbs. per acre pre-development to 33 lbs. per acre in the final year and gross output per acre from £6 to £12.10.0.

(e) Feed Reserves: Because the property is so vulnerable to both droughts and winter storms, feed reserves have been increased throughout the development programme. This reserve consisting of lucerne hay is sufficient for at least two full years' requirements.

(2) See Table 3.5.

(f) Fencing and Water Supply: As the larger areas are cultivated out of browntop they are subdivided into 25-30 acre paddocks and fenced accordingly, at a cost of approximately £3 per chain for materials.

The water supply has been extended also with the installation of a new loop race in the second year.

(g) Plant: A new roller is purchased in the second year and a new tractor in the seventh year. An allowance of £200 is set aside in the eighth year for replacement of cultivation plant.

(h) Buildings and Yards: The general standard of buildings and yards is poor and inadequate for increased stock numbers. A new hay shed is built in the third year. New sheep yards are built and relocated in the fourth year and the shearing shed replaced in the sixth and seventh years of the development.

(i) Labour: Over the first two years of development, the only permanent labour on the farm is the owner. A small amount of casual labour is employed in addition to shearers. In the third year a youth is employed for six months at a cost of £260, while in the fourth year a single man is employed for the whole year. Advantage is taken of the cottage on the property in the fifth year, and a married couple employed. Wages of management pre-development consist of £1,200 plus £100 life insurance and £50 taxation. This is increased until at the end of development, an allowance of £1,600 for wages of management, £150 life insurance, and £1,415 tax has been assessed.

(j) Costs and Prices: The costs and prices used in the study are based on the average prices ruling for the three years up to and including 1964.

Fat lambs are sold at £2. 5.0 and cull ewes at £1. Two-year ewes are bought in at £2.10.0, and wether hoggets, bought in at 37/6 are sold at 55/- in the late winter.

The wool price used is 48 pence per lb. net of all handling charges.

(k) Summary of Development: The physical components of the development programme as detailed above are summarised in the following table. The movement in overdraft during the development is also shown.

TABLE 6.1

The Physical Components of Development and Movement
in Overdraft during Development - Plan A

| Year | Annual Increase in Stock Units Carried | | Hay Reserves (bales) | Area of Improved Pasture Sown | | Topdressing | | Plant and Build- ings | Over- draft Sit- uation * |
|--|---|------------------|----------------------------|--|--------------|----------------|---------------|--------------------------------|------------------------------------|
| | Winter (S.U.) | Spring (S.U.) | | Luc. (ac) | N.G. (ac) | Fert. (ton) | Lime (ton) | | |
| | | | | | | | | b.f. | £3,350 |
| 1 | 250 | - | 1,000 | 48 | 30 | 28 | 110 | | £4,705 |
| 2 | 170 | 220 | 1,000 | 64 | 30 | 33 | 154 | Roller | 4,690 |
| 3 | 170 | 170 | 1,500 | - | 60 | 38 | 100 | Hayshed | 4,655 |
| 4 | 170 | 120 | 2,000 | 40 | - | 45 | 138 | Sheep- yards | 4,470 |
| 5 | 40 | 100 | 3,760 | 50 | - | 45 | 186 | - | 4,370 |
| 6 | 210 | 60 | 4,920 | - | 72 | 48 | 204 | Woolshed | 4,360 |
| 7 | 60 | 160 | 4,980 | 84 | - | 62 | 154 | " | 4,305 |
| 8 | 100 | 180 | 6,040 | - | 70 | 70 | 247 | Tractor | 4,255 |
| 9 | 250 | 220 | 6,400 | 89 | - | 68 | 213 | Cult. Plant | 3,225 |
| 10 | 250 | 230 | 7,360 | - | 82 | 77 | 238 | - | 1,255 |
| INCREASE: 1670 1460 375 344 | | | | | | | | | |

* As at end of each financial year.

6.9.2 Development Using External Finance: Programme B

(a) Finance: With additional finance available for development in programme B, a considerably increased rate of development is made possible. The additional

finance consists of a medium term development loan of £5,000 which is uplifted over the first three years of the development in three instalments of £2,000, £2,000 and £1,000 respectively. Used mainly for the purchase of additional stock, this loan makes possible a rapid increase in output, while maintaining the stock firm overdraft at a reasonable level, and within the specified limit (£5,000 in this case). Whereas programme A relies on the cash surplus available from the year's farming operations to initiate and maintain the development, the injection of outside capital early in programme B permits pasture renewal and stock numbers to increase at a faster rate and consequently output rises rapidly. This enables the carrying capacity to be lifted from 1.3 to 3.0 stock units per acre in six years compared with the ten years necessary under plan A.

In recent years medium term development finance has been more readily available, especially from Government Departments. Frequently the greatest need for development finance of this type is found where the equity is low or security poor, but potential high, as with the farm under study. Government Departments concerned with lending for development are now taking into account such development potential and acting accordingly. This type of development finance permits the planning of development on a sound basis, and releases the short term stock firm finance for the seasonal requirements.

(b) Pasture Improvement and Topdressing: The techniques of pasture improvement employed in programme B are similar to those detailed for programme A, but because of the less restrictive financial situation, the area improved each year is increased. In programme A, 50 acres are cultivated out of browntop each year compared with 100 acres in programme B. The topdressing rate is common to both programmes.

(c) Stock: With emphasis on increasing stock numbers as rapidly as possible two-year ewes are purchased as replacements over the first five years

of the development. Initially 650 are purchased, however, by the fifth year the number bought in is reduced to 130, as the number of replacements bred on the property increases. Corriedale ewes are mated to Corriedale rams for the first time in the second year of the development. At the conclusion of the development the replacement policy involves the mating of one half of the ewe flock to Corriedale rams and one half to fat lamb sires.

As in programme A, a buffer flock of between 250 and 350 cull ewes is maintained, throughout the development. In addition, 150-200 wether hoggets are wintered over the first four years of the development, thus effectively utilising the surplus winter feed, while at the same time, allowing considerable flexibility in the feed requirement.

The carrying capacity of the property rises from 1.3 stock units per acre to 3.0 stock units per acre over the six years of the development. Wool production per acre increases from 12 lbs. per acre pre-development to 31 lbs. per acre. and gross output from £6 to £12 per acre.

(d) Feed Reserves: As in programme A, large feed reserves in the form of lucerne hay (and sufficient for two years' requirements) are maintained throughout the development.

(e) Fencing and Water Supply: In the second year the water supply is extended through an additional loop race.

Further paddock subdivision and replacement of existing fences is carried out during the development.

(f) Plant: Additions to existing plant are made in the second year when a new roller is purchased, in the fifth year when a new tractor is purchased, and in the sixth year with the allowance of £200 for cultivation plant.

(g) Building and Yards: Allowance is made in the second year of development for the replacement of the sheep yards and the erection of a haybarn. In the third and fourth years the shearing shed is replaced.

(h) Labour: Because of the increased rate of development in programme B, it is necessary to employ a married couple from the first year of development. In addition casual labour is employed at shearing and a portion of the hay carted by contract. As in programme A the allowance for wages of management is increased from £1,200 pre-development to £1,600 in the fifth year. Life insurance also increases from £100 pre-development to £150 in the fifth year, while tax payments at £50 pre-development rise to £1170 by the end of development.

(i) Costs and Prices: The costs and prices used in programme B are similar to those previously outlined for programme A (see section 6.9.1 (j)).

(j) Summary: The following table summarises the more important physical components of this development programme. The movement in overdraft is also shown.

TABLE 6.2

The Physical Components of Development and Movement
in Overdraft during Development - Plan B

| Year | Annual Increase in Stock Units Carried | | Hay Reserves (bales) | Area of Improved Pasture Sown Luc. N.G. (ac.) (ac.) | | Topdressing Fert. Lime (ton) (ton) | | Plant and Buildings | Overdraft Situation * |
|--------------------|---|------------------|----------------------------|--|-----|--|-----|---------------------------------|--------------------------|
| | Winter (S.U.) | Spring (S.U.) | | | | | | | |
| 1 | 220 | - | 400 | 48 | 60 | 30 | 172 | - | b.f. £3,350 4,495 |
| 2 | 414 | 383 | 1400 | 64 | 32 | 40 | 92 | Roller Haybarn Sheepyards | 3,985 |
| 3 | 304 | 428 | 2200 | 60 | 60 | 53 | 200 | Woolshed | 4,190 |
| 4 | 190 | 174 | 3300 | 80 | 44 | 53 | 194 | " | 4,605 |
| 5 | 343 | 266 | 3770 | 70 | 60 | 70 | 130 | Tractor | 4,030 |
| 6 | 143 | 279 | 3880 | - | 82 | 77 | 219 | Cult. Plant | 2,505 |
| <hr/> | | | | | | | | | |
| TOTAL INCREASE: | 1614 | 1530 | | 322 | 338 | | | | |

* As at the end of each financial year.

6.10 Results

In order that the two development programmes A and B (as described above), may be compared, the general physical and financial results obtained are presented in Figures 6.1, 6.2 and 6.3.

6.10.1 Physical. As the area of improved pasture and lucerne is increased, stock numbers carried are increased also at a consistent rate, up to a level of three stock units per acre⁽³⁾ (as shown in Figure 6.1). The composition of the flock changes considerably during development, from 1400 mixed age ewes initially to 2,750 ewes and 650 ewe hoggets at the conclusion of the development programmes.

Figure 6.2, illustrates the increased physical output in terms of total wool produced and fat lambs sold. Wool output, reflecting the increased carrying capacity, increases from 11,300 lbs. pre-development to 30,800 lbs. and 28,000 lbs. respectively for development programmes A and B. Fat lamb production increases from 1,400 pre-development (100% of lambs bred) to an estimated 2,200 and 2,100 at the end of programmes A and B respectively. At this level approximately 78% of all lambs reared are sold as fats, the remaining being carried over as replacement stock. It will be noted that fat lamb output increases at first, then temporarily decreases in the third and fourth years for programmes B and A respectively. This reduction in lamb sales is a result of the initiation of a breeding policy in the second and third year of the respective programmes, and the consequent withholding of stock in the following years⁽⁴⁾.

6.10.2 Financial. In Figure 6.3 the main financial results for both programmes are shown. These are summarised in Table 6.3 and 6.4 and detailed in Appendix E.5. Gross output is shown to rise rapidly from £5,630 pre-development

(3) Total stock units carried during the spring, divided by the effective area of the farm.

(4) A more accurate reflection of change in stock output would be given by a 'net stock production' figure in which wool and livestock sold, and stock retained for replacement purposes were allowed for.

to an estimated £11,690 under programme B, and, after a period of consolidation while a breeding policy is initiated, to £11,805 under programme A. In both programmes gross output is expected to level off at approximately £11,800 or £12.2 per acre. At this level lamb sales constitute 43% income, wool 53% and cull stock 4%. Gross farm expenditure⁽⁵⁾ rises throughout the development from £4,280 to an estimated £6,840 in programme A and £6,875 in programme B. In programme A expenses reach a peak in the eighth year, however, in programme B, where development is more rapid, expenditure is at a maximum in the first year, largely as a result of high expenditure on additional stock. Although expenditure has increased throughout the development, gross output has increased at an even faster rate. Before development was initiated the level of expenditure was approximately 75% that of output. At the conclusion of development, the level of expenditure was reduced, relatively, to 63% of gross output.

In both programmes the farmer's taxable surplus is depressed as development proceeds, but after the first year recovers again and in the case of programme B increases at a rapid rate up to an estimated £4,585. In programme A, where finance is restrictive, the increase in taxable surplus is slow until the seventh year when development expenditure decreases relative to output. It is estimated that the taxable surplus will stabilise at approximately £4,600 for both programmes A and B.

The maximum overdraft permitted under programme A is £5,000. At the end of the first year and as a consequence of considerable development expenditure, the level of overdraft reaches £4,705, which is in effect, at the limit when fluctuations within the year are allowed for. From this point on, the overdraft reduces slowly until in the eighth year, following a considerable rise in gross

(5) In addition to all cash expenditure, gross farm expenditure includes capital development items.

TABLE 6.3

Summary of Financial Results of Development Programme A

| Year: | Pre- Dev. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Post- Dev. * |
|---|--------------|--------|-------|-------|-------|-------|-------|-------|-------|--------|--------|-----------------|
| (1) Cash Income | 5,630 | 6,620 | 7,340 | 8,255 | 7,885 | 8,230 | 8,665 | 8,680 | 9,535 | 10,635 | 11,485 | 11,805 |
| (2) Gross Farm Expend. Plus Depreciation | 4,280 | 6,625 | 6,005 | 6,775 | 6,200 | 6,550 | 6,900 | 6,820 | 7,495 | 7,190 | 6,775 | 6,840 320 |
| Wages of Management | 1,200 | 1,200 | 1,200 | 1,200 | 1,200 | 1,300 | 1,400 | 1,500 | 1,600 | 1,600 | 1,600 | 1,600 |
| Life Insurance | 100 | 100 | 100 | 100 | 100 | 125 | 125 | 125 | 150 | 150 | 150 | 150 |
| (3) ∴ TOTAL EXPENSES | 5,580 | 7,925 | 7,305 | 8,075 | 7,500 | 7,975 | 8,425 | 8,445 | 9,245 | 8,940 | 8,525 | 8,910 |
| (4) Surplus Pre-Tax | +50 | -1,305 | +35 | +180 | +385 | +255 | +240 | +235 | +290 | +1,695 | +2,960 | +2895 +289 |
| (5) ∴ Net Add'n Cost Dev. | - | -1,355 | +15 | +130 | +335 | +205 | +190 | +185 | +240 | +1645 | +2910 | +2845 +284 |
| Plus Tax | 50 | 50 | 20 | 145 | 200 | 155 | 230 | 180 | 240 | 665 | 990 | 1415 150 |
| (6) ∴ TOTAL EXP. | 5,630 | 7,975 | 7,325 | 8,220 | 7,700 | 8,130 | 8,655 | 8,625 | 9,485 | 9,605 | 9,515 | 10,325 1041 |
| (7) Surplus Post-Tax | - | -1355 | +15 | +35 | +185 | +100 | +10 | +55 | +50 | +1030 | +1970 | +1480 +139 |
| (8) ∴ Net Add'n Cost Dev. | - | -1355 | +15 | +35 | +185 | +100 | +10 | +55 | +50 | +1030 | +1970 | +1480 |

* The figures in this column indicate the stable post-development situation, after making adjustment for the taxation assessed on the post-development taxable surplus.

TABLE 6.4

Summary of Financial Results of Development Programme B

| Year: | Pre-Dev. | 1 | 2 | 3 | 4 | 5 | 6 | Post-Dev. * | |
|---------------------------|----------|--------|--------|--------|-------|--------|--------|-------------|--------|
| (1) Cash Income | 5,630 | 6,990 | 8,400 | 8,480 | 9,470 | 10,415 | 11,075 | 11,690 | |
| (2) Gross Farm Expend. | 4,280 | 8,785 | 8,490 | 8,130 | 8,240 | 7,895 | 7,010 | 6,875 | |
| Plus Depreciation | | | | | | | | 230 | |
| Wages of Management | 1,200 | 1,200 | 1,300 | 1,400 | 1,500 | 1,600 | 1,600 | 1,600 | |
| Life Insurance | 100 | 100 | 100 | 125 | 125 | 150 | 150 | 150 | |
| (3) ∴ TOTAL EXPENSES | 5,580 | 10,085 | 9,890 | 9,655 | 9,865 | 9,645 | 8,760 | 8,855 | |
| (4) Surplus Pre-Tax | +50 | -3,095 | -1,490 | -1,175 | -395 | +770 | +2,315 | +2,835 | 2,835 |
| (5) ∴ Net Add'n Cost Dev. | - | -3,145 | -1,540 | -1,225 | -445 | +720 | +2,265 | +2,785 | 2,785 |
| Plus Tax | 50 | 50 | - | 30 | 20 | 195 | 790 | 1,170 | 1,460 |
| (6) ∴ TOTAL EXPENSES | 5,630 | 10,135 | 9,890 | 9,685 | 9,885 | 9,840 | 9,550 | 10,025 | 10,315 |
| (7) Surplus Post-Tax | - | -3,145 | -1,490 | -1,205 | -415 | +575 | +1,525 | +1,665 | +1,375 |
| (8) ∴ Net Add'n Cost Dev. | - | -3,145 | -1,490 | -1,205 | -415 | +575 | +1,525 | +1,665 | |

* The figures in this column indicate the stable post-development situation after making adjustments for the taxation assessed on the post-development taxable surplus.

Fig. 6.1

STOCKING RATE PER ACRE
DURING DEVELOPMENT

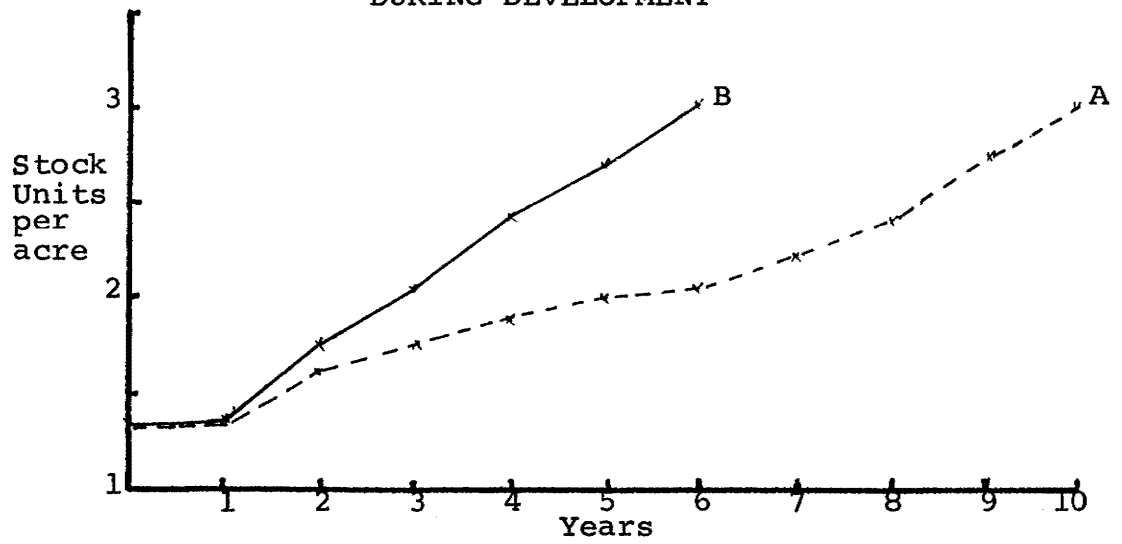


Fig. 6.2

FAT LAMB AND WOOL PRODUCTION
DURING DEVELOPMENT

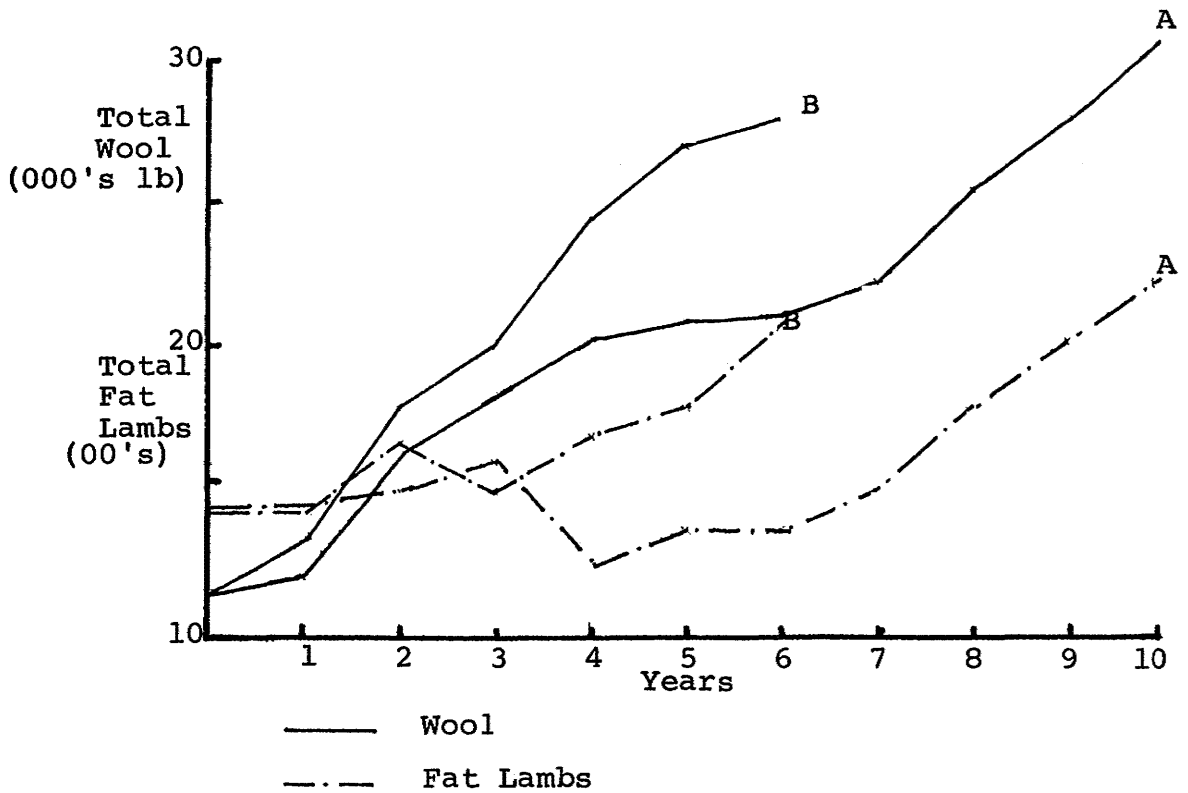
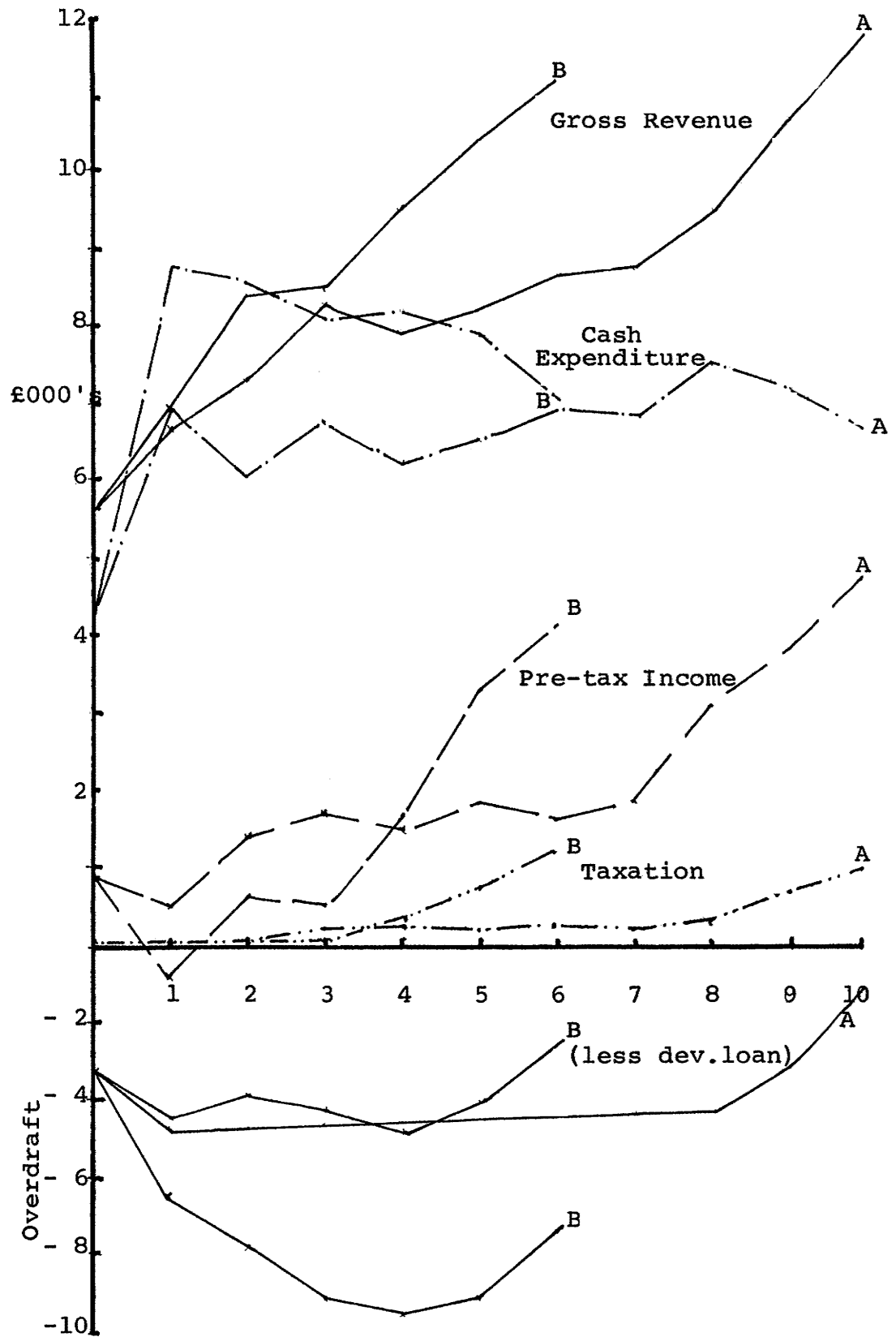


Fig. 6.3

FINANCIAL PERFORMANCE DURING DEVELOPMENT



output and lower expenditure, the overdraft is reduced markedly to a deficit of only £1,255 at the end of development.

In programme B, where development is more rapid, a portion of development costs is diverted from the stock firm overdraft, to a medium term development loan (from the State Advances Corporation). This loan of £5,000 is uplifted over the first three years, and has the effect of maintaining the stock firm overdraft within the specified maximum of £5,000. The overdraft is increased initially, reaching a peak of £4,605 in the fourth year. From then on, however, the overdraft is reduced to a level of £2,505 in the final year. Figure 6.3 also indicates the level of overdraft which would result if the development as planned in programme B was financed completely on current account from the stock firm. This emphasises the increased demand placed on finance when development is rapid. Without the injection of additional development finance (e.g. from the State Advances Corporation or other suitable source), the rate of development achieved in programme B would not be possible under the restricted lending policy imposed by the stock firm, in this particular case. Taxation assessed each year, is in both programmes less than £500 per year, until the fifth year of programme B, when £790 is assessed, and the eighth year for programme A, when £665 is assessed. In both programmes taxation is estimated to stabilise at approximately £1,500 per annum. While this level of taxation represents a large increase over the pre-development figure, the farmer's real post-tax income (i.e. when wages of management, life insurance plus the stabilised post-tax surplus are summed) has increased by approximately £1,800 under each programme.

6.10.3 Change in Equity. Following the completion of a development programme on an unimproved property, after-tax income increases, but in addition considerable capital appreciation occurs. This gives rise to an increased net worth, which from the farmer's viewpoint, is often of greater importance than the change in after-tax income.

An assessment of the farmer's net worth position following development is shown in the following balance sheets⁽⁶⁾.

Programme A (as at completion of development).

ASSETS:

| | | |
|--------------------|---------------|---------|
| Stock | 8,765 | |
| Plant | 1,000 | |
| Land and Buildings | <u>57,000</u> | £66,765 |

less LIABILITIES:

| | | |
|-------------------------|---------------|----------------|
| Current : Overdraft | 1,355 | |
| Long Term: Private Loan | 1,090 | |
| 1st Mortgage | <u>22,000</u> | <u>£24,445</u> |
| ∴ Net Worth = | | <u>£42,320</u> |

Programme B (as at the completion of development).

ASSETS:

| | | |
|--------------------|---------------|---------|
| Stock | 8,575 | |
| Plant | 1,300 | |
| Land and Buildings | <u>57,000</u> | £66,875 |

less LIABILITIES:

| | | |
|-------------------------|---------------|----------------|
| Current: Overdraft | 2,505 | |
| Development Loan | 5,000 | |
| Long Term: Private Loan | 1,090 | |
| 1st Mortgage | <u>22,000</u> | <u>£30,595</u> |
| ∴ Net Worth = | | <u>£36,280</u> |

These values used in the balance sheets were assessed in consultation with valuers who were familiar with the area. They represent the estimated total value of the property at the completion of the respective development programmes,

(6) Land, Buildings and stock are included at "fair sale value" and plant at its depreciated value.

based on present day values. A guide to this value is given by the paddock value (capital value less buildings and other improvements) per stock unit, which when based on comparable sales in this particular area, is approximately £18 per stock unit⁽⁷⁾.

In programme A the farmer's net worth rises by £21,135 from £21,185 to £42,320 or at £2,114 per year over the ten years of the development. In programme B, where external finance is injected, the net worth rises by £15,095 to £36,280 or £2,517 per year. Furthermore in the remaining four years under programme B the development loan could be completely paid off.

This higher net worth may be used to refinance further development (or expansion) or made available as cash should the property be sold.

6.11 Analysis of Results

6.11.1 The Individual Farmer's Viewpoint. The analysis of this development is from the farmer's viewpoint only. In the evaluation of the profitability of a development programme the farmer is basically concerned with:

- (a) The additional income following development.
- (b) The appreciation in his net worth position as a result of development.

While these two aspects are the prime consideration, the farmer is also vitally interested in the additional capital input necessary during the development, and the time which lapses before the increased income is available. It must be emphasised that since the analysis is from the farmer's viewpoint, living allowances, taxation and non-farm cash commitments must be incorporated in the budgets and included in the analysis.

(7) It will be noted that the paddock value per stock unit in the pre-development balance sheet is approximately £26. This value is inflated by the willingness of buyers to pay for farm potential. As stock numbers are increased and the farm potential is realised, the paddock value per stock unit falls.

6.11.2 The Techniques of Analysis Used. It is necessary to incorporate the dimension of time in the analysis of a development programme, where a stream of investment of additional capital occurs over a period of years, and where additional income occurs at some point in the future. Because of time preference for the present in relation to the future, compound interest procedures must be introduced to relate future returns to the present. The techniques by which this is achieved and the criterion used to measure the profitability of development have been the subject of considerable discussion in recent years⁽⁸⁾.

In this study, the two main measures used in the analysis of the development are 'Present Value' and 'Internal Rate of Return', both of which have been discussed in detail elsewhere⁽⁹⁾. They are outlined briefly here.

(a) Internal Rate of Return: This technique is an attempt to use compound interest techniques to determine a true rate of return on capital. The internal rate of return has been defined by Ward⁽¹⁰⁾ as being:

"... in effect Keynes' marginal efficiency of capital for a particular type of capital asset⁽¹¹⁾. Adopting Keynes' original definition, we may define the internal rate of return in relation to farm development as that rate of discount which would make the present value of a series of net returns expected from the improvement just equal to the supply price".

Clearly in farm development, the supply price is not a lump cost, but a series of costs incurred over the development period. The internal rate of return may be thought of as measuring over a period of years, the rate of interest

(8) F.A. & V. Lutz, (1961), "The Theory of Investment of the Firm". Princeton, New York.

E.L. Grant and W.G. Ireson, (1960), "Principles of Engineering Economy". The Ronald Press, New York.

P.N. Karmel, (1959), "The Marginal Efficiency of Capital". The Economic Record, 35.72.

(9) J.T. Ward, (1964a), "Investment Analyses for Farm Improvement". Ag.Econ.Res.Unit, Lincoln College, Pub. No.9.

J.S. Holden, (1965), "The Profitability of Hill Country Development". Ag. Econ.Res.Unit, Lincoln College, Pub. No.14.

(10) J.T. Ward, (1964a), op.cit., p.28.

which could be paid on capital if it were all borrowed from a lending institution. As such it may be called the "solving rate" of interest for a set of investment returns.

The internal rate of return (r) may be determined from the following equation:

$$0 = \sum_{j=1}^k x \cdot \frac{1}{(1+r)^j} + \frac{x^1}{r} \cdot \frac{1}{(1+r)}$$

Where x = difference between the post-tax surplus during development and the pre-development surplus.

x^1 = the increase in post-tax surplus following development.

j = 1, 2, k being the length of the development period.

r = internal rate of return for which the equation is being solved.

This equation may be solved either by a trial and error method where successive values of r are used until an approximate value is obtained, from which the final figure can be interpolated, or by using a computer programme. The technique has some computational problems in that the equations which must be solved for r are polynomial functions with as many roots as there are years in the development programme. Where, however, a series of negatives is followed by a series of positives in the equation (as in the present programmes), a single real rate of return is produced. A conceptual weakness in this technique is in the assumption that the internal rate of return applies to both negative as well as positive values in the equation, implying that the farmer borrows at the rate of interest which the development yields. In fact this would occur only occasionally. The real advantage of this technique is that it is flexible. It can take into account any number of years, incorporate periodic profits and overdrafts and the concepts of net income and capital appreciation can be allowed for.

(11) J.M. Keynes, "The General Theory of Employment Interest and Money".
McMillan, 1936, p.135.

(b) Present Worth: The present worth of a development programme is defined as the sum of the annual discounted additional surpluses (positive or negative), with the post-development surplus capitalised at the discount rate, then discounted and added to that sum.

The present worth of the development (P.W.) is given by:

$$P.W. = \sum_{j=1} \frac{x}{(1+r)^j} + \left(\frac{x^1}{r} \cdot \frac{1}{(1+r)^k} \right)$$

Where x = The additional surplus during development.

x^1 = additional surplus following development.

j = 1,2, k being the length of the development period.

r = discount rate.

The rate of discount which is chosen will depend on several factors, including the current borrowing and lending rates, the farmer's rate of time preference, and the degree of risk and uncertainty associated with the development programme. It may well be that the farmer's rate of time preference is considerably higher than has been accepted in the past.

The value obtained for the P.W. may be interpreted as follows:

Should a sum of money equal to the P.W. be invested such that the interest rate is equal to the discount rate, the annuity so earned would be equal to the average surplus generated by the development programme and the post-development surplus. This concept of evaluating development projects has been discussed in detail by Ward⁽¹²⁾ and used by Holden in the analysis of hill country development (using historic data)⁽¹³⁾.

(12) J.T. Ward, (1964b), "The Systematic Evaluation of Development Projects". Ag.Econ.Res.Unit, Lincoln College, Pub. No.1.

J.T. Ward, (1964a), op. cit.

(13) J.S. Holden, (1965), op. cit.

The present worth concept complies with all the theoretical requirements for a measure of project evaluation⁽¹⁴⁾, but, like the internal rate of return, has the practical weakness in that it is very sensitive to the pre-development and post-development surpluses, and care must be exercised in the calculation of these surpluses.

A more convenient and easily comprehended method of expressing the value of a development project to a farmer, is to convert the present worths of the development programmes to an average annual annuity which may be drawn off in equal amounts annually, over a given period of years. Grant and Ireson⁽¹⁵⁾ show that the annual annuity is related to the present worth of the programme by the following expression:

$$R = P.W. \left(\frac{i(1+i)^n}{(1+i)^n - 1} \right)$$

Where R = the end of year receipt in a uniform series, continuing for the coming n periods, the entire series being equivalent to P.W. at an interest rate i.

In calculating the present worths of the two development programmes A and B, the post-development surplus has been capitalised into perpetuity. In calculating R however, the time period n, over which the uniform series of receipts are made, must be specified. The expression:

$$\frac{i(1+i)^n}{(1+i)^n - 1}$$

is known as the capital recovery factor and which when multiplied by the present worth of a given investment (P.W.) gives R. In the present analysis, the time period n, over which the uniform series of receipts are made is estimated at 25 years. The farmer, aged 40, could expect an average annual annuity as a result of the development, to accrue for an additional 25 years,

(14) *ibid.*, p.4.

(15) E.L. Grant and W.G. Ireson, (1964), *op. cit.*, pp. 44-45.

this being the time horizon over which the farmer is assumed to have an active interest in the property.

The setting out of the above procedures can be made quite clear by the following example in which the present worths and annual annuities are calculated on the post-tax surpluses of programmes A and B at an interest rate of 6%.

The present worth of the post-development surplus (x^1), is estimated by compounding the sum into perpetuity and discounting at 6% over the ten and six year development periods for programmes A and B respectively, viz.

| | <u>Programme A</u> | <u>Programme B</u> |
|--|-----------------------------|------------------------|
| Post-tax post-development surplus (x^1)= (see final figure row 7, Tables 6.3 and 6.4) | £ 1,395 | £ 1,375 |
| Compounded into perpetuity and discounted @ 6% to equal the <u>present worth of the post-development surplus</u> | = £23,241 = +£12,978 | £22,908 £16,149 |

These present worths above are represented by the second term in the present worth equation on page 208.

The actual development surpluses or x_j 's (see first ten figures in row 7, Tables 6.3 and 6.4) when discounted at 6% over the development period, give the present worth of this stream, viz.

| <u>Programme A</u> | <u>Programme B</u> |
|---|---|
| $x_1 = -1355 \times \frac{1}{(0.06)} = -1278.3$ | $x_1 = -3145 \times \frac{1}{(0.06)} = -2966.9$ |
| $x_2 = +15 \times \frac{1}{(0.06)^2} = +13.3$ | $x_2 = -1490 \times \frac{1}{(0.06)^2} = -1326.1$ |
| $x_3 = +35 \times \frac{1}{(0.06)^3} = +29.4$ | $x_3 = -1205 \times \frac{1}{(0.06)^3} = -1011.7$ |
| $x_4 = +185 \times \frac{1}{(0.06)^4} = +146.5$ | $x_4 = -415 \times \frac{1}{(0.06)^4} = -328.7$ |

| <u>Programme A</u> | | | <u>Programme B</u> | | |
|-------------------------|-----------|--|--------------------------|-----------|---------------------------------------|
| x_5 | $= +100$ | $\times \frac{1}{(0.06)^5} = +74.7$ | x_5 | $= +575$ | $\times \frac{1}{(0.06)^5} = +429.7$ |
| x_6 | $= +10$ | $\times \frac{1}{(0.06)^6} = +7.1$ | x_6 | $= +1525$ | $\times \frac{1}{(0.06)^6} = +1075.0$ |
| x_7 | $= +55$ | $\times \frac{1}{(0.06)^7} = +36.6$ | ∴ present worth = -£4129 | | |
| x_8 | $= +50$ | $\times \frac{1}{(0.06)^8} = +31.4$ | | | |
| x_9 | $= +1030$ | $\times \frac{1}{(0.06)^9} = +609.7$ | | | |
| x_{10} | $= +1970$ | $\times \frac{1}{(0.06)^{10}} = +1100.0$ | | | |
| ∴ present worth = +£770 | | | | | |

These present worths are represented by the first term in the equation on page 208.

The analysis has revealed that although the present worth of the post-development surplus for programme B is greater than for programme A, the present worth of the actual development surpluses is greater for programme A. When summed, these give the total present worth of each programme, i.e.

| | <u>Programme A</u> | <u>Programme B</u> |
|-------------------------------|--------------------|--------------------|
| P.W. post-development surplus | 12,978 | 16,149 |
| P.W. development surpluses | <u>770</u> | <u>- 4,129</u> |
| ∴ <u>Total present worth</u> | = £13,748 | £12,020 |

When converted to annual annuities for comparison, the total present worths give:

| | <u>Programme A</u> | <u>Programme B</u> |
|----------------|--------------------|--------------------|
| Annual Annuity | £1,076 | £940 |

Thus bringing the post-development surplus forward four years (i.e. development in 6 years under programme B compared with 10 years under programme A), favours

programme B, but the cost of financing this rapid development more than counteracts the gain so that the total present worth of both elements favours programme A.

6.11.3 Discussion of Analysis. An analysis of the results obtained from development programmes A and B, is given in Table 6.5. Since the individual farmer is interested in the growth of his personal income and net worth as a result of development, the analysis has been made with this in view.

TABLE 6.5
Summary of Analysis of Results Obtained in Development
Programmes A and B

| | A | B |
|--|---------|---------|
| 1. <u>Present Worth</u> | | |
| Pre-tax @ 6% | £28,743 | £29,137 |
| 8% | £18,231 | £18,324 |
| 10% | £12,343 | £12,090 |
| Post-tax @ 6% | £13,748 | £12,020 |
| 8% | £ 8,561 | £ 6,678 |
| 10% | £ 5,627 | £ 3,700 |
| 2. <u>Annuity</u> | | |
| Pre-tax @ 6% | £ 2,249 | £ 2,279 |
| 8% | £ 1,708 | £ 1,717 |
| 10% | £ 1,360 | £ 1,332 |
| Post-tax @ 6% | £ 1,076 | £ 940 |
| 8% | £ 802 | £ 626 |
| 10% | £ 620 | £ 408 |
| 3. <u>Internal Rate of Return</u> | | |
| based on income - Pre-tax | 34.1% | 22.9% |
| Post-tax | 24.6% | 15.0% |
| based on increase in net worth - Pre-tax | 43.0% | 28.1% |
| Post-tax | 39.6% | 26.9% |
| 4. Annual Increase in net worth | £ 2,114 | £2,517 |

After ten years of development as outlined in programme A, the

farmer's post-tax surplus (i.e. after allowing for wages of management, life insurance and tax) rises by £1,395 as a direct result of the development⁽¹⁶⁾. This development which is financed entirely out of income is relatively slow, but because of this, the income sacrificed during development is extremely low. In fact, only in the first year of development does total expenditure exceed income.

Development under programme B, which is completed in six years, gives rise to an increase in post-tax surplus of £1,375⁽¹⁷⁾. Because of the increased rate of development, expenditure is high in the initial years, and actually exceeds income in the first four years of the six year development.

The present worth of the development programmes A and B, are shown in Table 6.5. These have been calculated at three rates of discount in order to explore the effect of increased rates of time preference on the present value of the two programmes. The present worth of the development programmes before tax is assessed, is approximately £29,000, £18,000, and £12,000 at discount rates 6, 8 and 10% respectively for both programmes A and B. Taxation must be allowed for however where the farmer's viewpoint is being considered and this has a considerable impact on the present worths of the respective programmes. At each rate of discount, the present worth of programme A is greater than that of programme B, the difference increasing with the rate of discount.

This result can be explained by dissecting the total present worth into its two component parts (i.e. the present worth of the development surpluses, and the present worth of the post-development surplus), as detailed in section 6.11.2(b).

-
- (16) The farmer's real post-tax income, however, is increased by £1,845 (after allowing for the increase in wages of management and life insurance) as a result of development under Programme A.
- (17) Similarly, the real post-tax income resulting from development under Programme B is £1,825.

The higher present worth of programme A can be attributed largely to the nature of the stream of development surpluses. The level of output on the property pre-development was low, so that substantial increases in output are achieved as stock numbers increase in programme A. As a consequence the actual development surpluses (or x_j 's), used in the calculation of the present worths, are dominantly positive in development programme A. This is in contrast to programme B where the development surpluses are dominantly negative as a result of the high level of expenditure in the initial years. When discounting procedures are applied to these two development streams, their nature ensures that the present worth of programme A is significantly higher than that of programme B.

The second part of the total present worth is the present worth of the post-development surplus. Since both development programmes achieve the same level of physical development it is reasonable to expect the post-development surpluses to stabilise at an approximately similar figure. In programme A, the post-development surplus (or x^1) is £1,395, and in programme B, £1,375. Clearly, when these sums are compounded into perpetuity and then discounted over the development period, programme B, in which development is most rapid generates the higher present worth.

Thus when only the present worth of the post-development surplus is considered, programme B (in which the increased surplus is available after only six years) is superior to programme A. However the cost of achieving this result (in terms of the discounted development surpluses), more than counteracts the advantage gained, so that the total present worth for programme A is greater than for programme B at each level of discount under the post-tax situation.

If the present worths discussed above are converted to a series of uniform end-of-year receipts which can be secured for the investment of a sum

equal to the present worths, the development programmes can be more easily comprehended and critically compared. These series of uniform receipts (or annual annuities), shown in Table 6.5 indicate the annual yield which would accrue from the present worths of the two development programmes, where the present worths are based on different rates of time preference. When calculated on the pre-tax net worth, insignificant differences are found between the two programmes however when the post-tax present worths are converted to annual annuities, the uniform receipt is greater for programme A at each rate of time preference, and as with the present worth, the difference increases with the rate of time preference. This, in effect, means that the present worth of a given development programme to the farmer decreases as his rate of time preference increases. As the difference between post-tax present worth of each programme increases with increasing rates of discount, so also does the annual annuity (where the present worth is invested at an interest rate equal to the discount rate). The present worth of programme A at a discount rate of 6% is equal to £13,748 and programme B, at £12,020. These amounts invested at 6% (and repaid over 25 years) yield £1,076 and £940 per year respectively. At a discount rate of 10% the reduced present worths, when invested yield £620 and £408 per year for the two programmes. The difference between the two programmes at the higher rate of interest then is significantly greater than that at the lower rates.

The internal rate of return for programmes A and B are also shown in Table 6.5. These are based on the stream of development surpluses, and the post-development surplus, which have already been discussed in relation to the present worths. In programme A the large increase in post-development income, in conjunction with the small sacrifice in income during development, is equal to an interest return of 24.6% per annum. With a post-development surplus comparable to programme A, but with greater expenditure during development, the increase in

surplus in programme B is equivalent to an interest return of 15.0% per annum.

Taxation has a considerable impact on the rate of return earned, reducing this by approximately 10% and 8% for programmes A and B respectively.

In addition to the increased post-tax surplus generated by the development of the property, the capital value of the property has increased considerably, as a result of the improvements carried out during development. This increase in value following development is reflected in the higher net worth of the farmer. Should this increased net worth (amounting to £21,135 in programme A) be released by selling or refinancing, it would be equivalent to a rate of savings interest of 39.6% on income forgone in programme A. In programme B, where the net worth increases by £15,095, it is equivalent to a rate of savings interest of 26.9%.

6.12.4 Conclusions. In this case farm study of light land development, two development programmes have been constructed and the results analysed from the farmer's viewpoint. While the planning horizons assumed in this study are considerably longer than this particular farmer operates on (possibly three to four years only), this increase is justified by the need to illustrate the effect of rate of development on profitability. Both development programmes achieve a prescribed level of physical development, so that the comparison here is restricted to the financial results obtained only.

The results of the analysis of the two development programmes outlined in Table 6.5 show the development of light land to be highly profitable from the farmer's viewpoint. Programme A, in which development is financed out of income, and is spread over a ten year period, is significantly more profitable than programme B, where the rate of development is increased through the use of additional external finance. The internal rates of return, present worths, and annual annuities, which have been calculated to indicate profitability, all show programme A to be superior to programme B, particularly under the post-tax

situation and where the present worths and annual annuities are calculated at high rates of discount. These results contradict those obtained on South Island hill country development by Gow⁽¹⁸⁾. He has suggested that in general, the most profitable development occurred where the rate of development was greatest. The results obtained in the present study can be attributed to the nature of the streams of additional costs and returns which occurred during the development phase of the programme. The low level of output prior to development and the slow rate of development in programme A has meant that in all but the initial year of the development programme, the additional returns exceed the additional costs (as contrasted with programme B, where in four of the six years of development, costs exceed returns). Thus the stream of surpluses from which the internal rate of returns and present worths are calculated, is dominantly positive for programme A, so that with the capitalisation of similar post-development surpluses in both programmes A and B, the nature of the equation ensures that programme A appears more profitable in this analysis. The increase in net worth of the farmer under programme A is some £6,000 higher than under programme B, basically because of the refinancing and increased debt in programme B.

In drawing conclusions from the above results, several other critical factors must be considered first. The farmer's post-tax income following development is approximately the same for both development programmes yet programme A, which appears more profitable when subjected to the rigorous profitability analysis above, requires that the farmer wait an additional four years for this increased income, as compared with programme B. In addition, the length of the development programme introduces an element of uncertainty with respect to the terms of trade facing the particular farmer. The likelihood of this adversely affecting the programmed results is increased where the planning period is longer. Programme B, in which faster development appears less profitable under the above analysis,

(18) N.G. Gow; pers. comm.

enables the farmer to obtain this increased income earlier than under programme A. Where the farmer has this level of achievement as a goal, he may favour programme B. This programme also gives the highest annual increase in net worth (although the total increase over the development period is considerably less than in programme A). The management input required is likely to be increased and there is a higher degree of financial risk associated with this development which although more rapid, places the farmer in a more financially vulnerable position in the initial years.

Should the farmer be interested in realising on his net worth following development, he may consider taking the lower net worth after only six years in order to reinvest this sum elsewhere, rather than wait the extra four years for the increased net worth under programme A. If the farmer attaches importance to the rapid achievement of this goal, or increased income is given high priority (i.e. the farmer has a rate of time preference well in excess of 10%), then programme B may be chosen. Where the planning period is longer however, and increased income is less significant, programme A, which generates a higher internal rate of return, net worth, and annual annuity, is to be preferred.

To summarise the results: where the farmer's rate of time preference is high or the farmer places a high value on the rapid achievement of this level of development and/or the planning period is short and external finance is available for injection into the development, programme B, with its associated risks, should be chosen. Conversely, where the planning period is longer, and the farmer's rate of time preference for increased income is lower, programme A with its significantly higher profitability and higher net worth increase, is preferable from the farmer's viewpoint.

It is worthy of note that when the two development programmes, A and B, are compared over a similar time period different conclusions can be drawn. From the farmer's viewpoint, the increase in net worth, and available

income which results from an extension of programme B over four extra years makes it more attractive than programme A. If after six years under programme B, development ceases, but the stable post-tax surplus of £1,375 is generated for an additional four years (and assuming the farmer takes out wages of management only), this accumulates to a surplus of £5,500. This sum is sufficient to repay the £5,000 development loan, and increases the farmer's net worth under programme B (after ten years) to a position comparable with that of programme A. Now after six years of development under programme A, the farmer receives £1,400 as wages of management and £125 for life insurance, compared with £1,600 and £150 under programme B, so that at this point the farmer's available income is highest under programme B.

Thus after ten years, the farmer's net worth is similar under the two programmes, but under programme B following the heavy initial injection of capital, the farmer's available income increases more rapidly, so that overall programme B appears the more attractive. When the two programmes are compared over ten years, using the present worth concept, the mechanics of the discounting formula ensure that the present worth of programme A (post-tax) remains considerably higher than that of programme B. (In fact it is the same as in the original analysis.) Thus the conclusions drawn depend largely on the basis of analysis. In this case study, the nature of the streams of surpluses is such that when discounted, the present worth of programme B is less than that of programme A, yet in terms of income and net worth over ten years, programme B appears more attractive.

The results of this analysis demonstrate the high degree of sensitivity of the present worth and internal rate of return techniques to the nature of the development surpluses and the length of the development period. The need for careful interpretation of results obtained using these techniques is obvious, and, if correct conclusions are to be drawn from these studies, a close appraisal of

the farmer's actual income and net worth situation should be made. A technique for evaluating development which could take account of the time factor, but exhibit lower sensitivity to the length of the development, and the nature of the development and post-development surpluses, would be of considerably greater value to those applying these techniques in practice.

6.13 Summary

In this temporal study, the physical and economic problems associated with the development of light land have been explored in detail. The basic principles of balanced development have been reviewed in Part I.

The particular case study examined in Part II involves the development of one light land farm, from a carrying capacity of 1.3 stock units per acre to 3 stock units per acre. Following a description of the property pre-development, the farmer, and his capital position, the physical and financial components of two alternative development programmes have been detailed. These two development programmes have been projected forward at different rates, to illustrate the effect of speed of development on profitability. In programme A, development is financed out of income and is spread over ten years, while in programme B, refinancing allows an injection of additional capital which enables the prescribed level of development to be reached in only six years. Both achieve comparable levels of physical development, so that the comparison here is confined to the relative profitability of the two programmes, from the farmer's viewpoint.

The development of this particular property results in a considerable improvement in the level of financial performance attained. The increased carrying capacity generates a gross output of £11,800 at the completion of development, as compared with £5,630 before development. Expenditure increases, especially in the initial years of programme B, however taxable surplus shows a significant increase from £895 before development to approximately £4,600

post-development, with the post-tax surplus increasing by approximately £2,200. The farmer's net worth in the property also increases as a direct result of development, from 44% of the market value of the property prior to development, to 63% after the implementation of programme A or 54% after the implementation of programme B.

Two alternative development programmes were analysed and compared using the internal rate of return, and present worth techniques. Although the subject of considerable controversy in recent years, these concepts are of value when used in the present context, namely, in comparing the profitability of two alternative programmes on a given property. When the present worth of a given development programme is converted to a uniform series of annual annuities, the value of the development to the farmer is more easily comprehended.

An analysis of the results, using these criteria, indicates that programme A where development is financed out of income, and occurs over a ten year period, is more profitable (as measured by internal rate of return, present worths and annual annuities) than programme B where external finance is injected to increase the rate of development. This is particularly evident where the present worth and annual annuities are compared under the post-tax situation and at high rates of discount.

Clearly other factors must be considered before drawing valid conclusions from such results. For example, the additional risks and management input associated with rapid development, and the time which lapses before the additional income is received should be considered. It is concluded that where the planning horizon is relatively long and the farmer's rate of time preference for additional income is not high, then slower development of programme A with its higher net worth gain and profitability is preferable, however, should the farmer's planning horizon be short and/or the desire for additional income high, then programme

B, with its associated risks might be chosen instead. (When both programmes are compared over a ten year period, programme B appears the most attractive in terms of net worth and income.)

CHAPTER VII

CONCLUSIONS

The standard of farming and the level of productivity of the light land of Canterbury has increased remarkably since early settlement, but particularly so in the last two decades. This increase has been achieved in a farming environment which, being characterised by a high degree of yield and price uncertainty, tends to inhibit rapid development and expansion of output. It is significant that the greatest increase in output has been achieved in recent years. Part of this increase can undoubtedly be attributed to a greater understanding and appreciation of the physical and economic problem inherent in the environment. This situation is the result of a comprehensive research programme which, in conjunction with the observations of leading farmers in the area, has led to the evolution of reliable techniques and principles of light land farming.

As the intensity of production increases however, the influence of environmental uncertainty becomes more significant. The problems of equating feed supply and demand at the higher stocking rates are more pronounced. With income derived almost completely from wool and fat lambs (and with little opportunity to diversify), the farmer's net profit fluctuates widely as a result of price changes. Thus at high levels of output, the light land farmer is particularly vulnerable to environmental influence. This situation can be partially overcome by prudent planning and the incorporation of a high degree of flexibility in the particular management system adopted. The choice between alternative management systems however becomes not only more difficult as the intensity of production increases, but of greater influence in relation to income.

In an examination of survey data on the management of light land farms

in Mid-Canterbury it was clear that there was little consistency in their production patterns. While this result was surprising, it may reflect the high level of uncertainty under which farmers must operate, particularly at the higher levels of output. This result may also indicate that the actual patterns of production are of less importance than the managerial skill with which they are implemented.

The first part of this study then is devoted to an investigation of the relative profitability of a range of the production alternatives open to the light land farmer, using an already developed case farm as a basis for this comparison. A wide range of different rotations and stock activities were considered using linear programming as the technique of analysis. The results have revealed that subject to the assumptions made about technical relationships and prices, several different systems of farming are profitable on this particular property. In the four basic systems of farming compared, the increased profits were due not only to a reallocation of resources, but also to an intensification in their use. The most profitable system of farming exposed by the analysis was one which included a high level of cereal cropping. When fertility and the uncertainty of yields were considered however, the more reliable all sheep system incorporating an increased area of lucerne and a mixed age Corriedale flock mated to the B.L. ram appeared to be more acceptable on this particular farm. When subject to wide price changes, this plan maintained its comparative advantage. The effect of restricting the area of lucerne entering the programmed plans was quite marked particularly under the non-cereal cropping systems.

Relatively high levels of physical production are being attained on light land, where modern techniques are being used. This study has shown that these high levels of production may be achieved by different methods, but that one which places emphasis on turnips for winter feed, large areas of lucerne for

high spring carrying capacity, and incorporates a flexible stock policy, is likely to give consistently higher returns.

It is generally conceded that from the nation's viewpoint, the marginal cost of obtaining increased agricultural production is lowest where this production is generated on existing farms. A considerable area of the already occupied farm land in New Zealand is capable of increased physical output; the light land of Canterbury being no exception.

This situation prompted the writer to investigate the physical and financial aspects of light land development in Canterbury. The second section of this thesis then is devoted to a case study of light land development in which the carrying capacity of one case farm was lifted from 1.3 to 3.0 stock units per acre. This study was made from the farmer's viewpoint only, so that the result does not indicate the relative profitability, from the nation's viewpoint, of light land development as compared with, for example, irrigation development. What this study was intended to pinpoint was the sacrifices and likely rewards the farmer could expect when a substantial programme of development was embarked on. An exploration of the impact of rate of development on profitability was made. In the first instance the development programme was financed from income over a 10 year period, while secondly, after refinancing and the injection of additional finance, an increased rate of development was made possible.

As a result of the development, the farmer's real post-tax income was increased by a substantial amount (£1,800). The profitability of this development as measured by internal rate of return was shown to be highest where the development was relatively slow and financed out of income. (Similar conclusions were drawn when the net worth and annual annuities were calculated.) However, the farmer's rate of time preference could have an important influence on this result. Although the profitability was higher under slow development, the extra time which lapses

before the additional income or net worth is available and the farmer's sense of achievement in obtaining an increased level of output more rapidly, may reduce this advantage considerably.

The general nature and problems of light land development have been examined in this study. Subject to the assumptions made about prices and technical relationships, the development of this light land property appears to be extremely profitable from the farmer's viewpoint. It is suggested that where the level of physical production pre-development is higher than in this case study, the rate of return is likely to be lower.

In the case farm used for the linear programming study, a carrying capacity of four stock units per acre is achieved. Leading farmers on the light land, however, are attaining levels of the order of $5\frac{1}{2}$ stock units per acre. This increase in physical output has been the avenue through which light land farmers have maintained income in recent years, in the face of falling product prices and a steadily rising cost structure.

In this study of the management of light land considerable importance has been attached to the review of research into the problems of light land farming. It is this research which has led to the vastly increased productivity of the area in recent years. At the present level of technical knowledge, considerable potential still exists on large areas of light land. If it can be demonstrated to farmers that the exploitation of this potential is profitable from their viewpoint (as in the development study in Chapter VI), and farmers accept this challenge, then the productivity of the area as a whole could be increased quite significantly.

Just as research has contributed to the increased productivity of the light land in the past, there is good reason to believe that continuing research will add further to the present level of technical knowledge. As higher producing and

more persistent pasture species are introduced in association with a deeper understanding of the soil deficiencies, the ability to carry higher numbers of stock per acre is increased further. An area of research which has not been fully explored to date, but which is of vital importance, particularly at higher stocking rates, is the efficiency of conversion of the increased quantity of herbage grown into saleable products. Even if only small increases in the level of herbage grown per acre are made, a more efficient utilisation of this production could lead to substantial increases in carrying capacity and productivity. It is conceivable that 7 or even 8 stock units per acre might be carried on well developed and efficiently managed light land in the foreseeable future.

While the average income has been maintained by expanding output, the problem of fluctuations in this income between years remains unsolved. (This problem arises because of the heavy reliance on only two major products, wool and fat lamb.) With improved management over recent years, the fertility of the light land has been increased. It is envisaged that the continuation of this building process will lead eventually to a diversification of output on the light land. Research into the economics of alternative crops should be investigated continually to ensure that optimum use is being made of the available resources. The yield at which crops such as wheat and peas compete favourably with wool and fat lambs should be demonstrated. The possibility of introducing new enterprises as alternatives to the more conventional products should not be overlooked. For example lucerne, grown on contract for conversion to a concentrate meal, may be one avenue for expansion.

If some diversification is possible and a farming system can be demonstrated which achieves a higher degree of income stability then, in the writer's opinion, light land farmers would exploit more fully the potential of the area. It would seem unlikely that further investment and expansion of irrigation schemes on the

light land of Canterbury would be justified on economic grounds at the present level of technical knowledge⁽¹⁾. With the potential for further intensification of production on the light land, the profitability of a dry-land system of farming light land (as compared with irrigation), may be even higher in the future.

(1) The writer is engaged in a full cost-benefit study of a proposed irrigation scheme on the light land in Mid-Canterbury.

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APPENDIX ASOIL PROFILE DESCRIPTIONS AND CHEMICAL ANALYSISA.1 Lismore Stony Silt Loam

282,790 acres.

A profile east of Ashburton is:

6" very dark greyish brown friable silt loam with stones.

10" dark yellowish brown friable stony silt loam.

14" olive brown compact sandy gravels on firm greywacke gravels.

Chemical Analysis:-

| pH | P | Cit. Sol | C% | N% | C/N | C.E.C. | T.E.B. | B.S. |
|------|-----|----------|-----|------|-----|--------|--------|------|
| | | mg.% | | | | m.e.% | m.e.% | % |
| 0-5" | 5.3 | 4 | 2.8 | 0.23 | 12 | 14.3 | 4.7 | 33 |

A.2 Lismore very Stony Silt Loam

165,200 acres.

A profile near Burnham is:

6" dark brown very stony friable silt loam.

11" yellow brown very stony firm fine sandy loam.

8" pale olive brown sandy compact gravels, on sandy gravels.

Chemical Analysis:-

| pH | P | Cit. Sol | C% | N% | C/N | C.E.C. | T.E.B. | B.S. |
|------|-----|----------|-----|------|-----|--------|--------|------|
| | | mg.% | | | | m.e.% | m.e.% | % |
| 0-5" | 5.6 | 2 | 2.4 | 0.18 | 13 | 10.4 | 3.3 | 32 |

A.3 Chertsey Shallow Silt Loam

51,000 acres.

A profile near Aylesbury is:

7" dark greyish brown friable silt loam.

11" yellowish brown firm silt loam on greywacke gravels.

Chemical Analysis:-

| pH | P Cit. Sol | C% | N% | C/N | C.E.C. | T.E.B. | B.S. |
|----------|------------|-----|------|-----|--------|--------|------|
| | mg.% | | | | m.e.% | m.e.% | % |
| 0-6" 5.5 | 5 | 2.4 | 0.18 | 13 | 12.1 | 4 | 33 |

A.4 Eyre Stony Silt Loam

62,130 acres.

A profile near Bankside is:

5" brown firm silt loam.

12" yellowish brown friable very gravelly silt loam, on yellowish brown compact sands and gravels.

Chemical Analysis:-

| pH | P Cit. Sol | C% | N% | C/N | C.E.C. | T.E.B. | B.S. |
|----------|------------|-----|------|-----|--------|--------|------|
| | mg.% | | | | m.e.% | m.e.% | % |
| 0-5" 5.5 | 3 | 3.2 | 0.23 | 14 | 12.8 | 4.9 | 38 |

APPENDIX B

DETAILS OF TABLES 3.3 & 3.4

B.1 Owner's Surplus

(Total farm income) - (farm working expenses and interest on total farm capital).

B.2 Percentage Small Seeds

Percentage of the effective area of the farm in small seeds.

B.3 Percentage Crop

Percentage of the effective area of the farm in crop.

B.4 Percentage Lucerne

Percentage of the effective area of the farm in lucerne.

B.5 Stock Units per Available Acre

The following units were used to calculate farm carrying capacities:

| | | | |
|-----------------|---|--|------------|
| Romney Ewes | - | 1.0 | Stock Unit |
| Corriedale Ewes | - | 0.9 | Stock Unit |
| Hoggets | - | 0.67 | Stock Unit |
| Trading Stock | - | Part thereof-depending on period on farm | |

Area available for grazing was calculated for each farm, making due allowances for areas available for only part of year.

B.6 Lamb Meat per Available Acre

Total Lamb Meat produced (made up of fat lambs produced on the farm, with an allowance for store lambs bought for fattening), was divided by the area available for grazing.

B.7 Wool per Available Acre

Total wool produced on the farm (excluding slipe wool) was divided by the area available for grazing.

B.8 Replacement Policy

The replacement policy was classified into one of the following:

- A. Buying in 2 yr. ewes.
- B. Buying in 2-tooth ewes.
- C. Buying in ewe lambs.
- D. Buying in a combination of two or more of A, B, C.
- E. Breeding a portion, and buying a portion.
- F. Breeding all requirements.
- G. Breeding all requirements and selling surplus as ewe lambs or two-tooths.

APPENDIX CDETAILS OF TABLE 3.5C.1 Sheep carried per acre

Total sheep on the property at 1st July converted to standard stock units and divided by the effective area of the property.

C.2 Meat Production per acre.

The Meat and Wool Boards' Economic Service figures represent the meat actually produced on the property during the year (i.e. allowing for meat brought in and sold as store or breeding stock) divided by the effective area of the property. The Ashley Dene figures include only lamb meat sold with an allowance for ewe lambs retained.

C.3 Wool Production per acre

The Meat and Wool Boards' Economic Service figures represent the wool actually grown on the property during the year (i.e. allowing for wool bought in on stock purchased and wool on stock sold) divided by the effective area of the property. The Ashley Dene figures represent the wool actually sold.

The meat and wool production figures for Ashley Dene are not strictly comparable with those from the Meat and Wool Boards' Economic Service farms, however they do indicate the production changes which have occurred on the more intensely stocked properties.

APPENDIX DDETAILS OF THE PROGRAMMING MODELD.1 Physical Output for Livestock and Crop ProductsD.1.1 Stock Performances

| Class of Stock | Lambing % (Survival to sale) | Wool/head (lbs) | Culling Rate (%) | Death Rate (%) |
|------------------------------|---------------------------------|--------------------|---------------------|-------------------|
| 1. Corriedale mixed age ewes | 110 | 10 | 20 | 3 |
| 2. Corriedale two-year ewes | 115 | 9 | 50 | 6 |
| 3. BL.C mixed age ewes | 125 | 10.5 | 20 | 3 |
| 4. Dry ewes | | 10 | 16 | 2 |
| 5. Corriedale ewe hogget | | 6 | | 4 |
| 6. BL.C ewes | | 7 | | 4 |

D.1.2 Crop Yields

| Crop | Yield per acre |
|-------------------------------------|----------------|
| 1. Wheat | 35 bu. |
| 2. Barley | 45 bu. |
| 3. Barley (second white straw crop) | 40 bu. |

D.2 Feeding Standards and Conversion Ratios

D.2.1 Carrying Capacities per acre for varying stock feed

| Class of Feed | Autumn | Winter | Lambing | Spring | Summer | Lamb Fattening |
|--|--------|--------|---------|---------------------|--------|----------------|
| 1. Pasture | 4.5 | 1 | 3.5 | 4 | 4 | |
| 2. New grass | | | 4 | 5 | 4 | |
| 3. Lucerne | 6 | 1 | 2.5 | 6 | 6 | 12 |
| 4. New Lucerne | | | 4 | 6 | 6 | |
| 5. Turnips and Italian ryegrass | | 15 | 3 | $\frac{1}{2}$ of 4* | | |
| 6. Italian ryegrass | | 10 | 3 | $\frac{1}{2}$ of 4* | | |
| 7. Ren. Sub. clover and Italian ryegrass | | 18 | 4 | | | |
| 8. Rape and Italian ryegrass | 6 | 3 | 3 | | | 12 |
| 9. Rape | 6 | | | | | 12 |

* The grazing available from these crops in the spring, is reduced by approximately 50% because of their situation in the 'rotations'.

For example, the area of turnips and Italian ryegrass is followed for new grass in mid spring, hence only half of the 4 stock units of feed grown is actually utilised.

D.2.2 Feeding values and yields per acre for class of supplementary feed

| | Feeding value | | Yield per acre | |
|----------------------------------|---------------|---------------|----------------|---------|
| | Winter | Summer | Spring | Autumn |
| 1. Lucerne hay | 8 s.u./ton | 12.6 s.u./ton | 1.5 ton | 0.5 ton |
| 2. Perennial ryegrass straw | 4 s.u./ton | 9.9 s.u./ton | | |
| 3. Short rotation ryegrass straw | 4 s.u./ton | 11.5 s.u./ton | | |
| 4. Feed Barley | 4.4 s.u./ton | 6.8 s.u./ton | | |

D.2.3 Conversion ratios

| Class of Stock | Autumn | Winter | Lambing | Spring | Summer |
|--------------------------|----------------------|--------|---------|--------|--------|
| 1. Corriedale ewe | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |
| 2. BL.C ewe | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 |
| 3. Dry ewe | 1.00 | 0.75 | 0.25 | 0.25 | 1.00 |
| 4. Corriedale ewe hogget | 1.00 | 0.75 | 0.50 | 0.50 | 1.00 |
| 5. BL.C ewe hogget | 1.05 | 0.79 | 0.53 | 0.53 | 1.05 |
| 6. Lambs F.O.F. | | | | | 1.50 |
| 7. Lambs Store | $\frac{1}{2}$ of 1.5 | | | | |
| 8. Rams | 1.00 | 0.75 | | | |

The feed provision and conversion ratios used are based on the standardised stock unit system, where the Corriedale ewe has a feed requirement of 0.90 stock units at each period during the year.

D.3 Examples of the Calculation of Per Unit Net RevenuesD.3.1 Rotation 1 (P_1)

Unit = 11 acres

| | | |
|-----------------------------|---------------|-----------------|
| 1. Variable Costs | £ | £ |
| (a) Cultivation | 2.358 | |
| (b) Seeds and Manure | 8.400 | |
| (c) Maintenance Topdressing | <u>12.900</u> | 23.658 |
| 2. ∴ Net Revenue per Unit = | | <u>£-23.658</u> |

D.3.2 Breeding Ewe Activity. Mixed age Corriedale ewes mated toDown Rams (P₃₃)

Unit = 5 ewes

(lambling 110%; death rate 3%; culling rate 20%)

| | £ | £ |
|--|--------------|--------------|
| 1. Total Revenue (not including wool or fat lambs) | | |
| (a) Cull ewe, 1 @ 20/- | <u>1.000</u> | 1.000 |
| 2. Variable Cost (not including ewe replacement) | | |
| (a) Shearing and crutching | 0.375 | |
| (b) Dipping, drenches etc. | 0.700 | |
| (c) Ram costs | <u>0.125</u> | <u>1.200</u> |
| 3. ∴ Net Revenue per Unit = | | - £0.200 |

D.4 Estimation of Total Farm Capital and Overhead CostsD.4.1 Total Farm Capital

£

1. Land and Buildings:

| | | |
|--------------------------|--|--------|
| 440 acres @ £75 per acre | | 33,000 |
|--------------------------|--|--------|

2. Stock:

| | | |
|-------------------------------------|------------|-------|
| 1300 mixed age Corriedale ewes @ £3 | 3,900 | |
| 20 Down rams @ £6 | <u>120</u> | 4,020 |

3. Plant:

2,500

39,520

4. Working Capital:

| | | |
|---|--|--------------|
| (5% of land and buildings, stock and plant) | | <u>1,980</u> |
|---|--|--------------|

5. ∴ Total Farm Capital:

£41,500D.4.2 Overhead Costs

£

1. Administration - telephone, accountancy etc.

80

2. Working Expenses - casual labour,
electricity, general

150

3. Vehicle and Motor Expenses:

| | | |
|----------------------------------|----|--|
| Tractor hours, 200 @ 3/- per hr. | 30 | |
|----------------------------------|----|--|

| | | |
|--------------------------------|-----------|-----|
| Car miles, 2000 @ 9' per mile. | <u>75</u> | 105 |
|--------------------------------|-----------|-----|

4. Repairs and Maintenance:

| | | |
|------------------------|-----|--|
| Buildings, £5000 @ 2½% | 125 | |
|------------------------|-----|--|

| | | |
|-------------------------|----|--|
| Fences, 500 chain @ 2/- | 50 | |
|-------------------------|----|--|

| | | |
|-------------------------|----|--|
| Tractor, 1050 hrs @ 1/3 | 65 | |
|-------------------------|----|--|

| | | |
|-------------------------|------------|------------|
| Machinery, £2,000 @ 7½% | <u>150</u> | <u>390</u> |
|-------------------------|------------|------------|

C/F

725

£ 725

5. Depreciation -

Buildings, £5000 @ $2\frac{1}{2}\%$ 125Car, $\frac{1}{2}$ of 20% on £600 80

Tractor, £500 @ 20% 100

Machinery, £1,900 @ 10% 190495

6. ∴ Overhead Cost

£ 1,220

7. Interest @ 6% on T.F.C. of £41,500

£ 2,490

APPENDIX EDETAILS OF THE DEVELOPMENT PROGRAMMESE.1 Physical Output for Livestock

| Class of Stock | Lambing % (Survival to sale) | Wool/head (lbs.) | Culling Rate (%) | Death Rate (%) |
|------------------------------|---------------------------------|---------------------|---------------------|-------------------|
| 1. Corriedale mixed age ewes | 105% | 9 lb. | 20% | 3% |
| 2. Corriedale two-year ewes | 110% | 8.5 lb. | 50% | 6% |
| 3. Corriedale ewe hoggets | | 5.5 lb. | 5% | 3% |
| 4. Corriedale ewe lambs | | 2.5 lb. | | |
| 5. Corriedale wether hoggets | | 5 lb. | | |
| 6. Corriedale wether lambs | | 2.5 lb. | | |
| 7. Down rams | | 6 lb. | | |
| 8. Corriedale rams | | 10 lb. | | |

E.2 Feeding Standards and Conversion Ratios

E.2.1 Carrying capacities per acre for various stock feeds (expressed in stock units per acre).

| Class of Feed | Winter | Spring |
|--|--------|---------------------|
| 1. Pasture | 1 | 3.5 |
| 2. New Grass | | 4 |
| 3. Lucerne | 1 | 5 |
| 4. New Lucerne | | 5 |
| 5. Turnips and Italian ryegrass | 15 | $\frac{1}{2}$ of 3* |
| 6. Italian ryegrass | 10 | $\frac{1}{2}$ of 4* |
| 7. Renovated Sub.clover and Italian ryegrass | 10 | $\frac{1}{2}$ of 3* |
| 8. Browntop | 0.5 | 1.5 |

* See Appendix D.2.1 for calculation of these coefficients.

E.2.2 Feeding value and yield per acre for lucerne hay.

| | Feeding value | Yield per acre |
|-------------|---------------|----------------|
| Lucerne hay | 8 s.u./ton | 1.2 ton |

E.2.3 Conversion ratios (stock units).

See Appendix D.2.3 for details.

E.3 Standard Values used in BudgetsE.3.1 Standard values for taxation assessments.

| | |
|-------------------|------------------|
| 1. Ewes | £1.10.0 per head |
| 2. Ewe hoggets | £1.10.0 per head |
| 3. Wether hoggets | £1.10.0 per head |
| 4. Rams | £1.10.0 per head |

E.3.2 Standard Values for stock and produce sold.

| | |
|---------------------------------|------------------------|
| 1. Lambs | £2. 5.0 per head |
| 2. Wether hoggets | £2.15.0 per head |
| 3. Ewes and lambs 'all counted' | £1.10.0 per head |
| 4. Buffer flock ewes | 15.0 per head |
| 5. Cull ewes | £1.10.0 per head |
| 6. Wool | 48 pence per lb. (net) |

E.3.3 Standard values for stock purchased.

| | |
|--------------------|---------|
| 1. Wether hoggets | £1.17.6 |
| 2. Ewe hoggets | £2. 0.0 |
| 3. Two-year ewes | £2.10.0 |
| 4. Corriedale rams | 12 gns. |
| 5. Down rams | 8 gns. |

E.4 Glossary of Terms Used in the Development Budgets

E.4.1 Standing changes: Includes rates and land tax £265, insurance £50, mortgage interest £1,320, and interest on current overdraft.

E.4.2 Depreciation: Calculated at $2\frac{1}{2}\%$ on quarter of dwelling, $2\frac{1}{2}\%$ on buildings, 20% on motorised plant, 10% on other plant, and 10% on half of car.

E.4.3 Wages of Management: An estimate of the reward the farmer could expect for his own labour and management input. (N.B. this increases during development.)

E.4.4 Taxation: Current payment based on previous year's income and calculated from the standard income tax tables. Thus tax paid in the first year of the development is assessed on the taxable income in the pre-development budget.

E.4.5 Total Cash Expenditure: Includes all cash farm expenditure, personal and capital expenditure.

E.4.6 Overdraft: This is the balance in the current account at the end of the financial year.

E.4.7 Taxable Gross Income: Gross farm income less expenses and depreciation.

E.4.8 Taxable Income: Net farm income less depreciation and tax exemptions.

E.4.9 Real Income: The post-tax surplus plus the allowance for wages of management and life insurance.

E.5 BUDGET DETAILS FOR DEVELOPMENT PROGRAMMES

E.5.1 Programme A

| | Pre- Development | Cash | Tax | Year 1 | Cash | Tax | Year 2 | Cash | Tax | Year 3 | Cash | Tax | Year 4 | Cash | Tax |
|---|---------------------|-------|-----|--------|-------|-----|--------|-------|-----|--------|-------|-----|--------|-------|-----|
| Income | | | | | | | | | | | | | | | |
| Lambs | 3150 | | | 3040 | | | 3265 | | | 3600 | | | 2800 | | |
| Ewes | 240 | | | 100 | | | 100 | | | 215 | | | 200 | | |
| Others | | | | 1050 | | | 675 | | | 665 | | | 810 | | |
| Wool | 2220 | | | 2410 | | | 3275 | | | 3750 | | | 4050 | | |
| Skins | 20 | | | 20 | | | 25 | | | 25 | | | 25 | | |
| Total Cash Income | | 5630 | | | 6620 | | | 7340 | | | 8255 | | | 7885 | |
| Non Cash Income | | | | 905 | | | 235 | | | 295 | | | 75 | | |
| Gross Income | | 5630 | | | 7525 | | | 7575 | | | 8550 | | | 7960 | |
| Expenditure | | | | | | | | | | | | | | | |
| Stock Purchases | 730 | | | 2395 | | | 1150 | | | 1765 | | | 445 | | |
| Standing Charges | 1815 | | | 1845 | | | 1905 | | | 1905 | | | 1895 | | |
| Administration Charges | 120 | | | 120 | | | 120 | | | 120 | | | 120 | | |
| Wages | 185 | | | 195 | | | 320 | | | 560 | | | 1115 | | |
| Animal Health | 85 | | | 110 | | | 105 | | | 125 | | | 140 | | |
| Electricity | 20 | | | 20 | | | 20 | | | 30 | | | 30 | | |
| Freight | 65 | | | 120 | | | 65 | | | 80 | | | 50 | | |
| Feed | 70 | | | 65 | | | 65 | | | 110 | | | 110 | | |
| Fertiliser and Lime | 255 | | | 645 | | | 800 | | | 740 | | | 895 | | |
| Seeds | 205 | | | 295 | | | 350 | | | 220 | | | 220 | | |
| Weed and Pest | 10 | | | 20 | | | 30 | | | 40 | | | 50 | | |
| Woolshed | 45 | | | 60 | | | 60 | | | 60 | | | 65 | | |
| General | 95 | | | 105 | | | 135 | | | 140 | | | 140 | | |
| Vehicles | 175 | | | 225 | | | 225 | | | 225 | | | 225 | | |
| Repairs and Maintenance | 405 | | | 405 | | | 305 | | | 405 | | | 450 | | |
| Development (Deductible) | - | | | - | | | 150 | | | 50 | | | 250 | | |
| Total Farm Expenditure | 4280 | | | 6625 | | | 5805 | | | 6575 | | | 6200 | | |
| Depreciation | 455 | | | 415 | | | 350 | | | 305 | | | 270 | | |
| Total Non Taxable Expenditure | | 4735 | | | 7040 | | | 6155 | | | 6880 | | | 6470 | |
| Personal & Capital Expenditure | | | | | | | | | | | | | | | |
| Wages of Management | 1200 | | | 1200 | | | 1200 | | | 1200 | | | 1200 | | |
| Life Insurance | 100 | | | 100 | | | 100 | | | 100 | | | 100 | | |
| Tax | 50 | | | 50 | | | 20 | | | 145 | | | 200 | | |
| Capital Expenditure (Non Deductible) | - | 1350 | | - | 1350 | | 200 | 1520 | | 200 | 1615 | | - | 1500 | |
| Total Cash Expenditure | | 5630 | | | 7975 | | | 7325 | | | 8220 | | | 7700 | |
| Cash Gain or Deficit | | 0 | | | -1355 | | | + 15 | | | + 35 | | | + 185 | |
| Current Account Balance | | -3350 | | | -4705 | | | -4690 | | | -4655 | | | -4470 | |
| Tax Assessment | | | | | | | | | | | | | | | |
| Taxable Gross Income | | + 895 | | | + 485 | | | +1420 | | | +1670 | | | +1490 | |
| Less Life Insurance | | 100 | | | 100 | | | 100 | | | 100 | | | 100 | |
| . Taxable Income | | 795 | | | 385 | | | 1320 | | | 1570 | | | 1390 | |
| Tax Payable in following year | | 50 | | | 20 | | | 145 | | | 200 | | | 155 | |

| Year 5 | Cash | Tax | Year 6 | Cash | Tax | Year 7 | Cash | Tax | Year 8 | Cash | Tax | Year 9 | Cash | Tax | Year 10 | Cash | Tax | Post Development | Cash | Tax |
|--------|------|-----|--------|------|-----|--------|------|-----|--------|------|-----|--------|-------|-----|---------|-------|-----|------------------|-------|-----|
| 3075 | | | 3070 | | | 3415 | | | 4025 | | | 4590 | | | 4985 | | | 5040 | | |
| 435 | | | 835 | | | 775 | | | 390 | | | 410 | | | 510 | | | 560 | | |
| 540 | | | 540 | | | - | | | - | | | - | | | - | | | - | | |
| 4155 | | | 4195 | | | 4460 | | | 5090 | | | 5605 | | | 5960 | | | 6175 | | |
| 25 | | | 25 | | | 30 | | | 30 | | | 30 | | | 30 | | | 30 | | |
| | 8230 | | | 8665 | | | 8680 | | | 9535 | | | 10635 | | | 11485 | | | 11805 | |
| 365 | | | 40 | | | 170 | | | 440 | | | 465 | | | 120 | | | | | |
| | 8595 | | | 8705 | | | 8850 | | | 9975 | | | 11100 | | | 11605 | | | 11805 | |
| 815 | | | 340 | | | 110 | | | 455 | | | 435 | | | 120 | | | 120 | | |
| 1855 | | | 1845 | | | 1815 | | | 1875 | | | 1755 | | | 1695 | | | 1650 | | |
| 120 | | | 120 | | | 120 | | | 120 | | | 120 | | | 120 | | | 120 | | |
| 1125 | | | 1150 | | | 1170 | | | 1220 | | | 1245 | | | 1285 | | | 1350 | | |
| 140 | | | 140 | | | 150 | | | 165 | | | 180 | | | 190 | | | 200 | | |
| 30 | | | 30 | | | 30 | | | 60 | | | 60 | | | 65 | | | 70 | | |
| 60 | | | 80 | | | 60 | | | 40 | | | 35 | | | 30 | | | 30 | | |
| 105 | | | 105 | | | 110 | | | 135 | | | 85 | | | 135 | | | 140 | | |
| 1005 | | | 1160 | | | 1125 | | | 1460 | | | 1480 | | | 1535 | | | 1550 | | |
| 260 | | | 265 | | | 385 | | | 275 | | | 470 | | | 330 | | | 350 | | |
| 50 | | | 50 | | | 40 | | | 50 | | | 50 | | | 50 | | | 50 | | |
| 65 | | | 65 | | | 75 | | | 85 | | | 90 | | | 105 | | | 110 | | |
| 140 | | | 145 | | | 125 | | | 95 | | | 105 | | | 115 | | | 200 | | |
| 250 | | | 255 | | | 255 | | | 255 | | | 280 | | | 300 | | | 300 | | |
| 530 | | | 1150 | | | 1250 | | | 405 | | | 600 | | | 700 | | | 600 | | |
| - | | | - | | | - | | | - | | | - | | | - | | | - | | |
| 6550 | | | 6900 | | | 6820 | | | 6695 | | | 6990 | | | 6775 | | | 6840 | | |
| 230 | | | 200 | | | 180 | | | 220 | | | 350 | | | 350 | | | 320 | | |
| | 6780 | | | 7100 | | | 7000 | | | 6915 | | | 7340 | | | 7125 | | | 7160 | |
| 1300 | | | 1400 | | | 1500 | | | 1600 | | | 1600 | | | 1600 | | | 1600 | | |
| 125 | | | 125 | | | 125 | | | 150 | | | 150 | | | 150 | | | 150 | | |
| 155 | | | 230 | | | 180 | | | 240 | | | 665 | | | 990 | | | 1415 | | |
| - | | | - | | | - | | | 800 | | | 200 | | | - | | | - | | |
| 1580 | | | 1755 | | | 1805 | | | 2790 | | | 2615 | | | 2740 | | | 3165 | | |
| 8130 | | | 8655 | | | 8625 | | | 9485 | | | 9605 | | | 9515 | | | 10005 | | |
| + 100 | | | + 10 | | | + 55 | | | + 50 | | | +1030 | | | +1970 | | | +1800 | | |
| -4370 | | | -4360 | | | -4305 | | | -4255 | | | -3225 | | | -1255 | | | + 545 | | |
| | 1690 | | 1480 | | | 1725 | | | 2910 | | | 3610 | | | 4330 | | | 4495 | | |
| 230 | | | 180 | | | 240 | | | 665 | | | 990 | | | 1415 | | | 1500 | | |
| | 1615 | | 1605 | | | 1850 | | | 3060 | | | 3760 | | | 4480 | | | 4645 | | |
| 125 | | | 125 | | | 125 | | | 150 | | | 150 | | | 150 | | | 150 | | |
| 1690 | | | 1480 | | | 1725 | | | 2910 | | | 3610 | | | 4330 | | | 4495 | | |
| 230 | | | 180 | | | 240 | | | 665 | | | 990 | | | 1415 | | | 1500 | | |

E.5.2 Programme B

| | Pre- Development | Cash | Tax | Year 1 | Cash | Tax | Year 2 | Cash | Tax | Year 3 | Cash | Tax |
|---|---------------------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|
| <u>Income</u> | | | | | | | | | | | | |
| Lambs | 3150 | | | 3150 | | | 3730 | | | 3375 | | |
| Ewes | 240 | | | 900 | | | 100 | | | 725 | | |
| Other | - | | | 300 | | | 950 | | | 405 | | |
| Wool | 2220 | | | 2620 | | | 3590 | | | 3945 | | |
| Skins | 20 | | | 20 | | | 30 | | | 30 | | |
| <u>Total Cash Income</u> | | 5630 | | | 6990 | | | 8400 | | | 8480 | |
| <u>Non Cash Income</u> | | | | 1290 | | | 445 | | | 355 | | |
| <u>Gross Income</u> | | | 5630 | | | 8280 | | | 8845 | | | 8835 |
| <u>Expenditure</u> | | | | | | | | | | | | |
| Stock Purchases | 730 | | | 3080 | | | 1875 | | | 1045 | | |
| Standing Charges | 1815 | | | 1875 | | | 2055 | | | 2115 | | |
| Administration Charges | 120 | | | 120 | | | 120 | | | 120 | | |
| Wages | 185 | | | 975 | | | 1045 | | | 1100 | | |
| Animal Health | 85 | | | 120 | | | 125 | | | 145 | | |
| Electricity | 20 | | | 20 | | | 25 | | | 30 | | |
| Freight | 65 | | | 140 | | | 75 | | | 60 | | |
| Feed | 70 | | | 65 | | | 65 | | | 65 | | |
| Fertiliser and Lime | 255 | | | 815 | | | 725 | | | 1130 | | |
| Seeds | 205 | | | 410 | | | 215 | | | 480 | | |
| Weed and Pest | 10 | | | 20 | | | 25 | | | 30 | | |
| Woolshed | 45 | | | 45 | | | 60 | | | 70 | | |
| General | 95 | | | 110 | | | 125 | | | 145 | | |
| Vehicles | 175 | | | 245 | | | 245 | | | 285 | | |
| Repairs and Maintenance | 405 | | | 595 | | | 760 | | | 1210 | | |
| Development (Deductible) | - | | | 150 | | | 350 | | | - | | |
| <u>Total Farm Expenditure</u> | | 4280 | | | 8785 | | | 7890 | | | 8030 | |
| Depreciation | 455 | | | 415 | | | 355 | | | 300 | | |
| <u>Total Non Taxable Expenditure</u> | | | 4735 | | | 9200 | | | 8245 | | | 8330 |
| <u>Personal & Capital Expenditure</u> | | | | | | | | | | | | |
| Wages of Management | 1200 | | | 1200 | | | 1300 | | | 1400 | | |
| Life Insurance | 100 | | | 100 | | | 100 | | | 125 | | |
| Tax | 50 | | | 50 | | | - | | | 30 | | |
| Capital Expenditure (Non Deductible) | - | 1350 | | - | 1350 | | 600 | 2000 | | 100 | 1655 | |
| <u>Total Cash Expenditure</u> | | 5630 | | | 10135 | | | 9890 | | | 9685 | |
| <u>Cash Gain or Deficit</u> | | 0 | | | -3145 | | | -1490 | | | -1205 | |
| <u>Current Account Balance</u> | | -3350 | | | -6495 | | | -7985 | | | -9190 | |
| <u>Tax Assessment</u> | | | | | | | | | | | | |
| Taxable Gross Income | | | + 895 | | | - 920 | | | + 600 | | | + 505 |
| Less Life Insurance | | | 100 | | | 100 | | | 100 | | | 125 |
| <u>∴ Taxable Income</u> | | | 795 | | | - 820 | | | 500 | | | 380 |
| <u>Tax Payable in following year</u> | | | 50 | | | - | | | 30 | | | 20 |

[illegible]

APPENDIX F LINEAR PROGRAMMING MODEL

| Activities, Units, and Net Revenues | | | | APPENDIX F LINEAR PROGRAMMING MODEL | | | | | | | | | | | | | | |
|--|-----------------|---------------------|------------------|-------------------------------------|-----------------|-----------------|------------------|------------------|------------------|------------------|-----------------|-----------------|----------------------------|--------------------------|----------------------------|--------------------------|---------------------------------------|---------------------------------------|
| | | | | P ₁ | P ₂ | P ₃ | P ₄ | P ₅ | P ₆ | P ₇ | P ₈ | P ₉ | P ₁₀ | P ₁₁ | P ₁₂ | P ₁₃ | P ₁₄ | P ₁₅ |
| | | | | Rot.A (11 ac) | Rot.B (9 ac) | Rot.C (9 ac) | Rot.D (11 ac) | Rot.E (12 ac) | Rot.F (12 ac) | Rot.G (11 ac) | Rot.H (6 ac) | Rot.I (8 ac) | Spring Hay, 1 (1 ac) | Aut. Hay, 1 (1 ac) | Spring Hay, 2 (1 ac) | Aut. Hay, 2 (1 ac) | Feed ₁ Barley (10bu) | Feed ₂ Barley (10bu) |
| Disposal Vector Net Revenues, Constraints, Units, and Levels | | | | -23.658 | -15.725 | -14.700 | -18.100 | -27.725 | -29.550 | -27.825 | -19.800 | -32.000 | -3.125 | -1.300 | -3.125 | -1.300 | 0 | 0 |
| 0 | R ₁ | Land | acres 434 | ≥ | +11.0 | + 9.0 | + 9.0 | +11.0 | +12.0 | +12.0 | +11.0 | + 6.0 | + 8.0 | | | | | |
| 0 | R ₂ | Autumn feed | SU's 0 | ≥ | -54.0 | -31.5 | -31.5 | -42.0 | -45.0 | -42.0 | -51.0 | -20.0 | -29.5 | | + 6.0 | | + 6.0 | |
| 0 | R ₃ | Winter feed | SU's 0 | ≥ | -23.0 | -35.0 | -24.0 | -26.0 | -23.0 | -33.0 | -18.0 | -19.0 | -19.0 | -12.0 | - 4.0 | | | - 4.4 |
| 0 | R ₄ | Pre-lambing feed | SU's 0 | ≥ | -24.0 | -31.5 | -28.0 | -38.0 | -32.0 | -35.0 | -35.0 | -17.0 | -21.0 | | | | | |
| 0 | R ₅ | Spring feed | SU's 0 | ≥ | -48.0 | -27.0 | -30.0 | -29.5 | -28.0 | -30.0 | -30.0 | -16.0 | -17.5 | + 6.0 | | + 6.0 | | |
| 0 | R ₆ | Lamb fattening feed | SU's 0 | ≥ | -12.0 | | | -12.0 | -12.0 | -12.0 | | | -12.0 | | | | | |
| 0 | R ₇ | Summer feed | SU's 0 | ≥ | -48.0 | -28.0 | -28.0 | -32.0 | -32.0 | -32.0 | -32.0 | -14.0 | -12.0 | | | -18.9 | - 6.3 | - 6.8 |
| 0 | R ₈ | Spring Lucerne | acres 0 | ≥ | - 8.0 | | | | | | | | | + 1.0 | | + 1.0 | | |
| 0 | R ₉ | Autumn Lucerne | acres 0 | ≥ | - 8.0 | | | | | | | | | | + 1.0 | | + 1.0 | |
| 0 | R ₁₀ | Max. Lucerne | acres 300; 50 | ≥ | + 8.0 | | | | | | | | | | | | | |
| 0 | R ₁₁ | Feed Barley | 10 bu. 0 | ≥ | | | | | | | | - 1.0 | - 0.9 | | | | + 1.0 | + 1.0 |
| 0 | R ₁₂ | Max.Barley fed | 1000 lb. 0 | ≥ | | | | | | | | | | - 6.7 | - 2.2 | | + 0.5 | |
| 0 | R ₁₃ | Lambs F.O.M. | lamb 0 | ≥ | | | | | | | | | | | | | | |
| 0 | R ₁₄ | Lambs F.O.F. | lamb 0 | ≥ | | | | | | | | | | | | | | |
| 0 | R ₁₅ | Corrie.Ewe Lamb | lamb 0 | ≥ | | | | | | | | | | | | | | |
| 0 | R ₁₆ | Corrie.Two-tooth | ewe 0 | ≥ | | | | | | | | | | | | | | |
| 0 | R ₁₇ | Corrie.Two-year | ewe 0 | ≥ | | | | | | | | | | | | | | |
| 0 | R ₁₈ | BL.C. Ewe lamb | lamb 0 | ≥ | | | | | | | | | | | | | | |
| 0 | R ₁₉ | BL.C. Two-tooth | ewe 0 | ≥ | | | | | | | | | | | | | | |
| 0 | R ₂₀ | Dry ewe | ewe 0 | ≥ | | | | | | | | | | | | | | |
| 0 | R ₂₁ | Max. B.E. | ewe 1700 | ≥ | | | | | | | | | | | | | | |
| 0 | R ₂₂ | Max. Store lambs | lamb 750 | ≥ | | | | | | | | | | | | | | |
| 0 | R ₂₃ | Corrie. Wool | 10 lbs. 0 | ≥ | | | | | | | | | | | | | | |
| 0 | R ₂₄ | BL.C. Wool | 10 lbs. 0 | ≥ | | | | | | | | | | | | | | |
| 0 | R ₂₅ | Max.Cereal Crop | acres 100 | ≥ | | | | | + 1.0 | + 1.0 | + 1.0 | + 1.0 | + 2.0 | | | | | |
| 0 | R ₂₆ | Wheat | 10 bu. 0 | ≥ | | | | | - 3.5 | - 3.5 | - 3.5 | | - 3.5 | | | | | |
| 0 | R ₂₇ | Malting Barley | 10 bu. 0 | ≥ | | | | | | | | - 3.5 | - 3.1 | | | | | |

| P ₃₇ | P ₃₈ | P ₃₉ | P ₄₀ | P ₄₁ | P ₄₂ | P ₄₃ | P ₄₄ | P ₄₅ | P ₄₆ | P ₄₇ | P ₄₈ | P ₄₉ | P ₅₀ | P ₅₁ | P ₅₂ | P ₅₃ |
|----------------------|--------------------------|----------------------|----------------------|-----------------------------|---------------------------|----------------------|--------------------------|--------------------------------|--------------------------|------------------------------|------------------------------|----------------------------|------------------------|--------------------------|-----------------------------|-----------------------------|
| B.E.4 (2 ewes) | Buy Ewe, 2 (1 ewe) | B.E.5 (5 ewes) | B.E.6 (2 ewes) | Sell E.L.2 (1 ewe 1.) | Sell Ewe, 2 (1 ewe) | B.E.7 (5 ewes) | Buy Ewe, 3 (1 ewe) | Buy EL, Ewe 2(1 ewe 1 lamb) | Ewe Hgt(1 ewe hgt) | Sell Lambs, 1 (1 lamb) | Sell Lambs, 2 (1 lamb) | Store Lambs (1 lamb) | Dry Ewe (6 ewes) | Buy Ewe, 4 (1 ewe) | Sell Wool, 1 (10 lbs) | Sell Wool, 2 (10 lbs) |
| +0.363 | -3.370 | -0.200 | +0.350 | +3.388 | +4.900 | -0.175 | -4.958 | -3.485 | -0.175 | +2.850 | +3.800 | +1.300 | +0.035 | -3.500 | +2.575 | +1.950 |
| + 1.8 | | + 4.6 | + 1.8 | | | + 4.8 | | | + 1.1 | | | + 0.8 | + 6.0 | | | |
| + 1.8 | | + 4.5 | + 1.8 | | | + 4.8 | | | + 0.8 | | | | + 4.5 | | | |
| + 1.8 | | + 4.5 | + 1.8 | | | + 4.8 | | | + 0.8 | | | | + 2.2 | | | |
| + 1.7 | | + 4.5 | + 1.8 | | | + 4.7 | | | + 0.5 | | | | + 1.5 | | | |
| + 1.4 | | + 1.5 | + 0.7 | + 0.5 | | + 2.0 | | | + 1.1 | | | + 1.5 | | | | |
| + 0.8 | | + 3.6 | + 0.9 | | + 1.0 | + 3.8 | | | | | | | + 5.9 | | | |
| - 1.4 | | - 1.8 | - 0.7 | | | - 5.0 | | | | + 1.0 | | | | | | |
| - 0.9 | | - 1.0 | - 0.5 | | | - 1.3 | | | | | + 1.0 | | | | | |
| | | + 1.2 | | | | | | | | | | | | | | |
| + 1.1 | - 1.0 | | + 1.1 | | | | | | | | | | | | | |
| | | - 2.8 | - 1.2 | + 1.0 | | | | - 1.0 | + 1.0 | | | | | | | |
| | | | | | + 1.0 | + 1.2 | - 1.0 | | - 1.0 | | | | | | | |
| | | | | | | | | | | | | | + 1.1 | - 1.0 | | |
| + 2.0 | | + 5.0 | + 2.0 | | | + 5.0 | | | | | | | | | | |
| | | | | | | | | | | | | + 1.0 | | | | |
| - 1.8 | | - 5.0 | - 1.8 | | | | | | | | | | - 5.9 | | + 1.0 | |
| | | | | | | - 5.2 | | | - 0.7 | | | | | | | + 1.0 |