Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.
APPLICATION OF LINEAR PROGRAMMING TO FARM MANAGEMENT ANALYSIS: INTENSIVE BEEF GRAZING SYSTEMS

A thesis presented in partial fulfilment of the requirements for the degree of Master of Agricultural Science in Farm Management at Massey University.

Alan F. McRae
September 1975.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter One: MOTIVATION, OBJECTIVES AND OUTLINE OF STUDY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Introduction</td>
</tr>
<tr>
<td>1.1.1 Intensive Grazing Systems</td>
</tr>
<tr>
<td>1.2 Motivation for This Study</td>
</tr>
<tr>
<td>1.2.1 The Systems Research Concept</td>
</tr>
<tr>
<td>1.2.2 The Usefulness of Mathematical Systems Models</td>
</tr>
<tr>
<td>1.3 Objectives of the Study</td>
</tr>
<tr>
<td>1.4 Thesis Outline</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter Two: THE BEEF GRAZING SYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Introduction</td>
</tr>
<tr>
<td>2.2 Components of the Grazing System</td>
</tr>
<tr>
<td>2.2.1 Interaction of the System Components Over Time</td>
</tr>
<tr>
<td>2.2.2 Uncertainty Within the System</td>
</tr>
<tr>
<td>2.2.3 Summary of System Components</td>
</tr>
<tr>
<td>2.3 Research Work on the Components of a Beef Grazing System</td>
</tr>
<tr>
<td>2.3.1 Pasture Production and Grazing Management</td>
</tr>
<tr>
<td>2.3.2 Animal Production and Feed Requirements</td>
</tr>
<tr>
<td>2.3.3 The Use of Research Data in This Study</td>
</tr>
<tr>
<td>2.4 System Modelling Studies on Beef Production in New Zealand</td>
</tr>
<tr>
<td>2.4.1 The Profitability Studies of Lattimore (1970) and Lowe (1971)</td>
</tr>
<tr>
<td>2.4.2 The Simulation Study of Wright, Vaillancé and Nicol (1973)</td>
</tr>
<tr>
<td>2.5 A Dairy Farming Systems Modelling Study</td>
</tr>
</tbody>
</table>
2.6 The Comparison of Linear Programming with Simulation as a Technique for Studying Grazing Systems

2.7 The Model Used

2.8 Summary

CHAPTER THREE: PASTURE GROWTH

3.1 Introduction

3.2 Factors Affecting the Regrowth of Pasture

3.2.1 The Pasture Regrowth Curve

3.2.2 Changes in the Growth Curves Throughout the Year

3.2.3 The Effect of Management on Pasture Growth

3.2.4 The Effect of Grazing Animals on Pasture Production

3.2.4.1 The Number of Animals Grazed

3.2.4.2 The Treading Effects of Animals

3.2.4.3 The Effect of Faeces

3.3 Pasture Production Data Used in This Study

3.3.1 Assumptions Involved in Defining Pasture Regrowth

3.4 The Pasture Production Model

3.4.1 Pasture Production Possibilities Within the Model

3.4.2 The Structure of the Model

3.4.3 The Representation of the Grazing Process by the Model

3.4.3.1 The Length of Spell Between Grazings

3.4.3.2 The Height to Which Pasture is Grazed

3.4.4 Comment on the Length of Spell Options Within the Pasture Production Model

3.5 DM Production Associated with the Pasture Production Activities

3.6 Limitations in the Pasture Production Model

3.7 Annual DM Production from the Pasture Production Model
3.8 Summary

CHAPTER FOUR: ANIMAL PRODUCTION

4.1 Introduction

4.2 The Intake of Grazing Beef Animals
   4.2.1 Factors Affecting the Potential Daily Intake of Grazing Beef Animals
   4.2.2 Factors that Affect the Shape of the Function Relating Available Pasture to Intake

4.3 The Representation of Animal Intake within the Model

4.4 The Conversion of Feed Intake into Animal Production
   4.4.1 The Energy Value of Feed
   4.4.2 Systems for Expressing Feed Requirements
      4.4.2.1 Published Feeding Standards

4.5 Feeding Standards Used in this Study
   4.5.1 Calculation of Feed Requirements
      4.5.1.1 The Relationship Between Animal Liveweight and Maintenance Requirement
      4.5.1.2 The Relationship Between Animal Liveweight Level of Performance (L.W.G.) and Production Requirement
      4.5.1.3 The Effect of Pasture Quality on Feeding Standards
      4.5.1.4 A Consideration of Compensatory Growth
      4.5.1.5 The Significance of Intake (Liveweight Gain) Restrictions in the Feed Requirements Model

4.6 Summary
CHAPTER FIVE: MODEL EXPERIMENTATION AND RESULTS

5.1 Introduction

5.2 Animals Considered in the Study

5.3 The Stocking Rate Decision

5.3.1 BEEF Production Systems

5.3.2 Maximization of Stocking Rates for BEEF Activities

5.3.3 Conditions that Prevent Further Increases in Stocking Rate for BEEF Systems

5.3.3.1 BEEF 1

5.3.3.2 BEEF 2

5.3.3.3 BEEF 3

5.3.3.4 BEEF 4

5.4 Discussion on Maximum Stocking Rates for BEEF Systems

5.5 Grazing Management Plans

5.5.1 Comparison of Grazing Management Plans for BEEF1 and BEEF2

5.5.2 Comparisons of Grazing Management Plans that Maximize Stocking Rate for BEEF2 with BEEF3 and BEEF4

5.6 Relating Grazing Management Plans to Farmer Practice

5.6.1 Uses of the Model for Grazing Management Studies

5.7 Supplementary Feeding

5.7.1 Hay and Silage Making Activities

5.7.2 Supplementary Feeding Activities

5.7.3 Experimentation with Supplementary Feeding Possibilities

5.7.4 Discussion on the Increased Stocking Rate Due to Supplementary Feeding

5.7.5 Further Experimentation Possible With the Model Including Supplementary Feeding Possibilities

5.8 Summary
CHAPTER SIX: EVALUATION OF STUDY

6.1 Introduction .................................................. 134
6.2 Verification of the Model ........................................ 135
   6.2.1 Pasture Production ...................................... 135
   6.2.2 Animal Production as a Function of Intake .......... 136
6.3 Analysis of Farm Management Problems Using L.P. Models . 138
6.4 Evaluation of Study ............................................. 141

APPENDIX ONE: THE PASTURE PRODUCTION MODEL ................. 143
APPENDIX TWO: BEEF ACTIVITIES .................................. 148
APPENDIX THREE: SHADOW PRICES ASSOCIATED WITH THE MAXIMUM STOCKING RATE FROM BEEF2 ........................................................ 150
APPENDIX FOUR: THE SUPPLEMENTARY FEEDING MODEL ........... 153

BIBLIOGRAPHY .......................................................... 157
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Fig.</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Two Aspects of Systems Analysis in Relation to Systems Synthesis</td>
<td>7</td>
</tr>
<tr>
<td>2.1</td>
<td>Components of a Beef Production System</td>
<td>13</td>
</tr>
<tr>
<td>2.2</td>
<td>Interrelationships Between Variables that Affect Production in the t'th Period of the Year</td>
<td>16</td>
</tr>
<tr>
<td>2.3</td>
<td>The Evolutionary Development of Grazing Management Systems</td>
<td></td>
</tr>
<tr>
<td>3.1</td>
<td>Generalized Pasture Regrowth Curve</td>
<td>35</td>
</tr>
<tr>
<td>3.2</td>
<td>Representation of Hypothetical Management Decisions</td>
<td>37</td>
</tr>
<tr>
<td>3.3</td>
<td>Pasture Regrowth and Daily Increments in DM/ha., After HIGH and LOW Defoliation</td>
<td>44</td>
</tr>
<tr>
<td>3.4</td>
<td>Pasture Production After Grazing HIGH and LOW in Period (t)</td>
<td>62</td>
</tr>
<tr>
<td>3.5</td>
<td>Grazing Pattern for Maximum Annual DM Production from the Model</td>
<td>64</td>
</tr>
<tr>
<td>4.1</td>
<td>Actual Daily Intake/Head as a Function of Available Feed/Head</td>
<td>68</td>
</tr>
<tr>
<td>4.2</td>
<td>A Relationship Between Pasture Available/Animal and Intake/Animal</td>
<td>72</td>
</tr>
<tr>
<td>4.3</td>
<td>A Generalized Representation of the Results of Reardon (1975)</td>
<td>74</td>
</tr>
<tr>
<td>4.4</td>
<td>Partitioning of Feed Energy Within the Ruminant</td>
<td>78</td>
</tr>
<tr>
<td>4.5</td>
<td>Partitioning of Available Energy</td>
<td>79</td>
</tr>
<tr>
<td>4.6</td>
<td>Comparison of the Feeding Standards of Lowe (1971), Jagusch (1973), and Those Shown in Table 4.1; for Three Levels of Liveweight Gain, and Three Liveweights</td>
<td>85</td>
</tr>
<tr>
<td>4.7</td>
<td>Maintenance Requirement as a Function of Liveweight</td>
<td>88</td>
</tr>
</tbody>
</table>
4.8 Maintenance Requirement as a Function of (Liveweight)$^{0.75}$  
4.9 Liveweight Gain as a Function of Production Intake/(Liveweight)$^{0.75}$  
5.1 Patterns of Liveweight Achieved by Animals in Beef Production Systems at Maximum Stocking Rates  
5.2 Daily Liveweight Gain Achieved  
5.3-5.6 Period Feed Requirements for BEEF 1, 2, 3 and 4, at Maximum Stocking Rates  
5.7-5.10 Grazing Management Plan for BEEF 1, 2, 3 and 4  
5.11 The Fate of 27 ha. Grazed LOW in Period (1)
ACKNOWLEDGEMENTS

The author would like to formally express his gratitude to Professor Robert J. Townsley, Professor of Agricultural Economics and Farm Management, Massey University, for supervision of the study. The time spent by Professor Townsley assisting the author with interpretation of results and presentation of this thesis is particularly appreciated.

The author benefited from discussions with several other staff members at Massey University, especially Dr. A. Wright and Dr. A.W.F. Davey.

The staff of the Massey University Computer Unit have been particularly helpful.

The Ministry of Agriculture and Fisheries have been tolerant employers throughout the somewhat extended duration of this study. Their financial assistance is gratefully acknowledged.

The author is appreciative of the efficient manner in which Mrs. Hilde Godenho typed the bulk of this thesis. Thanks are also due to Miss Cathey Harris for typing parts of the thesis, and Mr. Rick Godenho for assistance in presentation of many of the text diagrams and tables.

The author would also like to thank many others, friends and flatmates, who helped make the period of this study a more enjoyable time than it may have otherwise been.

Finally, thanks are due to the author's parents for the interest they have shown, and the encouragement they have offered in this and earlier studies.
ABSTRACT

In the absence of quantitative data from the practical farm situation, Linear Programming (L.P.), was used as a framework for collecting research information on an intensive beef grazing system.

Three hundred pasture production activities were defined so that pasture was available for grazing at two grazing severities in each of 30 periods throughout the year, after a range of spelling lengths. Seventeen supplementary feedmaking activities allowed hay or silage to be made over the late spring, early summer period. Supplementary feed could be fed out in any period of the year subject to the constraint that per animal intake of supplementary feed did not exceed maintenance requirement.

Animals considered by the model are Friesian bulls purchased at three months of age, and 100 Kg. liveweight, and grazed within the system for 12 - 18 months, until they reached a liveweight of 380 Kg. Animal requirements were calculated as a function of liveweight and level of liveweight gain. These requirements were expressed in terms of pasture dry matter per animal, and were adjusted for assumed changes in the available energy (M.E.) content of pasture throughout the year.

Although the model could not be verified in relation to the real-life situation, due to lack of quantitative data, the capability of the model for solving farm management problems was investigated. An iterative procedure for solving the stocking-rate decision was developed, and results presented and analysed. The use of the model for investigation of beef farm management problems was discussed.