THE PROFITABILITY OF NITROGEN FERTILISER APPLICATIONS ON SEASONAL SUPPLY DAIRY FARMS

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

April 1972

ACKNOWLEDGEMENTS

The author wishes to thank Professors A.R. Frampton and R.J. Townsley for their advice, encouragement and helpful criticism throughout the study.

The author also benefited from discussions with Mr. J.N. Hodgson, Mr. A.W.F. Davy, and Dr. A. Wright, at Massey University, Mr. J.A.Lancashire at the D.S.I.R., Palmerston North, and helpful written communication from Dr. J.B. Hutton at the Ruakura Animal Research Station.

The author is particularly indebted to Mr. R. Ball at the D.S.I.R., Palmerston North, for making his experimental results available and for his time and co-operation on a great number of occasions.

Thanks are also due to Mrs. O.J. England who typed this thesis, and a special thanks to Mrs. R. Pollard for her assistance and encouragement during this study.

This study was financed by Kempthorne and Prosser Company Limited and this support is gratefully acknowledged as is the financial assistance provided by the Manawatu Co-operative Dairy Company.

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CHAPTER 1

PRESENT USE OF NITROGEN FERTILISER IN NEW ZEALAND AND OUTLINE OF THE STUDY

1.1 INTRODUCTION

Grassland farming in New Zealand is characterised by an almost complete reliance on pasture herbage as the diet for livestock throughout the year. Nitrogen (N) for grass growth is obtained from legumes, particularly white clover. The success of this grass-clover association can be largely attributed to the very high levels of N fixation possible under New Zealand climatic conditions 1/. The supply of available N in the system is not regular, however, and periods of temporary N deficiency occur annually in mixed pasture. Consequently, the question arises as to whether the productivity of the grass-clover pastures can be profitably raised by the use of fertiliser N.

1.2 SCOPE OF THE STUDY

If the use of fertiliser N is to be economic, it must either allow a new farming system to become feasible and profitable, or improve the profitability of an existing system. Advocates of increased N fertiliser use in New Zealand are not in agreement as to which alternative shows the greatest potential.

Mitchell (1969) anticipates a considerable decline in future fertiliser N costs and suggests that it could be used to substitute entirely for clover N. Animals are yarded throughout the year and are fed by high yielding summer and winter adapted crops, which are liberally dressed with fertiliser N, cut, and stored in silos 2/.

Such a system, it is argued, will deliver high quality feed at low unit cost to the animal. Full utilisation of the feed is ensured and supply can be easily adjusted to animal requirements. Time limitations, however, have forced the author to eliminate a consideration of this system from the study and consider only the application of N fertiliser to grazed ryegrass-clover swards. However, an economic comparison of these two basic systems must be undertaken in the future.

1/ Sears (1965) measured 600lbs of elemental N/acre fixed by white clover.

2/ The system of farming commonly referred to as 'zero' grazing.

The results of such an analysis will have a great influence on the future role of fertiliser N as an input in the New Zealand dairy industry.

The study is further restricted to a consideration of only seasonal supply dairy farming systems that may profitably use fertiliser N.

1.3 PRESENT FERTILISER N USAGE IN NEW ZEALAND

Considerable reductions in ammonia production costs have occurred in recent years throughout the world, as advances in mechanical equipment combined with changes in raw material supplies have allowed large scale plants based on oil or natural gas to replace smaller plants based on coke. High analysis fertilisers, (approximately 80% N content), can be produced by liquifying ammonia under pressure 1/ or dissolving ammonia in water 2/. However, these fertilisers are untried commercially in New Zealand. Ammonia is also used in the manufacture of low analysis N fertilisers, such as: urea, sulphate of ammonia (S/A) and compound fertilisers, such as Di-ammonium-phosphate (DAP), which are the major forms of N fertiliser used in New Zealand. Sales from the Hornby and Awatoto fertiliser works in North Canterbury and the East Coast of the North Island respectively, are presented in Table 1.1. The composition of total N fertiliser sales at Awatoto between 1964 and 1971 are also shown in Table 1.1.

TABLE 1.1 N FERTILISER SALES (,000 lbs N)

Fertiliser Works	Fertiliser	N content %	1964	1965	1966	1967	1968	1969	1970	1971
Awatoto*	S/A	21	294	299	224	195	179	356	125	188
	DAP***	18	-	-	-	38	174	545	400	408
	Urea	48	2	8	-	-	21	571	1546	2178
	Total		296	307	224	233	374	1472	2071	2774
Hornby**	Total		325	-	-	430	1137	2667	3162	-

* Figures supplied by B.T. Robertson (pers. comm.).

** Figures supplied by D. Davies (pers. comm.).

*** DAP also contains 20% Phosphorus.

1/ Annhydrous Ammonia.

2/ Aqua Ammonia.

The main differences of practical interest between commonly used N fertilisers in New Zealand are in N content 1/, cost/unit N, efficiency as a source of N and effects on pasture production.

Because of the advent of cheaper ammonia production and despite rising shipping freight costs, there has been a general decline in the price of urea and S/A in New Zealand in recent years. However, prices increased during 1971 and early 1972, due mainly to the Japanese currency revaluation in 1971. Price trends between 1965 and 1972 are presented in Table 1.2. The prices of different forms of N fertiliser can vary widely between and within districts. Ball (1970) surveyed merchants in the Manawatu and received quotations for urea that ranged from $71 to $105/ton, (6.9 to 10.2c/lb N).

TABLE 1.2 N FERTILISER COSTS (c/lb N ex works)*

	1965	1966	1967	1968	1969	1970	1971	1972
S/A	11.4	12.1	11.5	10.0	10.6	11.1	11.1	12.0
Urea	9.2	9.4	9.6	8.2	8.5	7.3	7.3	8.0

* A purchase subsidy of $7.50/ton of fertiliser is available at present. The effect of this subsidy on N fertiliser prices is not included in the table.

Figures for 1965-1969 supplied by O. Griffin. (pers. comm.). Figures for 1970-72 are average yearly prices at Awatoto fertiliser works.

DAP is a compound fertiliser consisting of 18%N and 20%P and is manufactured by reacting Phosphoric acid with ammonia. At present prices, it is slightly more expensive than a mixture of the equivalent amount of S/A and superphosphate. A further disadvantage is that DAP contains only 3% sulphur. However, with the price of phosphoric acid also falling overseas 2/, this fertiliser may become competitive with present N fertilisers in the future if pasture responses are satisfactory. The effect of DAP on pasture productivity could not be assessed in the present study because most experimentation has been conducted with urea or S/A.

1/ See Table 1.1

2/ Roberts (1967).

Neither urea or S/A are leached rapidly from the soil. Losses of ammonia to the atmosphere can occur, however, when urea is applied to the surface of the soil, although these losses are unlikely to be of practical importance unless high rates of urea are applied. Losses with urea can be reduced to a minimum if it is washed into the soil immediately after application by rain or irrigation water 1/.

S/A has an acidifying effect on soils and During (1967), on the basis of Department of Agriculture trials, suggests that approximately 130 lbs of lime are required to counteract the soil acidity caused by 100 lbs of S/A. Its fine particle nature may also cause it to lodge on herbage, particularly clover and flat weeds, causing 'scorching' at heavy rates of application 2/.

However, Ball (unpub.), found no difference in efficiency, or effect on pasture composition between urea or S/A, so it would appear on economic grounds that urea is the more favourable form of N to use. This may explain why urea sales have represented an increasing proportion of total N fertiliser sales in recent years, (Table 1.1).

Australia, despite an upsurge in consumption of ammonia fertilisers, now faces an over-production problem, and it has been suggested that, if imported in large quantities, further reductions in N fertiliser costs in New Zealand may occur 3/. As the use of higher analysis N fertilisers involves the application of a concentrated liquid at or below the soil surface, a considerable initial investment in high pressure tanks, sophisticated metering devices and injection devices, would be required. There is also the annual cost involved in servicing and maintaining the plant and added precautions required for application such as the need for protective clothing. It is unlikely that demand for such an imput will occur until it can be demonstrated that the regular application of N to large areas of the farm is economically justified.

Although the decline in N fertiliser costs has been accompanied by a general increase in demand as shown in Table 1.1, information is not available to partition this demand between the different farming

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1/ During (1967).

2/ Ball (pers. comm.).

3/ Walton (1971).

industries. Consequently, the amount of N used on seasonal supply dairy farms at present is unknown. However, McKenzie (1970) surveyed commercial firms in Taranaki and found that the percentage of dairy farmers using fertiliser N had risen from 12.1% in 1966/67 to 25.2% in 1968/69. These figures indicate tht farmers are in the process of exploring and evolving systems of production using N fertiliser. However, as yet there is little research information available on how N fertiliser could be most profitably incorporated into dairy farm management systems.

1.4 OBJECTIVES OF THE STUDY

The objectives of the study are to examine in detail both technical and economic factors associated with fertiliser N use in seasonal supply dairy farming. The conditions under which fertiliser N, at present prices, is likely to be profitable are to be defined and pasture management adjustments that should follow N application to ensure that the pasture response is fully utilised are to be established. Adjustments to N use that should accompany any further reductions in N cost or changes in butterfat price will also be examined.

1.5 THE APPROACH ADOPTED

The possibility of assessing the economics of N fertiliser use by surveying farmers known to have used this input was considered 1/, and approximately twenty farms in the Levin/Otaki area were visited. While valuable information was gathered on the technical aspects of N fertiliser use, information on economic factors proved disappointing.

Many farmers were still in the process of testing N to see if they could obtain a reliable pasture response on their farms and had not taken steps to ensure that any increased growth was efficiently utilised. Consequently, any response that has been obtained was not reflected in farm output.

Of those farmers who had incorporated N permanently into the farm plan, their use of it was largely confined to hay and silage paddocks or to small grazing areas for newly calved cows in early spring. While enthusiastic about the responses obtained at this particular time of the year, most had not yet tested applications at other times of the year, although many expressed interest in doing so in the future.

1/ Graham (1963) had conducted a survey in Taranaki to investigate the profitability of high rates of fertiliser application.

In the author's opinion, the limited use of N, both in amount applied and time of application provided insufficient information to conduct a full economic evaluation of the potential for N use. Consequently, it was decided to construct a mathematical model of a grazing system for this purpose, rather than persist with the farm survey in other dairying areas.

The objectives of the study were extended to include a consideration of major problems to overcome in developing a realistic grazing model. It was expected that limitations would be imposed because of insufficient experimental data. The construction of a model, however, does allow a 'stocktaking' of available information to be made so that areas where further research is required can be indicated.

1.6 ORGANISATION OF THE STUDY

In Chapter Two the grazing complex is discussed and in Chapters Three and Four the grazing model is developed. Chapters Six, Seven, and Eight outline the experimental work conducted on the model and the results obtained. In Chapter Nine, limitations of the study are discussed and Chapter Ten presents a summary of results and conclusions.

CHAPTER 2

THE GRAZING COMPLEX

2.1 INTRODUCTION

In this chapter, the grazing management problem to be studied is specified, and the selection of an appropriate technique to solve this problem is described.

2.2 A DESCRIPTION OF THE SEASONAL DAIRY FARMING GRAZING MANAGEMENT PROBLEM

The objective of grazing management is to most efficiently allocate available feed resources to revenue-producing animals throughout the year. Problems arise when defining the factors that constrain the physical performance of the system, because of three main difficulties inherent in the nature of the grazing complex.

2.2.1. Uncertainty

The decision making environment is characterised by climatic and economic uncertainty. Decisions must reflect a compromise between planning on the most likely course of future events and minimising the penalty of making a wrong decision.

2.2.2. The influence of time

The process of animal production occurs over time, hence grazing involves decisions about the timing, as well as levels, of inputs used in the production process. Because of the nature of the inter-relationships among variables in animal/pasture production systems, the timing of one decision can affect the decision possibilities at future times. In this context, management decisions are interdependent over time.

2.2.3. Interdependence between system components

The interdependence between most variables means that adjustments to one factor can rarely be made without inducing changes in other factors.

An attempt is made in this study to describe the physical and biological nature of the dairy production system. Once this is accomplished, economic experiments may be conducted.

2.3 THE GRAZING SYSTEM MODEL

The grazing system is considered to be composed of four major sub-systems . The components and the primary output of each sub-system are shown in Table 2.1.

The output of each sub-system represents a component in another sub-system. Components can be common to different sub-systems. For example, the frequency and severity of grazing, besides influencing available pasture at a particular grazing will also affect future pasture production. Therefore, the performance of the system as a whole will depend on the type of relationships existing both within and between each sub-system.

In the past, much of the agricultural research effort in New Zealand has been concerned with specialised fields within each of the sub-systems in Table 2.1. The aim is to provide knowledge that can be used to synthesise more efficient animal/pasture production systems. It is possible that systems modelling could be a useful research technique in the area of synthesising and evaluating alternative production systems. However, this study is mainly concerned with the problems of building such a model rather than with questions concerning the relative merits of alternative methodologies in systems research.

As published information was frequently not available, the author was dependent to a large extent on subjective estimates concerning the nature of various relationships required by the model. Research workers at the Department of Scientific and Industrial Research, at Palmerston North, and staff at Massey University, were frequently consulted and many expressed interest in the project, and the concept of systems research [1/]. Particular interest was expressed in the potential that the systems approach might offer for an increase in the efficiency of research efforts and eventual application of research results under practical conditions. Again, however, an evaluation of the potential benefits from a systems research approach in these areas is largely beyond the scope of this study.

1/ Wright (1970) discusses systems concepts and systems research in detail.

TABLE 2.1 THE GRAZING SYSTEM

SUB-SYSTEM	COMPONENTS	OUTPUT
1	Pasture composition Soil type Climatic factors Soil nutrient availability Frequency and severity of grazing Treading effects	PASTURE GROWTH
2	Pasture growth Pasture trampling and decay Frequency and severity of grazing	PASTURE AVAILABILITY
3	Pasture availability Pasture utilisation Stocking rate Amount of supplementary feed available Productive state of the animal Feed palatability	ANIMAL INTAKE
4	Animal intake Feed quality Food conversion efficiency Animal liveweight Stage of lactation	ANIMAL PRODUCT

2.4 SYSTEMS MODELS AND SOLVING PROBLEMS

Given an adequate model of the production system of interest, solution to decision making (management) problems can proceed via analytical or numerical methods. The particular method used for obtaining solutions depends largely on the mathematical nature and complexity of the model that has been used to describe the production system of interest.

Dillon and Burley (1961) have discussed the problems involved in using analytical methods to investigate grazing management problems.

Numerical methods for solving problems may use iterative or experimental procedures. Where linear programming (LP) has been used to model the production system of interest, an iterative technique is used to determine the system that maximises some objective function [1/]. Where simulation has been used as the modelling technique, experimental procedures are used to obtain solutions to management problems. In this case, decision rules are imposed on the model and results are observed over a number of 'runs'. In this way the behaviour of the system over a number of years, under a given set of decision rules, can be predicted. We can then experiment with different decision rules in an attempt to obtain new and improved production systems.

Linear programming and simulation are two of the mathematical modelling techniques that can be used to describe a production system. Associated with the LP model is an iterative method that allows us to determine the optimum solution to a problem, whereas with a simulation model the optimum solution to a problem is approached via a process of experimenting with the decision rules in the same way as experiments are conducted with real systems. Differences exist, however, between LP and simulation as methods for describing production systems. In using simulation models, no restrictions are placed on the mathematical forms of the functions used to describe the system of interest. The restrictions associated with LP as a model may or may not be important, but the main requirement of any model is that it should be capable of adequately reflecting the nature of the biological and economic relationships involved in the problem context of interest. The major limitation of

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1/ For example, profit/acre/year.

LP in this respect is its deterministic nature, and although attempts have been made to overcome this in order to adapt the technique to decision making under risk [1/], it is suggested that simulation has greater potential in this area as stochastic relationships can be incorporated into the model [2,3,4/].

2.5 SIMULATION

Climate represents a major source of variability in the performance of a grazing system, especially through its action on pasture production. Consequently, it was decided to investigate the possibility of constructing a simulation model that would take into account the effects of climatic variability on grass growth.

Published simulation studies of individual farm systems are reviewed by Wright (1970). Few studies have taken full advantage of the potential of this technique for studying the uncertainty of the real world decision making environment; in particular the effects of climatic uncertainty on grass growth. This may be largely due to the lack of statistical data on the frequency distribution of grass growth throughout the year and its relationship to climatic factors. The influence of climate is further complicated by the fact that climate parameters may not be independent.

Only one stochastic climatic element has been included in most published simulation studies [5,6/]. Wright (1970) justifies this approach by suggesting that:

> 'For most farming regions there is usually some one factor which is regarded as contributing the major climatic influence on a grazing system.'

1/ Heady and Candler (1963).

2/ Wright (1970).

3/ Hardaker (1967).

4/ Arcus (1963).

5/ Arcus (1963).

6/ Wright (1970).

Brougham (1959a) determined the effect of seasonal climatic, and temporary (weekly) weather variations on the growth rate of pasture and noted that more than just a single climatic factor exerts a major effect on pasture growth at different times of the year in the Manawatu region. It was demonstrated during the winter and spring months that weekly fluctuations in growth were closely associated with light and temperature variation. However, during the summer and early autumn when clover was the dominant pasture component, fluctuations in growth were associated with fluctuations in temperature. It is likely that soil moisture levels will also significantly contribute to growth fluctuations over this period, but the pasture was irrigated in the summer months and water was at all times adequate for growth. The experiment was conducted for only one year, pasture quality assessments were not made and interactions between weather effects and stage of growth could not be determined. Nevertheless, it does contribute a considerable amount of information towards the construction of a pasture growth model that incorporates the effects of climatic uncertainty. It is significant to note that this is the only published study for New Zealand conditions that was designed solely for the purpose of explaining pasture growth in terms of seasonal and weather effects that the author could find. It is precisely these effects that must be assessed when planning ahead under practical farming conditions.

Wright (1970) discusses the need to have a balance of detail throughout the model. In the light of this discussion, the author felt that there was little to be gained from spending a considerable amount of time in specifying complex pasture growth/weather relationships when similar detail could not be obtained in other parts of the model. The fragmentation of New Zealand research effort into specialist fields of pasture production and animal nutrition has resulted in a considerable lack of knowledge on relationships existing at animal/pasture interfaces. For example, very little information exists on the effects of the grazing animal on pasture growth or the validity of results obtained from mowing trials as compared with the same treatments under grazing conditions.

Owing to the severe limitations on time and information, only an extremely simplified simulation model could have been built. A more detailed model of pasture growth relationships for a particular period of the year, (say the critical late winter/early spring period), could have been attempted 1/, but again deficiencies in supplementary information on animal/pasture relationships would have limited the approach. Also, as most factors involved in grazing management interact throughout the year, it is necessary to know the longer term effects induced by a particular decision, so that its outcome may be fully evaluated. For example, a change to later calving may result in better per cow feed supply in early lactation but a dry summer period and shorter lactation length may result in earlier calving being more profitable. As well as the factors mentioned above, this approach would have placed a considerable restriction on the range of possible uses of N that could have been studied.

Consequently, it was decided to build a deterministic model of a grazing system using LP, and concentrate particularly on the effects of grazing frequency on pasture growth and availability for an 'average' year. A per cow butterfat response function was also incorporated into the model to take into account the effect of variable feed supplies throughout the year on butterfat production and farm profits. These factors have received little attention in previous LP studies.

2.6 A BRIEF DESCRIPTION OF THE GRAZING MODEL

The grazing area in the model consists of one acre of productive ryegrass/clover pasture grazed by Jersey cows of high butterfat production potential. No attempt is made to include 'economies of size' considerations. The pasture area is used to meet the feed requirements of the cows. The management and provision of feed for young replacement stock is not considered. Provision is made for the production and feeding of hay and silage, the application of N to pasture and meal feeding. Butterfat and hay sales are the only revenue producing activities considered in the model.

Five stocking rates are considered 2/. The study is primarily concerned with the efficient organisation of feed resources for a given stocking rate. That is, only a stable situation based on different stocking rates is considered. No attempt is made to consider the organisation of resources required, or the profitability of a farm development programme.

1/ Suggested by A. Wright.

2/ 1.0, 1.2, 1.5, 1.7, and 2.0 cows/acre.

Each month was divided into two equal time periods, with the exception of October and November, which were divided into four periods. The small time intervals used were necessary for satisfactory experimentation with grazing frequency and N application. The use of weekly periods throughout the year would have been more satisfactory, but twenty-eight time intervals represented the limit for the model with available computing facilities 1/.

2.7 SUMMARY

Because of the stochastic nature of the inter-relationships involved, it appears likely that simulation models are most appropriate for systems modelling studies of grazing management systems. However, where little information is available on the stochastic nature of the inter-relationships involved, and which are the important stochastic variables, any 'first approach' systems modelling exercise will be largely deterministic in nature and based on 'average' conditions. In this situation LP offers a fairly comprehensive modelling framework and was chosen as the method of analysis for this study. It is possible that, in this 'lack of information' situation, simulation models are more efficient than LP models in synthesising relationships and exploring questions about the relative importance of different inter-relationships in the model, but such questions concerning the relative merits of alternative approaches in systems research are beyond the scope of this study.

The following chapters provide details of the information and assumptions used to construct the LP dairy production model.

1/ An IBM 1620 computer was used with a provision for a LP matrix containing only 250 rows.

CHAPTER 3

FACTORS AFFECTING PASTURE GROWTH

3.1 INTRODUCTION

This chapter outlines some of the important factors influencing pasture growth that were considered in the study.

3.2 ANNUAL PASTURE PRODUCTION

On the basis of results obtained from a cutting trial, Brougham (1959a) estimates that the potential annual yield of a short-rotation ryegrass/white clover pasture under summer irrigation in the Palmerston North locality is approximately 22,000 lbs DM/acre/year. Brougham suggests, however, that actual pasture growth recorded under grazing conditions is generally between 12 and 16,000 lbs DM/acre/year, because of low available soil moisture during the summer months and incomplete utilisation of light energy by the pasture, due to severe defoliations at different times of the year. The presence of the grazing animal would also cause further discrepancies between cutting and grazing yields.

3.3 THE EFFECTS OF THE GRAZING ANIMAL ON PASTURE GROWTH

Brougham (1968) demonstrated that differential defoliation of different species may result in marked changes in botanical composition and subsequent regrowth characteristics of the sward.

Animal excreta is a key factor in the circulation of nutrients through the soil-pasture-animal complex. Because of differential response of pasture species to the nutrients returned, changes in growth and composition of pasture can be large [1/].

With respect to cutting experiments, the grazing animal seldom harvests an area as completely as a mower. Forage may be rejected by the animal because of faecal contamination, trampling damage, poor palatability or simply because available forage is surplus to animal demands.

In cutting experiments it is difficult to assess the losses that would occur under grazing due to plant senescence and accumulated dead

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1/ Sears (1953).

matter. Much of this material is often included in the total dry matter yields obtained from cutting experiments. Under grazing conditions, much of the material not consumed may be rejected at subsequent grazings, resulting in only new growth being grazed [1]. This rejected material will die, accumulate at the base of the sward and affect regrowth characteristics of the pasture until this material aventually decays [2].

Mechanical damage to pasture, largely as a result of treading, may also significantly reduce total yields. Edmonds (1966) found that treading effects on pasture regrowth were largely related to the amount of trampling, (grazing pressure). Recovery growth was sigmoid although trodden pasture recovered at a slower rate. Plant competition was also altered by treading as white clover was damaged more than ryegrass.

More detailed experimentation on animal intake-pasture utilisation interactions is required before factors affecting pasture growth and decay under grazing conditions can be adequately quantified.

3.4 SPECIFICATION OF PASTURE GROWTH RELATIONSHIPS USED IN THE STUDY

A fundamental unit in any consideration of pasture growth is the growth curve, which describes the pattern of dry matter production with time, following defoliation. The slope of the growth curve at any point in time is defined as the pasture growth rate.

Brougham (1955) demonstrates that the general form of the pasture growth curve is sigmoid, and it is made up of three distinct phases: increasing, constant and finally decreasing growth rate with time following defoliation. The duration of the first phase of growth (increasing growth rate) is related to pasture leaf area and light interception. This growth phase continues until there is sufficient leaf area to intercept all incident light. The more intense the level of defoliation at a particular grazing, the longer it takes to attain the maximum growth rate, (Phase II).

The duration of Phase II is dependent on factors such as climate and the season, the species in the pasture, the fertility of the soil, the incidence of pests and the effects of plant diseases, mutual

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1/ Greenhalgh (1970).

2/ Campbell (1964).

competition for light and other growth factors, and aging and death of leaves. All of these factors determine the commencement of the third period of growth, where the growth rate declines and finally stops or even show a negative value, as occurs in autumn saved pasture under long spelling [1].

Initially growth curves for pasture, from time of defoliation, at monthly intervals throughout the year were derived. These curves were largely based on results from cutting trials published by Brougham (1955, 1956a, 1956b, 1959a) and unpublished experimental data from Ball. With considerable assistance from staff members at the D.S.I.R. [2], the growth curves were then adjusted to reflect likely dry matter yields and seasonal trends [3] occurring under grazing conditions in the Manawatu environment for an 'average' year.

The relationship between dry matter production and length of spell following defoliation for each curve is shown in Appendix 1. Growth curves from the time of defoliation, at fortnightly intervals, were extrapolated from these monthly relationships. The growth curves were not altered for 'experimentation' with the different stocking rates used in this study, as Campbell (1969) and Smith (1964) have observed that under similar systems of grazing management, increased stocking rate has little effect on total annual dry matter production.

3.5 THE EFFECTS OF N FERTILISER ON PASTURE PRODUCTIVITY [4]

3.5.1 Available experimental results

A large number of experiments involving artificial N application to mixed swards have been conducted overseas. While these experiments are obviously of assistance to agronomists in planning experiments under New Zealand conditions, the results are of limited value because of different climatic conditions, pasture productivity, management practices, farm input costs and animal product prices.

1/ Brougham (1960).

2/ Particularly J. Lancashire.

3/ Climatic effects are assumed to follow regular seasonal trends.

4/ The effects of soil availability levels of other important plant nutrients on pasture growth are considered in detail in Chapter 7.

Experimentation in New Zealand has largely been confined to the application of single strategic dressings of N to pastures. Experimental work in this country has been briefly reviewed by Cumberland et al (1970). Results have been characterised by widely differing responses and extreme variability within experimental treatments. In addition, most experimental reports have not measured pasture characteristics, climatic factors during the experiment or soil conditions, and attempts at interpreting the results in terms of these important factors are rare. The publishing of this data is important as it is only in this way that a reliable body of information on these factors can be built up, and used to predict responses to N fertiliser. Without this information, little attempt can be made to explain the large amount of variability both within and between experiments, and only inaccurate predictions of both size and reliability of response can be made for a given set of farming conditions.

3.5.2 Factors affecting short-term response

In the past, N use has been recommended, if at all, as a strategic 'single application' for the production of 'out of season' grass. That is, N has been applied to pasture during the colder periods of the year when N mineralisation rates from soil organic matter have been low, causing periods of temporary deficiency in soil N availability. The application of N at such periods produces grass for newly calved cows before the onset of the spring flush of growth.

Present information on the factors affecting responses to small, single applications of N can go no further than suggest that, length of spell following application, time of application and amount of N applied, are important. Best results are obtained on freshly grazed, high producing pasture, on well-drained or free-draining soil with adequate moisture supply following application. In other words, the response to fertiliser N is likely to be greatest and most reliable under conditions that best suit grass growth, except in the late spring-early summer period. Here, although conditions appear ideal, ryegrass response is variable but generally small. The reasons for this are unknown, but may be related to the reproductive phase of ryegrass growth, or possibly high soil N content at that time of the year 1/.

1/ Ball (pers. comm.).

It is generally accepted that the addition of N fertiliser reduces the proportion of clover in the pasture, and that the response to a given rate of N is related to the initial composition of the sward 1/. Low rates of N on clover dominant pasture may even result in reduced total yield, (Figure 3.1).

Brougham and Ball (unpub.), however, have retained clover on irrigated pasture fertilised with high rates of N.

Further work relating to the effects of different rates of N on pasture composition is vital, especially if longer term effects on pasture yields are to be evaluated.

3.5.3 Effects lasting beyond the initial response

(a) Short-term beneficial effects

Trials conducted overseas indicate that the initial response as measured over, say, a 7-8 week response period is generally less than the total response, as residual effects measured at the second harvest following a N application have been consistently recorded. Stubbs (1969) suggests that N, besides encouraging top growth to produce a rapid response at the first harvest, may also increase root growth and protein content of the grasses, so enabling the grass plants to forage more successfully for nutrients and moisture and so rebuild grazed off plant tissue faster.

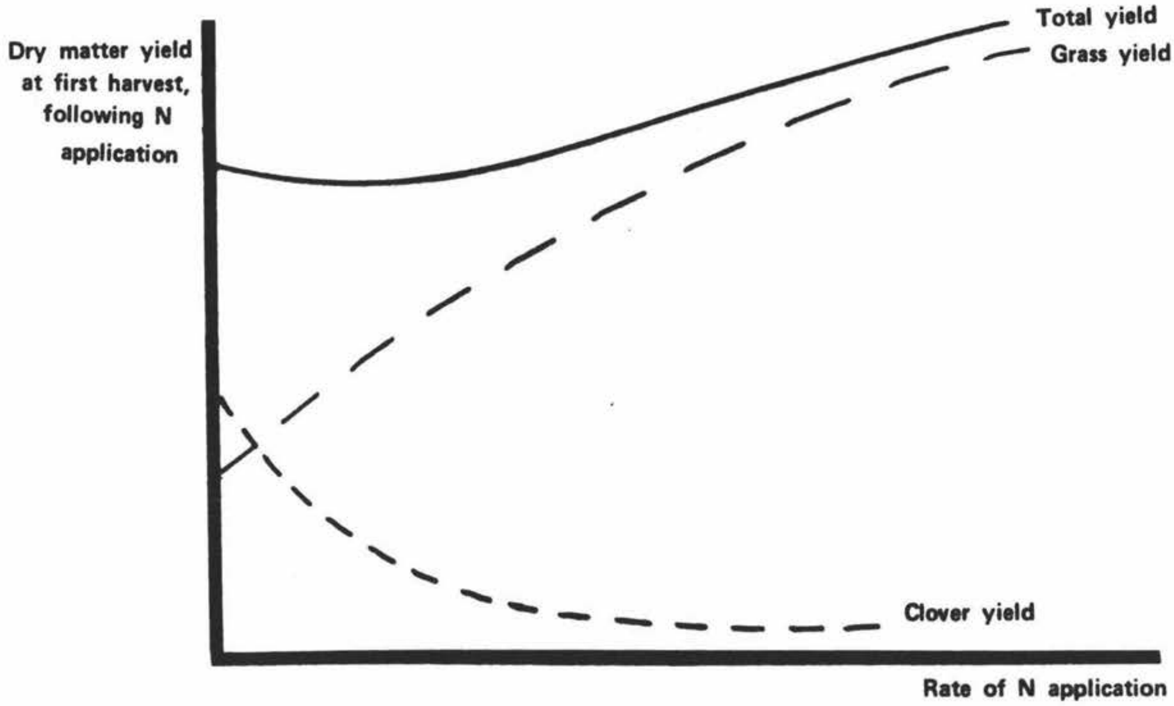
Most experiments in New Zealand, however, have measured only the immediate response and so residual effects of this nature have not been reported.

(b) Adverse longer term effects

During (1967) discusses a 'slump' in growth following N application, that was reported by many workers in the 1930's and occasionally since then. The slump appeared to occur mainly with late winter/early spring application of more acidifying fertilisers such as S/A, and often extended from mid-spring well into summer. The major drawback in explaining and attempting to predict the amount subsequent pasture growth will slump following N application, is that interactions occurring between pasture species under grazing conditions are not fully

1/ Walker (1956).

FIGURE 3.1 EFFECT OF NITROGEN APPLICATION ON CLOVER–DOMINANT PASTURE YIELD AT FIRST HARVEST



understood. Walker (1956) suggests that the slump is due to clover suppression, (demonstrated in Figure 3.2).

The stimulation of grass growth by the addition of N fertiliser enhances its ability to compete for light, nutrients and moisture supply, thereby reducing clover composition of the sward for a considerably longer time than the initial response period.

This raises the possibility that fertiliser N, rather than raising the potential pasture productivity level, may just redistribute pasture growth patterns. If this occurs, a decision to apply N for early spring growth must take into account reduced pasture growth later in the season. If clover is severely depressed the application of N for early spring grass may create a position of dependence on further artificial N supplies for adequate pasture production later in the season.

On the basis of recent experimentation, this would appear to be a pessimistic view. Ball and Field (unpub.) have applied high rates of fertiliser N [1/] in single applications to mixed swards without detecting the slump effect. Walker (1956) concludes that N fertiliser will suppress clover less if sufficient nutrients are available to meet the needs of the extra grass growth and still leave adequate supplies for clover. When using N fertilisers to produce spring grass, it may therefore be possible to restore vigorous clover growth for summer production by applying a proportion of the annual application of Phosphorus, Potassium and Sulphur fertilisers in the November/December period.

3.5.4 The value of results obtained from mowing trials

Mowing trials have provided the basis for most New Zealand experimentation into both the short and long-term effects of artificial N use.

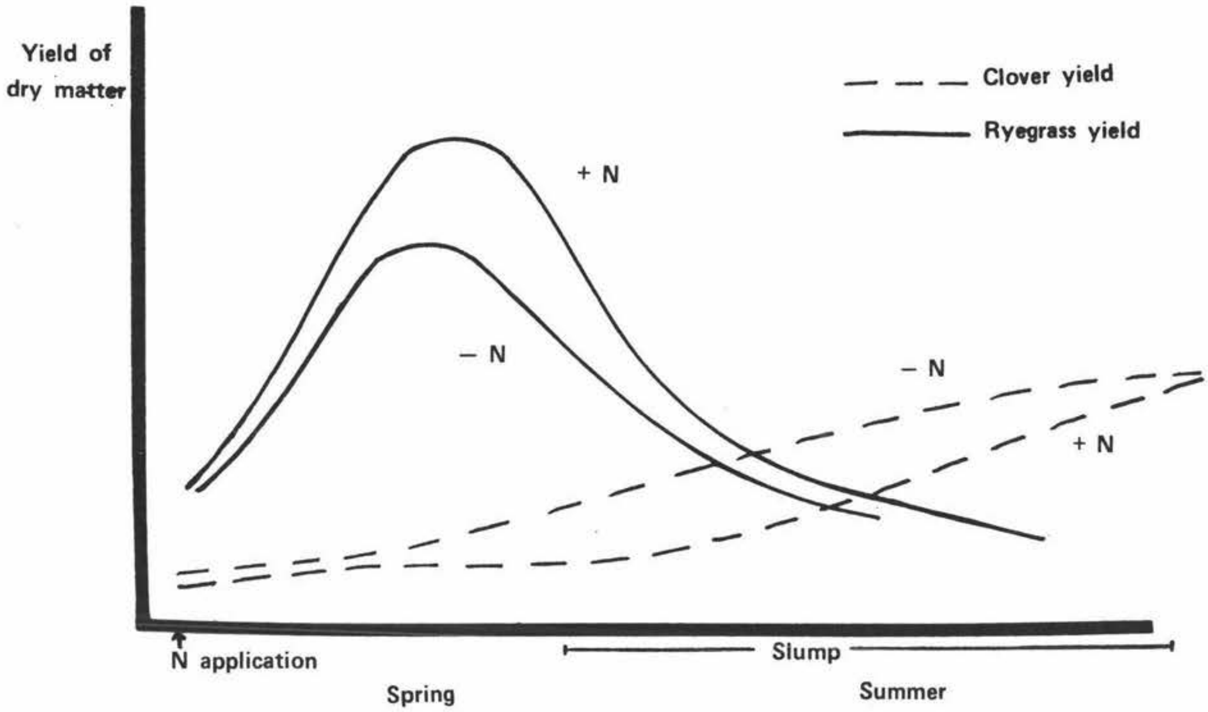
Mowing pasture over long periods increases the clover component of the sward relative to grazed plots [2/]. Therefore, as the magnitude of the 'slump' in growth following N application is largely related to the clover content of the sward [3/] conclusions drawn from long-term mowing trials used to evaluate the effect of N may be erroneous.

1/ Up to 160 lbs N/acre.

2/ Watkin (1952).

3/ Section 3.5.3(b).

FIGURE 3.2 LONGER TERM EFFECTS OF NITROGEN APPLICATION ON PASTURE YIELD



Also, in cutting trials, there is no accurate method of allowing for the recirculation of N through animal returns. Watkin (1954) has demonstrated beneficial effects from this recirculation. Ball (unpub.) found widely differing results following the initial response between grazed and mown plots subjected to the same N treatment.

It would appear, therefore, that results obtained from single applications of N fertiliser to previously grazed pasture would validly represent feed available under grazing conditions at the first cutting, but results obtained subsequent to this harvest on botanical composition or pasture yield are of little use in explaining pasture productivity that would follow under grazing conditions.

If agronomists are to persist with N fertiliser cutting trials, greater emphasis must be placed on attempting to simulate the effect of the grazing animal, particularly with respect to the cycling of N through dung and urine, and the consequent effects on pasture yield and composition. Such information is vital as results from cutting experiments have to be related to practices involving grazing.

3.5.5 Multiple N applications

Very little experimentation involving multiple applications of N throughout the year to the same area has been conducted in New Zealand. Karlovsky (1964) with trial plots continually grazed by sheep, and Weeda (1964) with a long-term cutting trial, both reported negligible yield increases in response to high annual rates of N fertiliser. A feature of these trials was the deterioration of the sward composition with clover being replaced by weed species.

Brougham and Ball (unpub.) have, however, found that high annual rates of N fertiliser applied after each grazing can considerably increase annual yields without adverse effects on sward composition.

The objective of these trials was to establish ceiling levels of production for grass/clover swards, rather than to determine what is economically feasible for the farmer. Even if the price of N dropped considerably, it is unlikely that the farmer would be best advised to apply N at fixed intervals. It would depend entirely on when feed shortages occur, the effect on botanical composition and future pasture yields, and whether N use could be economically competitive with alternative feed sourced.

3.5.6 Effects of N fertiliser on pasture quality

Raymond and Spedding (1965) indicate certain situations where pasture quality may be affected by N applications. By reducing the contribution to pasture yield of the more digestible clover component, digestibility may be reduced. By producing more new growth, the digestibility of the older pasture remaining from previous grazings may be diluted, thereby raising the average digestibility of feed on offer. However, the overall effects must be slight as most overseas experiments report insignificant effects on forage digestibility from the use of widely differing rates of N fertiliser 1/.

3.5.7 Specification of N response relationships

Response data was derived entirely from experiments conducted by Ball 2/ (1969, 1970, unpub.), as the information available from these experiments best met the data requirements of the production system under investigation. A number of trials were examined in detail, but the bulk of the data was obtained from seven growth rate trials beginning at approximately monthly intervals from mid-April 1969 until early October of the same year. Where results for a particular treatment appeared atypical 3/ other experiments were consulted, so that a system of relationships involving rates of N application, lengths of spell and times of application were gradually built up.

These relationships, for N applied at monthly intervals between April and October, (excluding June 4/), are shown in Appendix 2.

Obviously, these relationships only apply under the narrow range of experimental conditions that prevailed during the course of the trial. However, by experimentation with the model some idea of the effects of variation in N response on both N use and farm profits could be gauged.

1/ Blaser (1964).

2/ D.S.I.R., Palmerston North.

3/ Mainly because of pasture sampling errors or abnormal weather conditions.

4/ N Applications have not been considered in June because responses are small and unreliable, Ball (1969).

3.5.8 Assumptions made in the study concerning N use

Due to limitations imposed on model size and through deficiencies in experimental data outlined in the previous sections, assumptions made regarding response to N provide an extremely simplified representation of the real world situation.

The assumptions made are listed below:

(i) N response is a function only of the amount of N applied, the length of spell between application and grazing, and the time of application. The nature of the assumed pasture growth relationships and the shortage of experimental data on factors influencing the response to N did not justify other variables being included.

(ii) Results indicated that responses to single N applications were roughly linear up to 50 lbs N/acre, but fell off markedly as N rate was increased above this level. Consequently, only rates of 50 and 100 lbs N/acre at one application are considered as alternative N activities.

(iii) Only single applications of N between grazings are considered as production possibilities in the model.

(iv) The pasture response corresponding to each N activity is independent of all other N activities. This means that the application of N following a grazing will in no way modify responses obtained from subsequent N applications to that same area of pasture. That is, no residual or slumping effects are assumed to occur regardless of the total amount of N applied to a given area.

(v) All pasture is considered suitable for N application, and any application is assumed to be made immediately after grazing.

(vi) The quality and palatability of N fertilised pasture is assumed to be the same as unfertilised pasture.

(vii) Other possible advantages with N fertilised pastures such as reduced bloat incidence because of a reduced clover component have not been considered.

(viii) The N responses are assumed additive to pasture production production in each period.

Figure 3.3 shows the regrowth curves after grazing of pastures fertilised with 0, 50 and 100 lbs of N in August. (From Appendices 2.1 and 2.2).

3.6 THE EFFECTS OF GRAZING MANAGEMENT ON PASTURE GROWTH

The components of grazing management considered in the study are grazing frequency and severity. Grazing frequency refers to the length of time for which pasture is spelled between successive defoliations, whereas grazing severity refers to the level to which pasture is grazed at each defoliation.

3.6.1 Effects due to the shape of the growth curve

Because pasture growth curves are not linear, the frequency and level of defoliation imposed on a grazing system would be expected to influence total pasture yield. Brougham (1956b) subjected a ryegrass-clover pasture in spring to three different intensities of defoliation by cutting it down to 1,3 and 5 inches. He demonstrated that the intensity of defoliation has no bearing on the maximum growth rate attained 1/ but only on the initial rate of regrowth and duration of Phase I. In this experiment, pasture defoliated to 5" yielded approximately 100 percent more dry matter in the first fourteen days of regrowth than the 1" defoliation treatment. These results suggest that for maximum production of herbage, the amount of leaf left following grazing should be sufficient to ensure complete interception of light, to maintain growth at the maximum rate. Thus, the farmer should control grazing severity as well as frequency for increased pasture production.

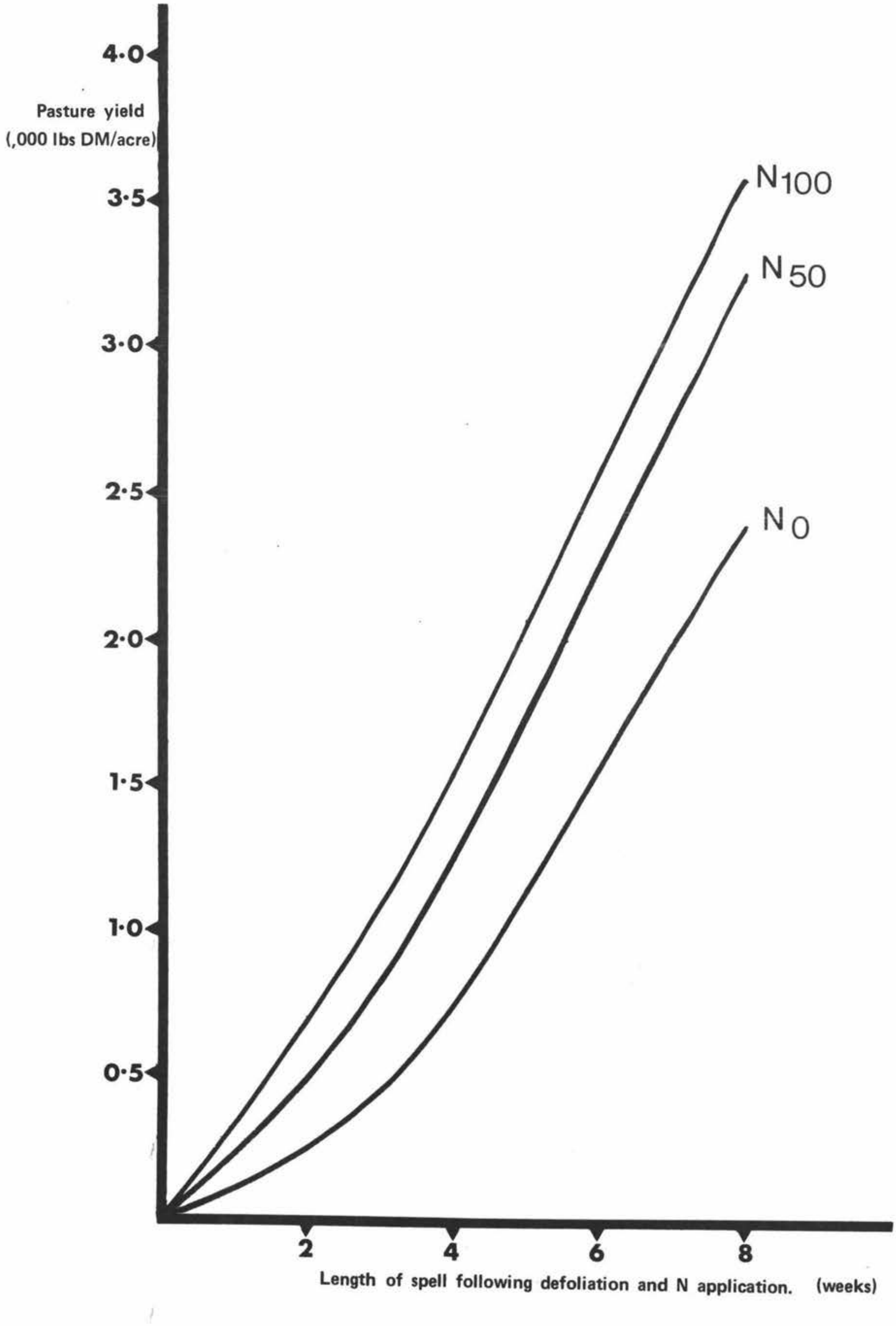
Effects of grazing frequency on pasture growth due to the shape of the growth curve are examined in greater detail in Chapter Four.

3.6.2 Effects of grazing management on pasture composition and subsequent regrowth characteristics

Brougham (1959b, 1960) has demonstrated that pasture productivity can be influenced in any year by the severity and frequency of grazing.

1/ Phase II of the sigmoid growth curve.

FIGURE 3.3 REGROWTH CURVES FOLLOWING DEFOLIATION IN MID–AUGUST, FOR PASTURE FERTILISED WITH 50 AND 100 lbs N/ACRE, AND UNFERTILISED PASTURE.



Differences in pasture growth patterns over a season can be produced by different grazing management practices. The growth patterns are determined by species tolerance to the grazing systems, and the action of weather factors on the growth of pastures that differ in herbage cover and botanical composition.

Brougham (1959) subjected a pasture consisting of short rotation ryegrass, red and white clover to four combinations of frequency and intensity of grazing over a two-year period. For each grazing severity treatment, (1" and 3" of pasture remaining after grazing), there were two grazing frequency treatments. (Grazing occurring at pasture heights of 3" or 9" on the severe grazing treatment, 7" or 12" on the lax grazing treatment). Considerable differences in botanical composition and therefore seasonal pasture production occurred between these treatments. Red clover yielded equally well under long spelling or frequent grazing provided the grazing was not severe. The growth of white clover was highest under frequent grazing whereas the growth of ryegrass was favoured by long spelling between grazings. Annual pasture production was highest under long spelling treatments although annual yields were also high under frequent, lax grazing. Annual pasture yields were markedly reduced by frequent severe grazing. This system induced low soil moisture availability levels over the summer/autumn months which resulted in widespread death of ryegrass plants. Consequently, pasture yields in the following winter were also reduced.

3.6.3 Grazing systems providing high annual pasture yields

Brougham (1959b) suggests that the management system based on frequent lax grazing may have some advantages over long spelling, although both produce similar total yields. In the former system, at all times of the year, the herbage eaten by the grazing animals is leafy and provides a high protein diet. By comparison, the feed offered to the animals in the long spelling system of management is at times less palatable because of the increased production of seedhead over the summer and a higher proportion of stem tissue. Brougham concludes, however, that probably neither system of management is fully satisfactory, as the productivity of this pasture type under different management systems shanges with the season.

Under practical conditions, feed shortages occurring during the year usually result in rotation speed being increased, (more frequent defoliation), and more intensive grazing. In an attempt to determine the immediate and subsequent effects of over-grazing on pasture productivity, and management adjustments that should be made to prevent this occurring, Brougham (1960) designed an experiment in which the following six treatments were applied to pasture and results observed over an 18 month period. Frequent hard grazing from 3" to 1" throughout the year, frequent less intensive grazing from 7" to 3" throughout the year and four treatments involving frequent hard grazings in each of the four seasons with frequent less intensive grazing for the remainder of the year.

The results suggested that the grazing system that provided a maximum sustained yield of herbage throughout the year involved less intensive grazing of pasture over the spring, summer and autumn period combined with hard grazing over the late autumn and winter. Severe grazing in the spring reduced immediate yields but because weather conditions are favourable for growth, no long-term adverse effects on species performance occur. Less severe grazing in summer, however, is required to ensure the persistency of pasture species so that subsequent yields are not adversely affected. Brougham suggests that this can be achieved by the supplementary feeding of conserved grass products or crops over this period to relieve the demand on available pasture. A severe grazing of all pasture in late autumn is recommended by Brougham to bring about a rapid change in botanical composition to grass dominance at this stage to allow high yields to be obtained in winter. Relatively high yields of herbage can be obtained from frequent intensive grazing of pasture during the winter, as this practice allows light to penetrate to ground level and encourages growth and tillering of grasses. Long spelling of pasture over the late autumn/winter/early spring period results in reduced dry matter yields and poor recovery growth in the spring.

Based on grazing management studies such as those described, Brougham (1970) indicates the pasture management system he considers desirable for ryegrass/clover pasture in the Manawatu environment and suggests that such a system should frequently provide annual dry matter yields of 16 - 17,000 lbs DM/acre. This system is described in Table 3.1.

TABLE 3.1 A GRAZING MANAGEMENT SYSTEM LIKELY TO PROVIDE HIGH ANNUAL DRY MATTER YIELDS

	Winter	Spring	Summer		Autumn
Spelling interval between grazings (weeks)	6–8	3–4	4–5	HARD GRAZE	4–6
Grazing intensity (ins)	1–2	1–3	3–4	1	1–2

Such a management system under seasonal supply dairy farming conditions, however, may not prove to be the best possible for supplying large amounts of high quality feed to the grazing animal when requirements are greatest. For example, long spelling between grazings over the late autumn and winter may be necessary to ensure sufficient feed for newly calved cows in late winter/early spring. More frequent grazing over the winter may increase pasture growth but animal requirements are low at this time of the year. Also, should regrowth be slow because of adverse weather conditions in the late winter period, underfeeding in early lactation may result in severe milk production 'carryover' effects later in lactation. This practice may therefore incur heavy financial penalties in some years.

3.6.4 The potential offered by grazing management models

If sufficient quantitative information was available, a grazing management model could prove to be a valuable aid in deriving a grazing system best suited to seasonal supply dairy conditions. Such a model would require information allowing both frequency and severity of grazing to be variable. Growth curves could be constructed for pasture subjected to different levels of defoliation throughout the year. The area grazed in each period, for a specified level of grazing intensity would then be determined by the shape of the growth curves and the pattern of animal requirements. However, as discussed, grazing frequency, (therefore area grazed, and so rate of movement around the farm in a practical farming situation), will modify the growth relationships assumed because of changes in the botanical composition of pasture. These effects could be taken into account only at considerable expense in terms of model complexity and computer operating time. Variability in pasture growth due largely to the influence of weather, would also be necessary to accurately define the pasture production system.

Because insufficient experimental work has been conducted to adequately describe these relationships, and also because of limited computing facilities, the pasture production model developed in the study is an extremely simplified representation of an actual pasture production system. The dry matter yields shown in Appendix [illegible] are relative figures, and they represent the amount of dry matter that is produced, above a minimum defoliation level, and so is available for grazing. Obviously, the regrowth curves assumed must apply to some minimum level of defoliation which, in turn, induces a specific pattern of pasture compositional change throughout the year. However, despite the importance of pasture composition in modifying responses obtained to N fertiliser, the pasture composition characteristics and the grazing height assumed in each season cannot be specified, neither can information be provided on changes in growth that would occur if this grazing height was altered. Consequently, grazing severity is not included in the study as an experimental treatment.

3.7 SUMMARY

In this chapter, pasture growth relationships used in the study have been specified.

Important factors affecting pasture growth, particularly grazing management and the use of N fertiliser are discussed.

The potential offered by grazing models in pasture management research is noted and some of the problems associated with developing realistic models are discussed.

CHAPTER 4

PASTURE AVAILABILITY AND UTILISATION

4.1 INTRODUCTION

In this chapter a pasture production model that supplies feed in each period in response to animal demands is developed. Factors affecting utilisation of feed made available are also discussed.

4.2 ESTIMATION OF PASTURE AVAILABILITY

Under practical dairyfarming conditions, the manager controls the amount of feed available to the grazing animal by controlling the area grazed. This, in turn, determines the speed of rotation around the farm. The area grazed and the feed available on this area, relative to the level of animal consumption, determines to what height pasture is grazed, (the severity of grazing).

The estimation of pasture availability is therefore extremely complicated, as different areas of the farm are grazed at different points in time, and may be subjected to different frequencies and levels of grazing.

4.3 ESTIMATING THE EFFECTS OF GRAZING FREQUENCY ON PASTURE AVAILABILITY

It was originally thought that by surveying farms where paddock grazing records were kept, some idea of the area grazed, and the length of spell of pasture grazed in each period could be obtained. This, together with the information contained in Appendix 1 could be used to determine pasture availability in each period, if the assumption was made that the level of defoliation throughout the year was constant.

By using this approach, however, the response to N fertiliser for any period may be incorrectly evaluated. As the response to N fertiliser is a time dependent relationship 1/ the current defoliation pattern may be unsuited to N fertiliser use. In a feed deficit period, the response to N may be overvalued as a more suitable distribution of available feed may be accomplished by altering the grazing pattern.

1/ Discussed in Chapter 3.

By considering the periods when feed supply is scarce, and those when it is in surplus, adjustments could be made to the area grazed in each period, with consequent alterations to the frequency of defoliation and pattern of feed availability. However, the author considered this method likely to be extremely cumbersome and an inefficient use of computing facilities.

A more efficient method would be to build a model in which the area grazed in each time period was automatically adjusted to most efficiently organise feed resources, under given conditions of pasture production and animal demands 1/. It would also provide valuable information on grazing management adjustments that should accompany changes in stocking rate or N fertiliser use if pasture growth is to be efficiently utilised. An added advantage is that adjustments to the length of the rotation may significantly affect both seasonal and annual production of pasture due entirely to the general shape of the growth curve 2/.

4.4 THE PASTURE PRODUCTION MODEL

To test the importance of frequency of defoliation on pasture productivity, an LP model consisting of 71 LAND USE activities and 57 constraints (rows) was developed. Details of the Matrix are explained in Appendix 3.

Each LAND USE activity represents one acre of land spelled for a specific period of time following grazing. The pasture spelling lengths following grazing in each period were restricted within the range shown in Table 4.1.

1/ Because of the large number of potential grazing management systems that exist, it is possible that the optimising principle inherent in a L.P. model may provide a more efficient initial approach in this study than the experimental approach used with simulation models.

2/ As is discussed in Section 3.6, frequency of defoliation may also cause changes in subsequent pasture productivity because of changes induced in pasture composition. Such changes have been disregarded in the model.

TABLE 4.1 RESTRICTIONS ON THE LENGTH OF TIME PASTURE MAY BE SPELLED FOLLOWING GRAZING IN EACH PERIOD

Period	Minimum length of spell (weeks)	Maximum length of spell (weeks)
Jul. 2	4.4	10.4
Aug. 1	4.4	9.3
2	4.3	7.1
Sep. 1	3.8	4.9
2	2.7	3.8
Oct. 1	2.2	3.3
2	2.2	3.3
3	2.2	3.3
4	2.2	3.2
Nov. 1	2.2	3.2
2	2.2	3.2
3	2.7	4.9
4	3.9	6.1
Dec. 1	4.4	6.7
2	4.4	6.5
Jan. 1	4.3	6.3
2	4.1	6.2
Feb. 1	4.1	6.3
2	4.3	6.5
Mar. 1	4.4	6.5
2	4.3	8.7
Apr. 1	4.3	10.9
2	6.6	10.9
May 1	6.5	10.9
2	6.5	11.0
Jun. 1	6.5	11.0
2	6.6	11.0
Jul. 1	4.4	11.0

Grazing is assumed to occur at the mid-point of a period. For example, the spelling of pasture between NOV 3 and DEC 2 is illustrated below:

	NOV				DEC	
	1	2	3	4	1	2
			X			X
Date of grazing			19/11			23/12

Length of spell = 11 + 23 days = 4.9 weeks

4.5 EFFECTS OF FREQUENCY OF DEFOLIATION ON PASTURE PRODUCTION

Total annual pasture production (F.PROD) was maximised and then minimised, subject to the constraints outlined, to provide two completely different grazing patterns, so that monthly and total pasture production could be compared. The defoliation pattern and pasture yields obtained are presented in Table 4.2. Other grazing systems that would result in considerably less pasture production could be devised. However, within the constraints of the model, grazing frequency is still responsible for a range of approximately 2,000 lbs DM/acre/year in pasture production.

Although these results obviously represent unacceptable patterns of defoliation for a dairy farm, where animal requirements must be met in every period, they serve to illustrate that grazing frequency may be a major factor in determining both seasonal and annual dry matter yields.

4.6 THE EFFECTS OF LENGTH OF SPELL IN SPRING ON PASTURE PRODUCTION

Experimental work suggests that pasture can be spelled for a considerably longer period in the spring than is general under practical farming conditions 1/.

Brougham (1955) found that maximum production of herbage in spring could be obtained if pasture was grown to a height of 12-15" before harvesting, (after approximately eight weeks of growth). The grass-clover ratio of the sward remained constant for the first five weeks of growth and only changed slightly in favour of the ryegrass component in the following four weeks of growth.

Measurement of pasture quality and palatability were not made but Johns (1955) found pasture at a similar stage of growth to be of high

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1/ Most farms the author visited in the Levin/Otaki district were following a 2-3 week grazing rotation over the spring period.

TABLE 4.2 EFFECTS OF FREQUENCY OF DEFOLIATION ON TOTAL ANNUAL DRY MATTER PRODUCTION (lbs DM/acre)

		I	II	III	IV
Jul.	2				
Aug.	1	x	x	800	500
	2				
Sep.	1		x		700
	2				
Oct.	1		x		1,000
	2	x		2,600	
	3		x		650
	4				
Nov.	1	x	x	1,100	700
	2				
	3		x		700
	4	x		1,300	
Dec.	1		x		900
	2				
Jan.	1	x		2,350	
	2		x		1,900
Feb.	1				
	2	x	x	1,600	1,000
Mar.	1				
	2		x		850
Apr.	1	x		1,300	
	2		x		700
May	1	x		1,000	
	2				
Jun.	1				
	2	x		900	
Jul.	1		x		1,275
No. Grazings/ year		9	12		
Total pasture yield				12,950	10,875

Note: x denotes a grazing in this period.
Columns I and III refer to the defoliation pattern and pasture yields obtained when F.PROD was maximised.
Columns II and IV refer to F.PROD when minimised.

nutritive value 1/. Maximum spelling of pasture in September, October and November was therefore extended to the intervals indicated in Table 4.3, (17 additional land use activities were required), and F.PROD was again maximised. The defoliation pattern throughout the year remained unchanged from that in Column I (Table 4.2) except in spring when pasture was spelled between OCT 2 and NOV 4 yielding 3,200 lbs DM/acre at the NOV 4 defoliation. This raised the maximum annual pasture productivity to 13,750 lbs DM/acre, obtained from eight defoliations.

Problems in utilising feed may arise in spring, where long spelling of pasture between grazings is practised. However, data on the relationships between pasture utilisation 2/ and pasture availability per unit area is not available. Such a relationship would be expected to be important in the determination of optimum grazing frequency in spring, where long spelling will considerably increase feed availability per unit area at individual grazings.

While grazing frequencies found under different grazing management systems on farms are unlikely to exert effects on pasture productivity of the order shown here, this factor was thought to be of sufficient importance to justify its inclusion in the model. The pasture production model described, was extended to take into account hay and silage production and the addition of N to pasture, and was included as part of the overall grazing system model. The longer spelling activities in spring were also included in the model as permanent LAND USE activities.

1/ Quality was assessed on the basis of crude protein percentage.

2/ Pasture utilisation is used here in the broad sense, including mechanical damage and fouling of pastures as well as the relationship between animal consumption and feed availability.

TABLE 4.3 AMENDED MAXIMUM RESTRICTIONS ON THE LENGTH OF TIME PASTURE MAY BE SPELLED OVER THE SPRING PERIOD

Period in which grazing occurs	Max. spelling length following grazing (weeks)
Sep. 1	6.0
2	6.0
Oct. 1	6.6
2	6.5
3	5.4
4	6.0
Nov. 1	7.1
2	6.0
3	7.1

4.7 THE NITROGEN ACTIVITIES

The N response curves for fortnightly periods were extrapolated from the monthly relationships presented in Appendix 2, and were added to the appropriate 1/ pasture growth curves presented in Appendix 1. In the model, 106 N activities representing N applied to pasture for grazing were used in the model 2/, with an additional 14 activities for N applied to hay and silage areas.

The inclusion of N activities in the matrix is explained in greater detail in Section A3.5.

4.8 HAY AND SILAGE PRODUCTION

The pasture conservation activities included in the model are presented in Table 4.4.

The method used to incorporate hay and silage activities into the matrix was similar to that used for each LAND USE activity, except that dry matter harvested, corrected for dry matter losses, entered hay or silage reconciliation rows. Losses in dry matter occur during the hay

1/ N may be applied to pasture following grazing in April, May, July August, September or October. The alternative spelling lengths following application permitted in the model are the same as for the LAND USE activities.

2/ Derived in Section 3.4.

TABLE 4.4 HAY AND SILAGE ACTIVITIES

Pasture Conservation activities	Period in which the conservation is closed	Period in which the grass products are harvested
(A) SILAGE PRODUCTION		
SIL 1	Sep. 2	Nov. 1
SIL 2	Sep. 2	Nov. 3
SIL 3	Oct. 1	Nov. 3
SIL 4	Oct. 2	Nov. 4
(B) HAY PRODUCTION		
HAY 1	Oct. 2	Dec. 1
HAY 2	Oct. 3	Dec. 2
HAY 3	Oct. 4	Dec. 2
HAY 4	Nov. 1	Jan. 1
HAY 5	Nov. 2	Jan. 1
HAY 6	Nov. 3	Jan. 2
HAY 7	Nov. 4	Jan. 2

and silage making operation and in storage, and these were assumed to be 10 percent of the dry matter harvested for silage, and 15 percent for hay. These figures assume high technical efficiency in the production process 1/.

The yield at each harvest was calculated from the pasture growth curves. It was assumed that pasture was not cut below the animal grazing level.

Activities allowing hay to be purchased or sold are also included in the matrix.

4.9 MEAL FEEDING

Meal feeding activities were included for each period between JUL 2 and APR 2 inclusive, meal being offered to lactating cows only.

Meal, besides offering an additional alternative source of dry matter, was primarily included to prevent the minimum animal intake restrictions in the Animal Model 2/ being violated in periods of extreme feed shortage or at high stocking rates.

1/ Lancaster (1966/67)

2/ See Chapter 5.

4.10 FACTORS AFFECTING PASTURE UTILISATION

The pasture production model supplies feed to the grazing animal in each period. It is necessary to decide, under grazing conditions, what happens to a given amount of pasture available for consumption at any grazing. Some pasture will be rejected because of faecal contamination and unpalatability, and some lost because of trampling 1/. Of the pasture that remains uneaten after a grazing, a proportion will decay before subsequent grazing.

4.10.1 Faecal contamination

Animals will reject feed either contaminated by excreta or surrounding a defaecation site, and this may lead to a considerable reduction in grazing cow consumption. MacLusky (1960) calculated that at least six percent of pasture area on most farms is contaminated by faeces each year. He considered that each defaecation affected the acceptability of herbage on an area six times its own area. The length of time for which areas affected by faeces remain unacceptable may be at least a year. Greenhalgh and Reid (1969) demonstrated that the area rejected because of faecal contamination is lower with high grazing pressure, as under these conditions herbage on rejected areas may be partially consumed.

4.10.2 Pasture palatability

Of particular relevance to the study is the effect of N fertiliser on grass palatability. As N uptake by pasture species following N application precedes dry matter production 2/, pasture grazed soon after application, (say 2-3 weeks), may be unpalatable due to high N content 3/. However, such early grazing is unlikely to be of economic value, because of insufficient time to produce a worthwhile response. Consequently, unpalatability effects due to N have been disregarded.

4.10.3 Pasture availability

For some given period of grazing, (for example, 12 hours), we need to quantify the relationship between pasture consumption per cow and available pasture per cow. Most experimental work in New Zealand has measured this relationship only indirectly, as the effect of stocking

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1/ Suitable quantitative information on the amount of pasture lost during grazing because of trampling could not be located.

2/ Ball (1970).

3/ McKenzie (1970).

rate on animal performance. Greenhalgh et al (1966, 1967) have shown that herbage availability and herbage intake are related in a curvilinear fashion. Virtually all the available pasture was consumed at low per cow levels of feeding but as available feed supply increased, consumption increased only slowly, so that cows capable of eating about 30 lbs DM/day achieved this when herbage allowance was approximately 50 percent greater than intake.

4.11 ASSUMPTIONS MADE IN THE MODEL CONCERNING PASTURE UTILISATION

Ideally, grazing pressure relationships should have been included in the model. For each alternative level of feed made available per cow, consumption would be specified and hence the residual amount of dry matter after grazing known. This approach would also have required knowledge about the inter-relationships that explain what proportion of the residual dry matter, after grazing, dies or is not acceptable to the animal at subsequent grazing. In addition, this approach would require knowledge about the inter-relationships between different quantities of feed not utilised at any grazing and the effect on subsequent pasture growth and quality. The author was unable to find sufficient research results to allow construction of such a pasture-production/animal-consumption model.

The approach used in this study is a highly simplified attempt to include the more important factors affecting pasture utilisation.

The relationships between dry matter production and length of spell following defoliation at different times of the year, as given in Appendices 1 and 2, assume a particular pattern of grazing pressure as indicated by the length of pasture following grazing 1/.

The combined effects of trampling and faecal contamination are assumed constant at all stocking rates and reduce pasture availability, (the pasture DM quantities in Appendices 1 and 2), at each grazing by 10 percent.

In the model, a fixed per cow level of intake is specified throughout the 'dry' period 2/. Consequently, the model provides the same level of feed available/cow, during the 'dry' period, at all stocking rates. It is assumed therefore that 90 percent of available feed is utilised by the 'dry' cows.

1/ See Table 3.1.

2/ See Chapter 5.

The assumptions made concerning losses in available feed that occur with lactating cows are shown in Table 4.5. These losses, after taking trampling and faecal contamination losses into account are assumed to be related only to the season and the stocking rate. This is an attempt to approximate utilisation losses that will occur at different stocking rates throughout the year because of variation in per cow feed availability levels.

It is further assumed that pasture not eaten is either of low palatability or old herbage of poor quality which decays before the next grazing.

In the animal model, dry matter requirements to produce a specified amount of butterfat in each period 1/, are increased to take into account the utilisation losses specified in Table 4.5.

TABLE 4.5 PERCENTAGE REDUCTION IN FEED AVAILABILITY

Lactating Cows

Stocking Rate	'Dry' Period	July Aug. Sept. Oct.	Nov. Dec.	Jan. Feb. Mar.	Apr. May
1.0	10	25	20	15	20
1.2	10	20	15	12	15
1.5	10	15	12	10	12
1.7	10	12	10	10	10
2.0	10	10	10	10	10

4.12 SUMMARY

In this chapter a pasture production model is constructed and used to demonstrate the effects of grazing frequency on pasture productivity. The use of the pasture model in the overall system model, as a means of calculating feed availability in response to animal demands in each period is described. Assumptions are also made concerning the proportion of feed made available that will not be consumed by the grazing animal because of faecal contamination, trampling or decay.

1/ Derived in Chapter 5.

CHAPTER 5

FACTORS AFFECTING BUTTERFAT PRODUCTION

5.1 INTRODUCTION

Chapters three and four have dealt with the production and intake of pasture dry matter under grazing conditions. In this chapter dry matter intake in each period is assessed in terms of nutrient content and relationships are established between nutrient intake and animal production. This enables the relationships between pasture growth and animal product to be used to evaluate the profitability of different management practices.

5.2 PASTURE QUALITY

5.2.1 The importance of pasture quality

Pasture quality measurements have rarely been made in New Zealand agronomic research, whereas most published animal production relationships express animal product as a function of nutrient intake level. The animal and pasture models used in the study, therefore, must be linked by some feed quality measure. The aim of management must be to organise feed resources so that an optimal balance of feed in terms of quantity and quality is available in response to animal demands. A consideration of the nutritive value of pasture produced may cause differences in recommendations from those based on agronomic research where dry matter yields only have been measured.

Pasture is evaluated in terms of energy content in this study. It is assumed that the protein and mineral composition of pasture, at any level of feeding likely to be encountered, is adequate. As New Zealand pastures normally provide a well-balanced ration in terms of these nutrients 1/, this is considered a reasonable assumption.

5.2.2 Assessing pasture quality

Feed quality may be assessed in terms of available energy or productive energy content. Available energy is a measure of the energy available to the animals from the feed, taking into account the various losses, of which the undigested fraction is by far the largest. Productive energy makes allowance for the heat wasted in the conversion

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1/ A.W. Davy (pers. comm.).

of available energy into stored energy. Therefore, the quantity of nutrients available to meet animal maintenance requirements and produce saleable animal product will be related to the level of dry matter intake and available energy content of the dry matter. The amount of animal production will be determined by the efficiency of conversion of available energy into productive energy.

Coop (1965) recommends that rations for dairy cows be evaluated in terms of available energy content. The measure used in this study takes into account faecal, urinal and gaseous losses of energy and is termed the metabolic energy content.

5.2.3 Factors influencing pasture quality

(a) Length of spell

In general, digestibility is closely related to forage maturity 1/. As the length of the spell following defoliation increases, pasture becomes less digestible. However, digestibility measurements have rarely been conducted during pasture growth experimentation in New Zealand despite their obvious importance in relation to animal productivity. The difficulties encountered in assessing pasture quality probably explain this omission 2/.

(b) Grazing management

Cutting trials yield a leafy pasture with a more predictable digestibility than under grazing conditions where ungrazed herbage, because of incomplete utilisation, remains to influence the digestibility of feed offered at subsequent grazings. However, under grazing conditions, forage consumed may not equal forage on offer, particularly at low grazing pressure, so that the digestibility of feed consumed may be more uniform than the digestibility of feed offered.

(c) Season

Pasture quality is also influenced by the time of year. Because of data limitations under New Zealand conditions concerning the influence of spell and grazing management on pasture quality, it is assumed that the average quality estimates used in Table 5.1 can be applied to each period 3/.

1/ Raymond (1969).

2/ Minson (1968).

3/ Figures supplied by J.B. Hutton (pers. comm.).

TABLE 5.1 PASTURE QUALITY

Period	Pasture Quality (Mcals ME/lb DM)
Jul., Aug., Sep., Oct.	1.28
Nov., Dec.	1.20
Jan., Feb.	1.10
Mar., Apr.	1.15
May, Jun.	1.20

5.2.4 Effect of pasture quality on food conversion efficiency (FCE)

FCE refers to the conversion of metabolisable energy to productive energy and allows for the heat wasted in this conversion. Raymond (1969) reviews factors affecting FCE and concludes that digestibility differences can account for many of the differences existing between feeds. As feeds become less digestible, an increasing amount of heat is produced for each unit of metabolisable energy derived from the feed.

Alternative feed rations are unlikely to differ in digestibility sufficiently to be of importance in this study. Consequently, it is assumed that at any time of the year, the metabolisable energy content of the ration is converted to net energy with equal efficiency, although FCE is assumed to change considerably throughout lactation 1/.

5.3 THE DEVELOPMENT OF A BUTTERFAT PRODUCTION MODEL

5.3.1 Lactation length

In the model, a fixed average lactation length of 295 days is assumed. Calving extends from the 15 July until the 31 August. Twenty percent of the herd is dried off on the 31 May.

The calving distribution and length of the dry period for different proportions of the herd are shown in Figure 5.1.

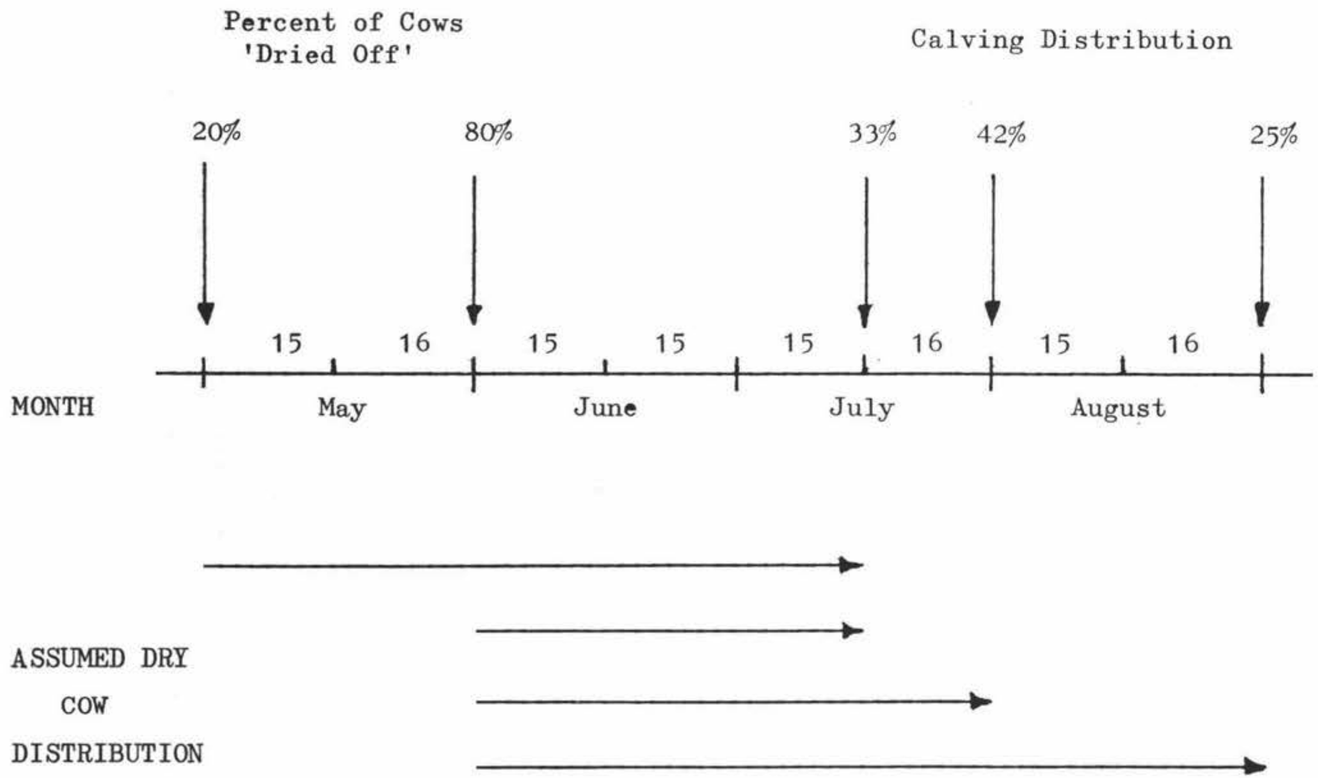
5.3.2 Dry cow energy requirements

In the model, a fixed per cow level of intake is specified throughout the 'dry' period, as trials at Ruakura have confirmed that severe depressions in milk production can result from inadequate prepartum feeding 2/.

1/ Section 5.3.4.

2/ Hutton (1971a).

FIGURE 5.1 THE CALVING DISTRIBUTION AND DRY PERIOD DISTRIBUTION ASSUMED IN THE MODEL



% of Dry Cows	Length of Dry Period (days)
20	76
13	45
42	61
25	92

Av. Length of Dry Period: 70 days

Hutton (1971b) reviews both overseas and Ruakura nutrition experiments and concludes that for a 95-day dry period the total requirements of a mature Jersey cow should be approximately 1,350 Mcals ME. Of this, 300 Mcals represent the energy requirement for foetal growth and increased metabolism of the pregnant cow. The maintenance requirement of a dry pregnant cow, (not including pregnancy allowance), is therefore assumed to be 11.0 Mcals ME/day and this requirement remains constant throughout the dry period.

The pregnancy allowance is assumed to vary according to the stage of pregnancy as shown in Table 5.2.

TABLE 5.2 DRY COW ENERGY REQUIREMENTS

Weeks from calving	Pregnancy requirement	Maintenance requirement	Total daily requirement
	(Mcals ME/cow/day)		
0 - 2	8.5	11.0	19.5
2 - 4	7.0	11.0	18.0
4 - 8	2.5	11.0	13.5
8+	1.0	11.0	12.0

The total dry cow energy requirements in each period are calculated and converted to dry matter requirements, (see Appendix 4.1), using the average pasture quality estimates presented in Table 5.1.

5.3.3 Published information on energy requirements of lactating cows

New Zealand data for pasture fed cattle is wholly derived from Ruakura experimentation, where results have generally been submitted to multiple regression analysis to partition total intake into requirements for maintenance, lactation and liveweight gain 1/. However, the equations are not in good agreement as to the partitioning of feed intake into these production functions. The equations also relate to observations made over the whole lactation period, and as such cannot be used for predictions on smaller segments of lactation. They are of little use in grazing management studies because, given an intake pattern and initial cow body weights, milk yields and weight changes through the year cannot be determined.

1/ Coop (1965).

Overseas feeding standards 1/ are of limited use in that requirements for milk production and live weight gain (LWG), again relate to observations or theoretical calculations over considerably longer segments of lactation than was required for study in the model.

Information is required on the relative partitioning of feed energy between body weight gain and milk yield, and the efficiency of conversion into productive energy at different stages of lactation.

5.3.4 Gross efficiency of conversion of feed into milk energy 2/

Between cow differences in efficiency appear to be related to animal live weight, age and level of milk production. Differences between cows are greatest at the beginning and the end of lactation. Animals achieving high conversion efficiency in early lactation generally maintain this advantage throughout lactation 3/.

Hutton (1963a) calculated the gross efficiency of conversion of feed energy to milk energy for Jersey cows, fed to appetite throughout lactation, and he noted a distinct stage of lactation effect. In all cases, highest conversion efficiency was achieved in early lactation because of the combination of initially high rate of milk secretion, relatively low initial energy intake and the loss of live weight that freshly calved cows experience while drawing on body reserves in early lactation. As intake rises, milk production begins to decline and a decline in conversion efficiency occurs for the duration of lactation.

It is assumed in the model that gross efficiency of conversion is related linearly to stage of lactation. For a Jersey cow, fully fed throughout lactation, efficiency of conversion immediately following calving is 30 percent. Efficiency then drops two percentage units each month, so that ten months later gross efficiency equals ten percent 4/.

5.3.5 Appetite

The construction of the animal model required that levels of intake needed to satisfy appetite, (i.e., the upper limit to dry matter consumption), be specified.

1/ e.g., Great Britain Agricultural Research Council (1965).

2/ Throughout, gross efficiency refers to the energy in milk production expressed as a percentage of gross energy intake.

3/ Hutton (1963a).

4/ From Hutton (1963a).

Evidence has been gathered under New Zealand experimental conditions to show that considerable changes in consumption occur throughout lactation under conditions of voluntary intake, where pasture is the sole source of feed [1/]. However, factors limiting intake in the grazing animal are not well understood [2/].

In this study the appetite level for each cow is assumed to vary with the stage of lactation as shown in Figure 5.2 [1/,3/]. A typical pattern of live weight change associated with Figure 5.2 would be a loss of bodyweight over the first six weeks following calving, a regain of this over the next four to six weeks, a steady increase in bodyweight for approximately twelve subsequent weeks and then maintenance of bodyweight at a fairly static level until the end of lactation [1/].

5.3.6 Butterfat production

Given the maximum intake pattern and efficiency of conversion estimates throughout lactation, the level of milk production corresponding to the maximum intake pattern can be calculated, (Table 5.3). The milk production curve derived in this way is shown in Figure 5.3.

Identical intake and milk production relationships throughout lactation are assumed for all cows. This information is agregated into a butterfat production function for an 'average' cow in the herd. For each period, information is then available on the butterfat production level corresponding to maximum feed intake of the herd, (point A in Figure 5.4).

5.3.7 The maintenance requirements of lactating cows

A maintenance level of feeding is defined for the purpose of this study as the level of feeding at which no milk production will occur and at which bodyweight will remain constant. The maintenance requirement of lactating cows, (point B in Figure 5.4), as well as being related to climatic factors and amount of activity, is also closely related to the weight of the animal [4/]. However, liveweight in each period will be related to intake levels in previous periods, and as liveweight changes

1/ Hutton (1963b).

2/ Hutton *et al* (1964).

3/ Hutton (pers. comm.).

4/ From Hutton (1963a).

FIGURE 5.2 CHANGES IN APPETITE INTAKE LEVEL THROUGHOUT LACTATION.

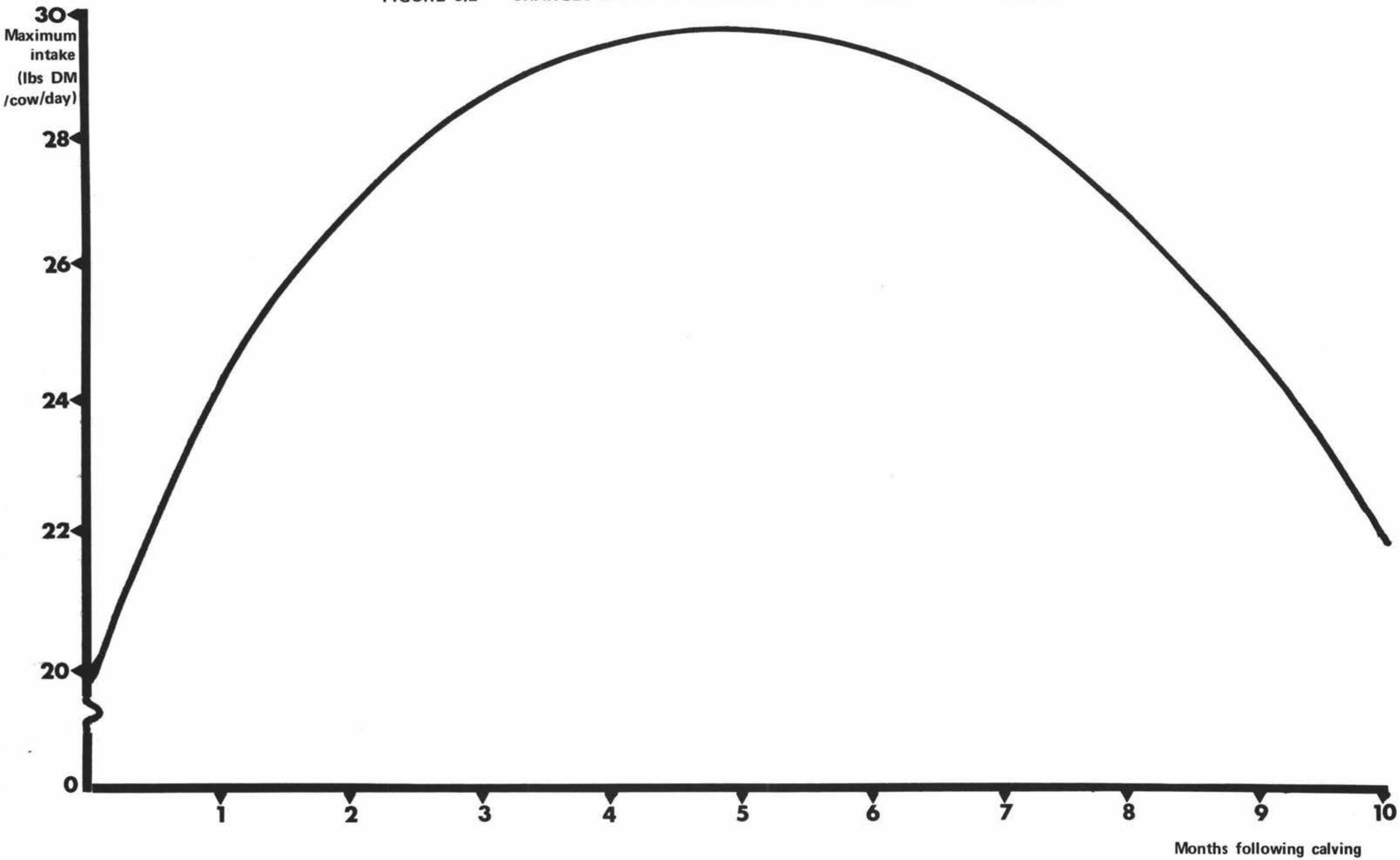


FIGURE 5.3 MILK PRODUCTION ASSOCIATED WITH AN APPETITE LEVEL OF INTAKE THROUGHOUT LACTATION.

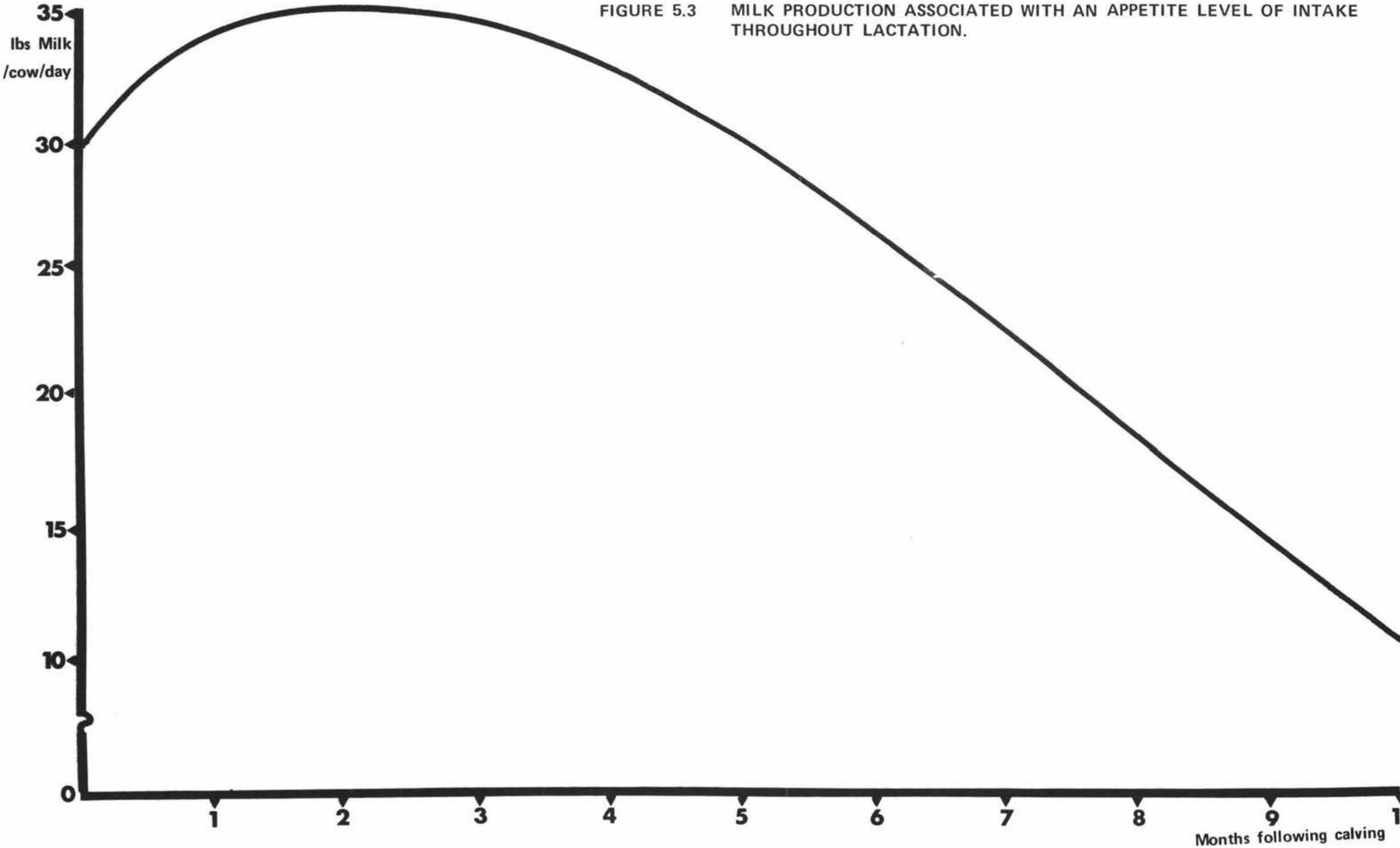


FIGURE 5.4 A TYPICAL BUTTERFAT PRODUCTION FUNCTION.

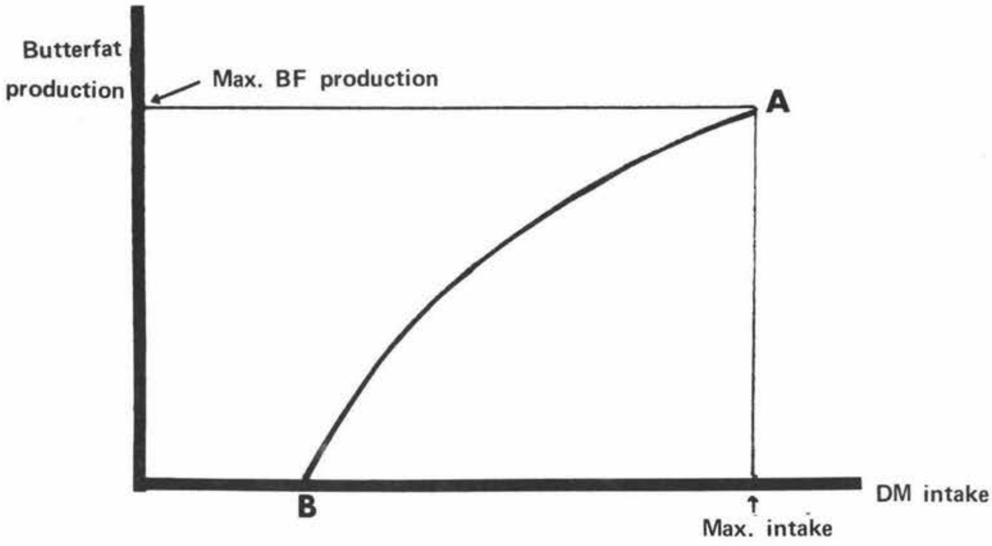


TABLE 5.3 PATTERN OF MAXIMUM INTAKE AND MILK PRODUCTION DURING LACTATION FOR AN AVERAGE COW

Months after calving	Gross* Effic. (%)	Intake per day (lbs DM)	Gross E** content of the feed (Mcals GE/day)	Energy content of milk prod. (Mcals)	Amount of*** milk prod./day (lbs)
0	30	20.0	40	12.0	30.0
1	28	24.5	49	13.7	34.3
2	26	27.0	54	14.0	35.0
3	24	29.0	58	13.9	34.8
4	22	30.0	60	13.2	33.0
5	20	30.0	60	12.0	30.0
6	18	30.0	60	10.8	27.0
7	16	29.0	58	9.3	23.3
8	14	27.0	54	7.6	19.0
9	12	25.0	50	6.0	15.0
10	10	22.0	44	4.4	11.0

Notes:

* Efficiency indices are expressed as the energy secreted in the milk as a percentage of the total amount of energy consumed.

** Gross energy content of pasture is assumed to be 2.0 Mcals/lb DM throughout the year. Hutton (1971b).

*** The amount of Fat Corrected Milk, (FCM = 4% Butterfat content), is calculated by assuming that the energy content of FCM is 0.43 Mcals/lb. (A. Davy, pers. comm.).

As milk production in the model is assumed to have a constant butterfat content throughout lactation, FCM production is then converted to a quantity of 5% milk containing an equivalent amount of energy, by using the relationship given by Perkins (1937):

$FCM = M(.4 + .15f)$

M = Amount of 5% milk produced.

f = Fat % (in this case f=5).

have not been included directly in the model no attempt can be made to calculate the maintenance requirements of individual animals in each period. In Table 5.4 the assumptions made concerning average maintenance requirements of lactating cows in each period are presented. This requirement is assumed to be 11.0 [1/] Mcals ME/day, rising to 12.0 Mcals ME/day towards the end of lactation to indirectly account for the effects of likely weight gain over this period [2/,3/,4/].

TABLE 5.4 THE MAINTENANCE REQUIREMENTS OF LACTATING COWS

Period	Average Maintenance Requirement (Mcals ME/day)
Jul., Aug.	11.0
Sep., Oct.	11.3
Nov., Dec.	11.6
Jan., Feb.	11.8
Mar., Apr., May	12.0

5.3.8 <u>The butterfat production function</u> [5/]

The estimation of butterfat production in response to varying feed supplies throughout the year requires that the nature of the butterfat production function be specified in each period. Extensive overseas work has demonstrated a diminishing butterfat response to successive increments of energy intake. The diminishing response under New Zealand conditions has been substantiated in a number of restricted feeding experiments [6/,7/,8/]. In each case, during the period of restricted intake, the immediate effects on milk production were often less than expected.

1/ This is also the assumed dry cow maintenance requirement derived in Section 5.3.2.

2/ Hutton(1962b).

3/ Hutton (1971b).

4/ A. Davy (pers. comm.).

5/ Measures butterfat output as a function of dry matter consumption in each period.

6/ Flux and Patchell (1954, 1957).

7/ Patchell (1957).

8/ Hutton (1962a).

The effects are, however, related to the length and severity of the underfeeding period, the amount and efficiency of utilisation of body fat reserves and the stage of lactation at which the intake is restricted. Hutton (1962a) restricted cow intake between the fourth and ninth month of lactation to approximately ten percent below the appetite level and noted an average increase in gross efficiency of one percentage unit. Hutton (1963a) suggests that in a grazing herd, increased efficiency of food conversion could be a most important consequence of increased stocking rate; as important as the improvements in pasture utilisation that are well recognised under high stocking rate conditions.

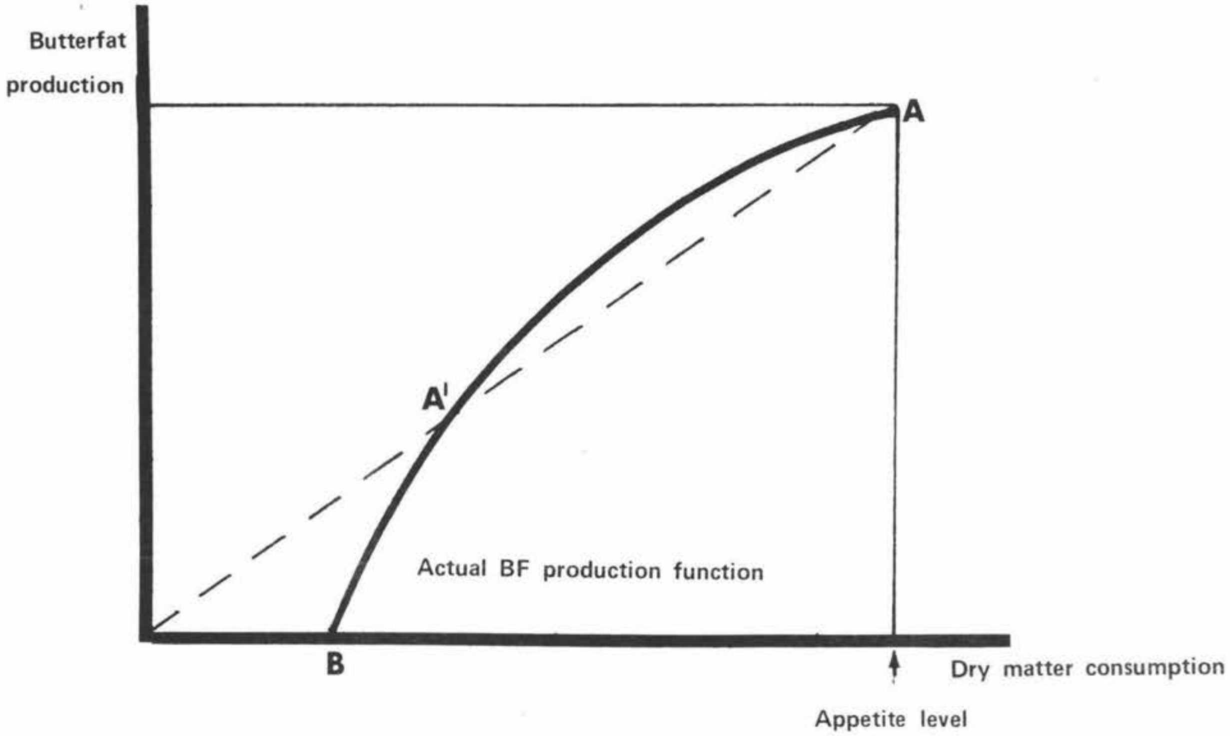
In Figure 5.5, all points on the broken line represent equal gross efficiency of conversion of feed energy into milk energy. Restriction of feed intake from the appetite level will depress yield but increase efficiency, so long as restriction is not severe enough to depress milk yield below the point A' in Figure 5.5. However, little published information is available on the shape of this function at different stages of lactation. It is possible that further analysis of existing lata could provide estimates of the butterfat production function at different stages of lactation or further trials using a range of feed restrictions at different stages of lactation may be required.

If a linear relationship is used to approximate the true curvilinear production function, for feed intake levels below the appetite level the amount of butterfat produced in any period will be underestimated. Feed availability will consequently be over-valued, since a restriction on intake in any period will reduce milk yield more than with a curvilinear relationship. At high stocking rates, where feed supply per cow will be considerably reduced, the value of N fertiliser may be over-estimated.

A curved relationship, while reflecting the true situation in the short-term, may undervalue feed in each period, as it may allow feed restrictions to be imposed that would in practice cause severe "carry-over" effects.

As insufficient time was available to make a comparison between results obtained using both a linear and curvilinear function, a curvilinear

FIGURE 5.5 EXPERIMENTALLY DETERMINING THE SHAPE OF THE BUTTERFAT PRODUCTION FUNCTION IN EACH PERIOD.



relationship only was used in the model. As insufficient information was available to explain interactions between stage of lactation, animal weight changes and severity and length of underfeeding, and thei· effects on immediate and longer term milk production, it was assumed that the full effects of an intake restriction in any period on butterfat production could be met in that period. In order to minimise the inaccuracy of results caused by neglecting possible "carryover" effects, limits were imposed on the amount butterfat production could be depressed in each period. These limits were gradually widened as lactation progressed. The small variation in butterfat production permitted in early lactation, reflects the importance of adequate feed at this time of the year if high levels of milk production are to be obtained throughout lactation.

5.3.9 The butterfat production model

In each period, the butterfat production function above a minimum intake level, (X_1 lbs DM in Fig. 5.6), is approximated by including linear segments of this function in the model.

In Appendix 4, (Table A4.2), the co-ordinates of points A, B, C and D in Figure 5.6 are presented for each period. The derivation of these co-ordinates is explained in Appendix 4. Before inclusion in the model the feed intale co-ordinates (X_1, X_2, and X_3) must be adjusted by the appropriate utilisation 1/ factor for that period to calculate the feed supply requirement per cow to produce Y_1, Y_2, and Y_3 lbs of butterfat, (Figure 5.6).

The incorporation of butterfat activities and fixed dry cow requirements into the model required a LP matrix consisting of 70 activities (columns) and 84 restraints (rows). Details of this matrix are presented in Appendix 5.1.

5.4 FEEDING HAY AND SILAGE

5.4.1 Dry matter losses

As animal requirements are increased to account for pasture grown but not utilised, the same utilisation figure is used for hay and silage feeding losses. Consequently, the minimum feeding loss possible in the model is ten percent. Wallace and Parket (1966) have shown that losses can be reduced to about five percent of dry matter with off-pasture feeding. However, it proved more convenient in the model to allow high

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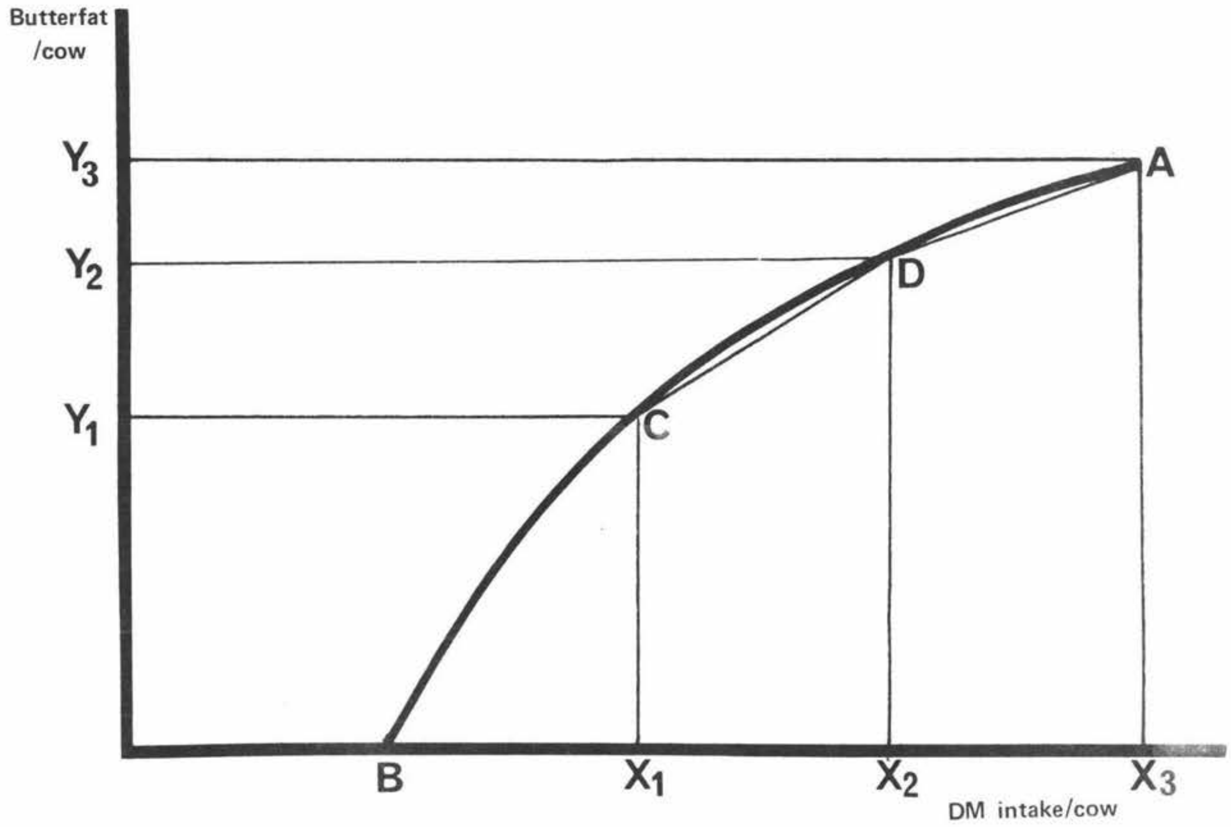
1/ See Table 4.5.

FIGURE 5.6 THE DERIVATION OF BUTTERFAT PRODUCTION ACTIVITIES IN EACH PERIOD.



feeding losses, and assume that they compensated for the high degree of technical efficiency difficult to achieve consistently under farming conditions.

5.4.2 Feed quality

The use of hay or silage in the ration will reduce potential butterfat production because of the poorer quality of these feeds relative to grass. Silage is assumed to contain 1.10 Mcals ME/lb DM and hay is assumed to contain 1.0 Mcals me/lb DM [1/].

5.4.3 Effects of supplementary feeding on intake

If it is assumed that maximum intake levels remain the same irrespective of the hay or silage content of the ration, the level of butterfat production achieved when cows are fully fed on hay or silage can be calculated. For example, in the 15-day period: OCT 1, maximum intake is 414 lbs of DM per cow [2/]. Feeding this quantity of silage will result in an 'effective' [3/] DM intake of 356 lbs DM. This will result in 23.5 lbs butterfat [4/] or 3.1 gals. milk/day/cow.

However, general observations at Ruakura suggest that where high producing cows are fed a sole diet of silage in early to mid lactation milk production rapidly declines, stabilising at a level of 1-2 gals. per cow per day [5/]. This is because milking cows cannot eat the same quantity of silage as they can of grass.

Campling (1966) suggests that with hay and silage feeding, intake is limited by the capacity of the reticulo - rumen, and feed digestibility which influences the rate of disappearance of digesta from this organ. As silage is generally more digestible than hay, [6/] no satisfactory explanation is available to explain low intakes occurring when silage replaces pasture in the diet. Raymond (1969) cites high moisture content, the presence of unknown chemical compounds or low pH as possible contributory causes.

1/ Hutton (pers. comm.).

2/ See Table A4.2.

3/ Corrected for silage quality: $414 \times \frac{1.10}{1.28} = 356$.

4/ From Figure A4.5.

5/ Wallace and Parker (1966).

6/ Hay generally falls within the range of 55 - 65 percent digestibility, but rarely reaches the upper limit and is more often close to the lower limit. Silage is generally in the range of 60 - 75 percent digestibility. Hutton (pers. comm.).

In view of the marked effects on intake that do result from heavy hay and silage feeding, it was necessary to develop and include in the model quantitative relationships between maximum intake and quantity of conserved grass products fed to milking cows. In OCT 1, a cow on a full diet of silage yielding 1-2 gals. milk/day will produce a total of 7.5 - 15.0 lbs butterfat in that period. From Figure A4.5, this production will require 170 - 235 lbs of total effective [1/] DM, or 11.3 - 15.0 lbs of effective DM/day. After correcting for silage quality, this represents a daily intake of 13.1 - 18.2 lbs DM/day. As the appetite level of grass in OCT 1 is 27.6 lbs DM [2/]; full silage feeding is assumed to reduce intake by 9.4 - 14.5 lbs DM/cow/day, (approximately 1 lb DM for every 1 lb silage DM fed).

However, the practice of feeding hay or silage as the sole dietary constituent is rarely encountered under practical farming conditions. Very little information is available, however, to determine the effect of hay or silage feeding on maximum intake at various levels of feeding and at different stages of lactation. It is unknown whether intake is affected over all levels of supplementary feeding and, if so, what the nature of the relationship is. It may be possible that a 'threshold' relationship exists and becomes operative only at a certain level of hay or silage feeding.

5.4.4 Assumption concerning the effects of hay and silage feeding on maximum intake

It was decided in the study to assume that the feeding of one pound of hay or silage DM results in a maximum intake reduction of 1 lb DM [3/] over all levels of supplement feeding and at all stages of lactation. The effects of this assumption on maximum milk production were tested in different periods and for different levels of supplementary feeding. For example, maximum milk production in DEC 2 when silage or hay constitute one third of the ration was calculated. In DEC 2 maximum grass intake is 480 lbs DM and corresponding milk production is 30 lbs/day. The feeding of 120 lbs DM of silage means that maximum intake is reduced by 120 lbs DM and therefore grass intake is 240 lbs DM. Total effective

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1/ That is, DM equivalent in quality to 170 - 235 lbs grass DM.

2/ Figure A4.3.

3/ This assumption is based on the analysis presented in 5.4.3 for silage fed to cows in OCT 1.

DM intake in this period is therefore 349 lbs DM as 120 lbs DM silage is equivalent in feeding value to 109 lbs grass DM in this period. Resulting butterfat production will be 18.0 lbs for the period, (from Fig. 5.), or 22.5 lbs milk per day.

Similarly, the feeding of a similar quantity of hay will result in 22.0 lbs milk/cow/day.

The assumed intake restriction, therefore, will depress maximum milk yield by 8 - 8.5 lbs/day when one third of the ration is fed as silage or hay. Hutton (pers. comm.) suggests that such a practice would be likely to result in considerable changes in butterfat production at this stage of lactation.

Similar calculations were performed for MAR 1. Where the feeding of hay and silage constituted one third of the ration, maximum milk yield was reduced to 18 lbs/cow/day. At Ruakura, similar feeding practices in late lactation do not appear to affect a daily milk production of 15 lbs cow/day 1/.

Consequently, the assumptions made about depressions in maximum intake due to hay and silage feeding to lactating cows were considered sufficiently realistic to include in the model. The submatrix containing hay and silage feeding activities and their effect on intake is discussed and explained in Appendix 5.2.

Because dry cow requirements are considerably less than those of lactating cows, intake restrictions have not been specified for dry cows. This allows dry cow feed requirements in the model to be met entirely by hay if necessary.

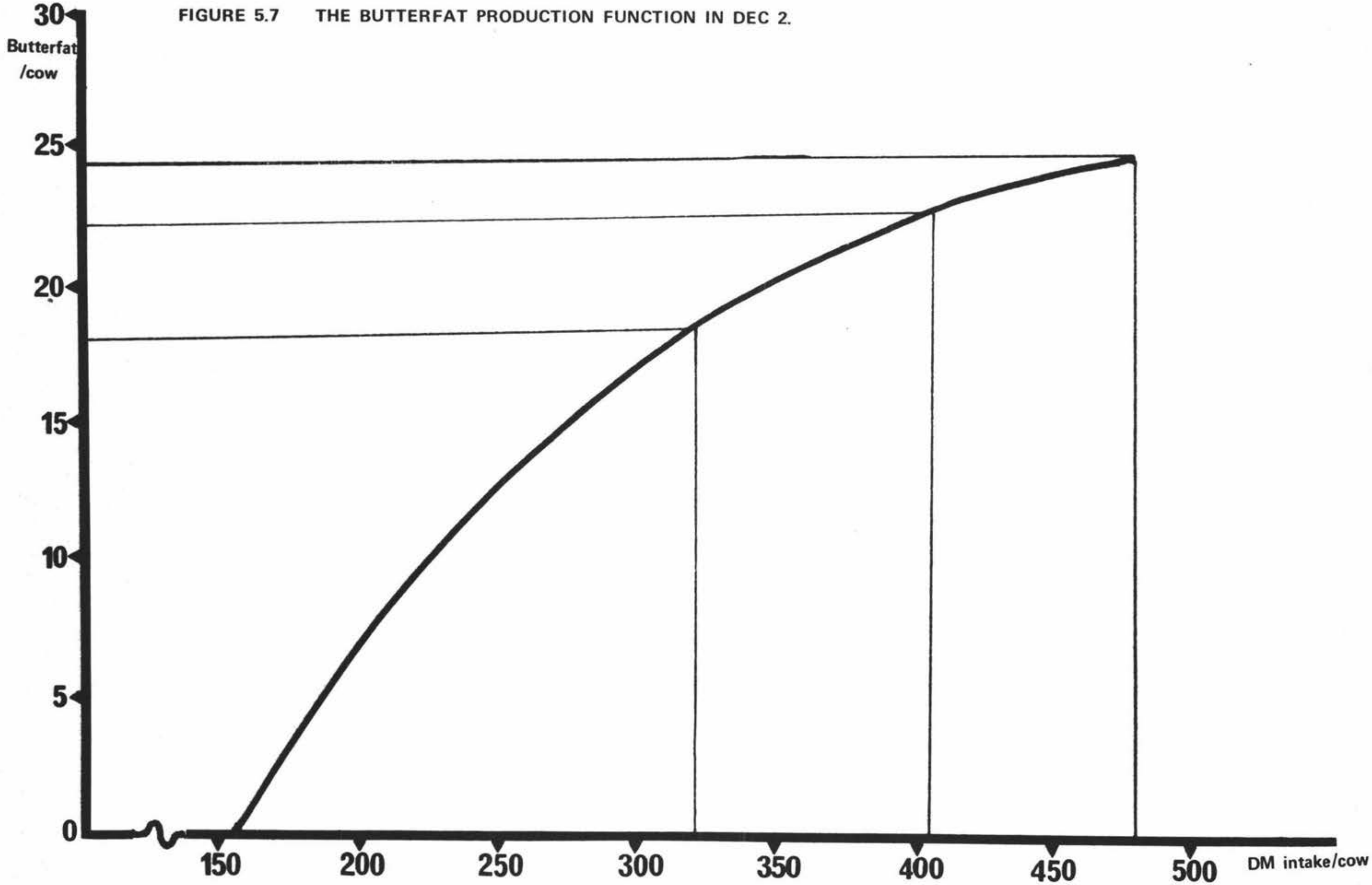
5.5 SUMMARY

In this chapter, the derivation of relationships used in the animal model are described. Rather than use overseas feeding standards, relationships between feed consumption and animal production have been derived from New Zealand experimental work.

Major limitations of the animal model arise from being unable to directly include the effects of animal weight changes with different levels of feeding or being unable to specify the shape of the butterfat production function in each period.

1/ Hutton (pers. comm.).

FIGURE 5.7 THE BUTTERFAT PRODUCTION FUNCTION IN DEC 2.



Assumptions are also made concerning the effects of hay and silage feeding on intake. However, because of data deficiencies, the validity of these assumptions could not be accurately determined.

CHAPTER 6

EXPERIMENTATION AND RESULTS

6.1 INTRODUCTION

Previous chapters have dealt with the development of the grazing model used in the study. This and subsequent chapters outline the experimentation conducted on the model and present the results obtained.

6.2 INFORMATION OBTAINED FROM THE MODEL

The model is designed to determine the grazing management system that maximises net profits at any specified level of stocking rate. Consequently, only variable costs for any specified stocking rate are considered. These costs are as follows:

	Cost (¢/lb DM)
Silage Production	.25
Hay Production	.50
Purchased Hay	1.00
Purchased Meal	3.50

Nitrogen is initially assumed to cost 10c/lb N but this price is varied in Chapter eight. As pasture production costs, apart from pasture produced by N, will be constant for all grazing management systems, at a given stocking rate level, these costs are not included. However, the validity of this assumption is considered in detail in Chapter 7.

Butterfat [1/] and hay [2/] are assumed to be the only saleable products. As the revenue from the sale of cull cows and calves will also be the same for all grazing management systems considered at a given stocking rate, these revenue sources are not included.

By experimenting with the model at different stocking rates, some idea of changes in grazing management that should accompany any change in stocking rate can be obtained. However, a change in stocking rate will also involve a change in many cash costs that have not been considered in the study. Therefore, the model cannot be used to determine the optimum stocking rate. Including these costs in the analysis would have required specification of farm and herd size, as Jackson (1971) has shown that significant economies of size do exist in dairy farming. Cash

1/ Price of BF assumed to be 30c/lb, but this price also is varied in Chapter 8.

2/ Hay selling price is .75c/lb DM.

costs such as insurance, repairs and maintenance, and labour, and non-cash costs such as depreciation, interest on investment and management reward will depend largely on the investment in land, stock and plant. An evaluation of this also requires that farm size be specified and assumptions made concerning the herd size at which 'lumpy' inputs such as extension to the dairy shed and water supply, and extra labour units be added.

The profitability of increasing stocking rate between two specific levels on a specified area of land also cannot be evaluated using this model as the economies of moving from one stocking rate to another is often a farm development problem and must be related to a particular farm. While the model can be used to indicate the optimum grazing management system and additional annual revenue forthcoming from efficient feed resource allocation at a higher stock rate, this must be balanced against the costs of development. These costs will be largely dependent on the stock of physical resources already available on the farm, relative to those required at the post-development situation.

6.3 MODEL VALIDATION

The validity of results obtained from experimentation with a systems model will depend on the accuracy of the relationships, and inclusion of all important relationships, in the model. In the present study, many of the relationships used were estimated by research personnel. To some extent these estimates are based on research results, but to some extent they are also subjective in nature and as such have not been experimentally verified.

The objective of this study was to improve control over existing grazing systems through adjustments to grazing management, and to design new systems by incorporating N activities into the range of production possibilities [1/]. A direct comparison could not be made between the performance of the real system and that produced by the model. Under these circumstances, Wright (1970) suggests that subjective validation may be used, where the eventual decision maker is incorporated into the validation process. The model is considered validated if it would be used by him as a basis for decision making.

1/ These two functions of design and control are usually referred to as systems synthesis, (Wright 1970).

TABLE 6.1 SUMMARY OF 'SELF-CONTAINED' PLANS AT EACH STOCKING RATE

	Stocking rate (cows/acre)				
	1.0	1.2	1.5	1.7	2.0
(1) ANNUAL DRY MATTER SUPPLY	(lbs DM/acre)				
Pasture supply for grazing	10,918	11,720	11,872	11,645	11,924
Silage Production	162	473	817	758	162
Hay Production	1,874	938	547	813	1,134
Hay Sales	1,805	590	-	-	-
Purchased Meal	-	-	-	-	724
Total DM Supply	11,149	12,541	13,236	13,216	13,944
Total Effective DM Supply*	11,116	12,423	13,047	12,950	13,873
(2) BF PRODUCTION					
(lbs BF/acre)	399.4	471.5	534.3	528.0	544.0
(lbs BF/cow)	399.4	392.9	356.2	310.6	272.0
NET REVENUE ($/acre)**	123.6	140.0	155.5	152.4	131.8

* Effective DM supply takes into account the quality of feed supplements.

** At a butterfat price of 30c/lb.

TABLE 6.2 SUMMARY OF STOCK FEEDING IN EACH 'SELF-CONTAINED' PLAN

	Stocking rate (cows/acre)				
	1.0	1.2	1.5	1.7	2.0
(1) LACTATING COWS			(lbs DM/cow)		
Silage	162	394	545	446	81
Hay	-	-	-	-	-
Meal	-	-	-	-	362
Pasture	10,000	9,022	7,227	6,252	5,435
Total DM Supply	10,162	9,416	7,772	6,698	5,878
Total Effective DM Supply*	10,144	9,381	7,726	6,646	5,967
(2) DRY COWS					
Hay	69	290	365	478	567
Pasture	918	745	687	598	527
Total DM Supply	987	1,035	1,052	1,076	1,094
Total Effective DM Supply*	972	972	972	972	972
(3) TOTAL Annual DM Supply	11,149	10,451	8,824	7,774	6,972
TOTAL Annual Effective DM Supply *	11,116	10,353	8,698	7,618	6,937

* Effective DM supply takes into account the quality of feed supplements.

At 1.7 cows/acre, a marked decline in butterfat production/cow results in a slight drop in total butterfat production and net revenue.

At 2.0 cows/acre, butterfat production per cow is at the minimum level permitted in the model. To achieve this level, meal feeding is required, the cost of which considerably reduced the net profit of the plan.

It appears, therefore, that relatively inexpensive feed sources such as purchased hay or pasture produced by N fertiliser may offer considerable potential at high stocking rates, for substituting for expensive feeds such as meal, for profitably raising animal intake and butterfat production levels. Subsequent experimentation was confined to an evaluation of the relative merits of these two feed sources in achieving this objective.

6.5 THE INFLUENCE OF HAY BUYING ON NET PROFIT

Hay buying activities were included in the matrix and optimun plans computed for stocking rates of 1.5, 1.7 and 2.0 cows/acre 1/. The resulting plans are summarised in Table 6.3. The annual distribution of feed supplied to dry and lactating cows are summarised in Table 6.4.

As stocking rate is raised above 1.5 cows/acre, large increases occur in the amount of hay that is purchased 2/. Less silage and pasture is fed to each lactating cow but the amount of hay fed is considerably increased. The net effect is that despite a reduction in effective dry matter supply to each lactating cow, which results in a slight decline in butterfat production/cow, butterfat production/acre and net profit increase as stocking rate is raised above 1.5 cows/acre.

By comparing Tables 6.1 and 6.3, it can be seen that where hay buying is permitted, less silage is produced, at 1.5 and 1.7 cows/acre and less hay is produced at all three stocking rates. Additional hay is also fed to the dry cows. Consequently, more pasture is supplied to the lactating cows. This, together with supplementary hay feeding, increases intake and butterfat production/cow. At 2.0 cows/acre, hay also replaces expensive meal feeding to the lactating cows.

1/ As hay is sold at 1.0 and 1.2 cows/acre (Table 6.1), these two stocking rates were not included.

2/ No hay is produced.

TABLE 6.3 SUMMARY OF 'HAY-BUYING' PLANS AT EACH STOCKING RATE

	Stocking rate (cows/acre)		
	1.5	1.7	2.0
(1) ANNUAL DRY MATTER SUPPLY		(lbs DM/acre)	
Pasture supply for grazing	12,490	12,912	12,950
Silage Production	727	424	334
Hay Production	-	-	-
Purchased Hay	852	2,244	3,876
Total DM Supply	14,069	15,580	17,160
Total Effective DM Supply	13,818	15,134	16,460
(2) BF PRODUCTION			
(lbs BF/acre)	560.4	622.4	683.1
(lbs BF/cow)	373.6	366.1	341.6
NET REVENUE ($/acre)*	157.8	163.2	165.4

* At a butterfat price of 30c/lb.

TABLE 6.4 SUMMARY OF STOCK FEEDING IN EACH 'HAY-BUYING' PLAN

	Stocking rate (cows/acre)		
	1.5	1.7	2.0
(1) LACTATING COWS	(lbs DM/cow)		
Silage	485	249	167
Hay	13	662	1,132
Pasture	7,787	7,139	6,143
Total DM Supply	8,285	8,050	7,442
Total Effective DM Supply	8,240	7,931	7,260
(2) DRY COWS	(lbs DM/cow)		
Hay	555	658	807
Pasture	539	457	332
Total DM Supply	1,094	1,115	1,139
Total Effective DM Supply	972	972	972
(3) TOTAL Annual DM Supply	9,379	9,165	8,580
TOTAL Annual Effective DM Supply	9,212	8,902	8,230

The contribution of hay buying to net profits at each stocking rate is calculated in Table 6.5 where the costs and returns of plans using purchased hay are compared with those presented in Table 6.1.

At 1.5 cows/acre, purchased hay raises butterfat production by 26.1 lbs butterfat/acre, but at a butterfat price of 30c/lb the increase in net profit is only $2.2/acre. It thus appears that little increase in profitability will occur from buying hay at this stocking rate with low butterfat prices.

At 1.7 cows/acre, butterfat production is increased by 94.4 lbs butterfat/acre. Additional hay buying costs limit the increase in profitability to $10.8/acre.

At 2.0 cows/acre, hay buying results in a considerable increase in net profit per acre over the no-hay plan. This increase, of $33.5 per acre, can largely be attributed to a reduction in costly meal feeding and an increase in butterfat output of 139 lbs/acre.

However, as shown in Table 6.3, net profit per acre at 2.0 cows is not much greater than at 1.7 cows/ acre. An increase in butterfat price though would widen the margin in favour of the higher stocking rate. An increase in butterfat price, for example to 50c/lb, would produce at least an additional $27.8 net profit per acre for the hay buying plan at 2.0 cows/acre compared with an additional $18.9 net profit at 1.7 cows/acre. This butterfat price would increase the net profit at 1.5 cows/acre by at least $5.2/acre.

6.6 THE ECONOMIC USE OF N FERTILISER

N activities were included in the matrix and optimum plans computed. Owing to the abundance of feed at 1.0 and 1.2 cows/acre, which permitted high per cow butterfat production levels 1/, N fertiliser was not used in the optimum plan at these stocking rates. The remaining plans are summarised in Table 6.6 The annual distribution of feed supplies to dry and lactating cows is summarised in Table 6.7.

1/ Section 6.4.

TABLE 6.5 CHANGES IN THE ANNUAL CASH COSTS AND RETURN STRUCTURE OF THE FARM WHEN PURCHASED HAY IS PERMITTED IN THE FARM PLAN

	Stocking rate (cows/acre)		
	1.5	1.7	2.0
<u>ADDED RETURNS</u>		($/acre)	
Extra BF Sales*	7.8	28.3	41.7
Reduction in Hay Production Costs	2.7	4.1	5.7
Reduction in Silage Production Costs	.2	.8	-
Reduction in Meal Production Costs	-	-	25.3
TOTAL	10.8	33.2	72.7
<u>ADDED COSTS</u>			
Purchased Hay	8.5	22.4	38.8
Extra Silage Production Costs	-	-	.4
TOTAL	8.5	22.4	39.2
MARGIN	2.2	10.8	33.5

* At 30c/lb BF.

TABLE 6.6 SUMMARY OF 'NITROGEN' PLANS AT EACH STOCKING RATE

	Stocking rate (cows/acre)		
	1.5	1.7	2.0
(1) ANNUAL DRY MATTER SUPPLY		(lbs DM/acre)	
Pasture supply for grazing	12,380	12,213	12,562
Pasture produced by N for grazing*	725	1,522	2,007
Silage Production	708	964	674
Silage Produced by N*	48	244	171
Hay Production	92	-	-
Purchased Hay	250	628	2,446
Total DM Supply	14,203	15,571	17,860
Total Effective DM Supply	14,078	15,367	17,377
(2) N FERTILISER USAGE*		(lbs N)	
N Applications for Grazing	58.4	114.0	148.6
N for Silage	2.7	15.6	10.8
Total	61.1	129.6	159.4
(3) BF PRODUCTION			
(lbs BF/acre)	569.0	636.1	720.2
(lbs BF/cow)	379.3	374.2	360.1
NET REVENUE ($/acre)**	159.7	168.5	173.6

* A distinction is made between feed produced with and without N. This is clearly necessary if we are to analyse the role of N fertiliser. N fertiliser usage in this and subsequent tables refers to an 'average' acre and does not, in general, refer to the <u>rate</u> of N application. At 1.5 cows/acre, for example, 2.7 lbs N are used to produce 48 lbs silage DM, but from only 5.3 percent of our 'average' acre. Appendix 6 provides greater detail on some of the plans discussed in this chapter.

** At a butterfat price of 30c/lb and an N price of 10c/lb.

TABLE 6.7 SUMMARY OF STOCK FEEDING IN EACH 'NITROGEN' PLAN

	Stocking rate (cows/acre)		
	1.5	1.7	2.0
(1) LACTATING COWS		(lbs DM/cow)	
Silage	504	711	423
Hay	-	-	677
N Produced Pasture	420	772	882
Pasture	7,523	6,624	5,859
Total DM Supply	8,447	8,106	7,841
Total Effective DM Supply	8,413	8,068	7,713
(2) DRY COWS		(lbs DM/cow)	
Hay	228	369	546
N Produced Pasture	63	124	122
Pasture	731	560	422
Total DM Supply	1,022	1,053	1,090
Total Effective DM Supply	972	972	972
(3) TOTAL Annual DM Supply	9,469	9,159	8,930
TOTAL Annual Effective DM Supply	9,385	9,039	8,689

The results presented in Table 6.6 show that in the optimum plans using N, both the amount of hay purchased and N fertiliser used, increase with increasing stocking rate. At 1.7 cows/acre, more N is used to produce silage than at the other two stocking rates considered. Although butterfat production per cow declines, as stocking rate increases to 2.0 cows/acre, both butterfat production and net profit/acre increase with increasing stocking rate.

The results presented in Table 6.7 indicate that increased amounts of N produced grass and conserved grass products are fed per lactating cow as stocking rate increases, but that a decline in pasture supply per cow results in an overall decline in effective DM supply per cow and hence butterfat production per cow. At 1.7 cows/acre, more silage is fed per lactating cow than at the other two stocking rates, while at 2.0 cows/acre the reduced amount of silage is replaced by hay so that this stocking rate has the highest level of feeding of conserved grass products per lactating cow. Changes in the dry cow ration between stocking rates are also shown in Table 6.7; the trend is to a ration consisting of more hay and N produced pasture as stocking rate increases.

Where the use of N fertiliser is permitted in the model, in addition to allowing for the purchase of hay; silage production increases while hay purchases decline, and there is a net increase in total effective DM supply/acre at each of the stocking rates examined, (comparison of the data in Tables 6.3 and 6.6). Comparison of the data in Tables 6.4 and 6.7 indicate changes in the ration of lactating and dry cows, at each stocking rate, that result from the use of N fertiliser in addition to the purchase of hay. Total effective DM supply/lactating cow is increased at each stocking rate and the consequent increases in BF/acre, BF/cow and net revenue/acre are obtained by the comparison of Tables 6.3 and 6.6. The effects of N fertiliser use on net profit per acre, in comparison with the hay buying plans, are analysed in more detail in Table 6.8.

For reasons discussed in Section 6.2, this study cannot indicate which stocking rate is actually the most profitable; meaningful comparisons can only be made between management systems at a given stocking rate. Therefore, two stocking rates (1.5 and 2.0 cows/acre) have been selected for a detailed examination of pasture management adjustments that should accompany the use of purchased hay and/or N fertiliser. However, no attempt is made to examine management adjustments that should be made in moving between these two stocking rates.

TABLE 6.8 ADDED COSTS AND RETURNS ASSOCIATED WITH 'N USE' COMPARED WITH THE 'HAY-BUYING' PLANS

	Stocking rate (cows/acre)		
	1.5	1.7	2.0
ADDED RETURNS		($/acre)	
Increased BF Production	2.6	4.1	11.1
Reduction in Hay-buying Costs	6.0	16.1	14.3
TOTAL	8.6	20.2	25.4
ADDED COSTS			
Increase in Hay Production Costs	.5	-	-
Increase in Silage Production Costs	.1	1.9	1.3
Cost of N Fertiliser	6.1	13.0	15.9
TOTAL	6.7	14.9	17.2
MARGIN	1.9	5.3	8.2

6.7 COMPARISON BETWEEN DIFFERENT SYSTEMS OF GRAZING MANAGEMENT AT 1.5 COWS/ACRE

6.7.1 'Self-contained' and 'hay-buying' plans

The grazing management and conservation practices, together with resulting dry matter production for the 'self-contained' and'hay-buying' plans, are contained in Tables A6.1 and A6.2 of Appendix 6, and are summarised in Figures 6.1 and 6.2 respectively.

The monthly allocations of feed to lactating and dry cows are contained in Figure 6.3 and Table 6.9 for the 'self-contained' plan and Figure 6.4 and Table 6.10 for the 'hay-buying' plan. In Appendix 8, a key to all feed production and consumption profiles is presented; this key may be folded out for easy reference.

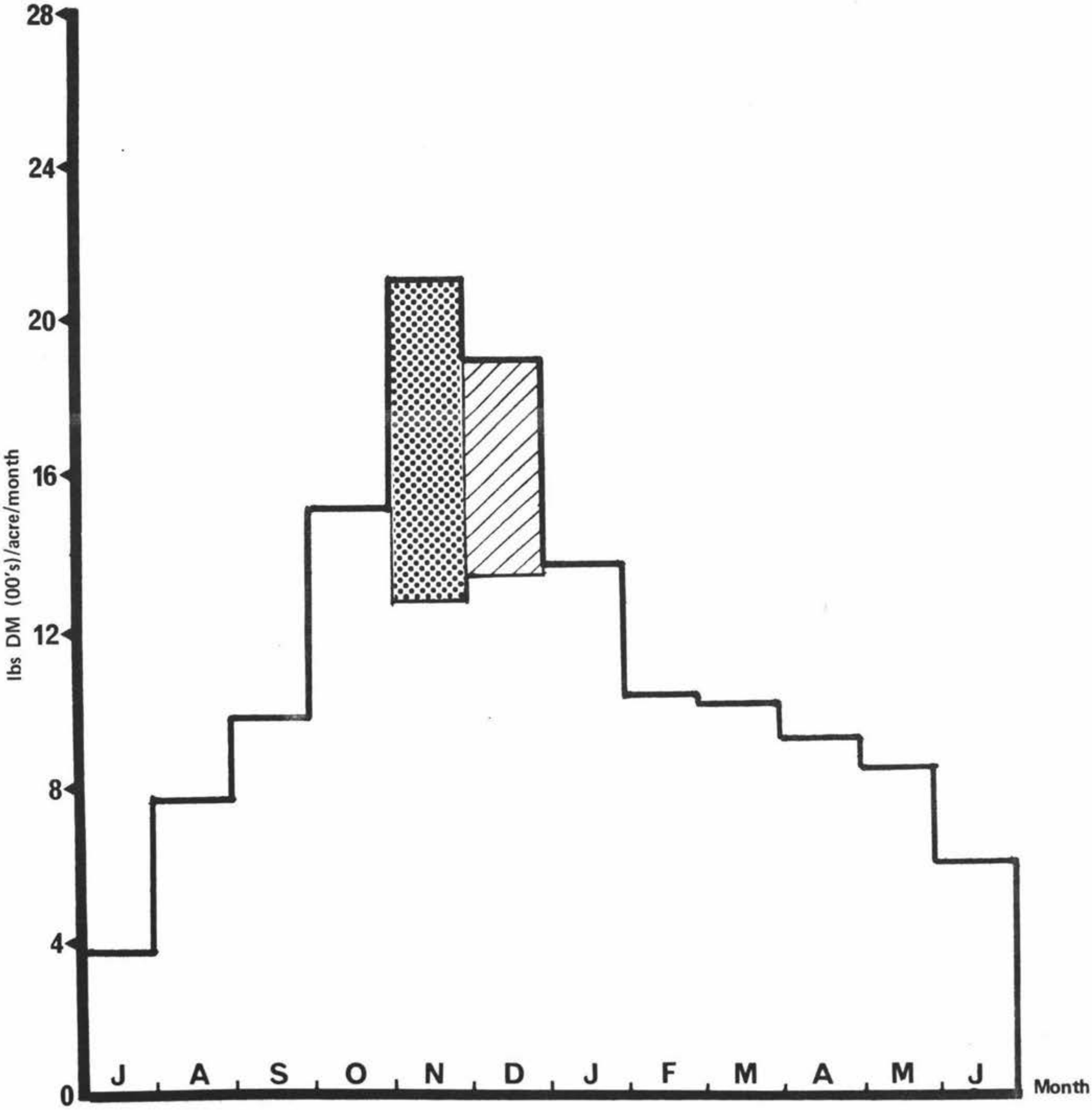
Monthly butterfat production is illustrated in Figure 6.5 for the 'self-contained' plan and Figure 6.6 for the'hay-buying' plan. In each butterfat production profile, the broken line refers to the amount of butterfat that would be produced if each lactating cow was fed to appetite level of intake on grass alone in each period. The unbroken line refers to actual daily butterfat production in each period.

All feed supply [1/] and butterfat production profiles, (and dry cow feeding tables), have been adjusted between May and August to refer to each lactating or dry cow, not a proportion of a cow that is lactating or is dry in any specified period. For example, feed is supplied in response to dry cow requirements in August. For example, at a stocking rate of one cow/acre, feed will be supplied for one quarter of a cow, (75 percent of the herd are assumed to be lactating at this stage). In the presentation of results, this particular amount of dry matter supplied would be multiplied by four to represent the amount supplied for each dry cow during August. Similar adjustments have been made for feed supplied to lactating cows and for butterfat production.

The major management differences between the 'self-contained' and 'hay-buying' plans at 1.5 cows/acre are as follows:

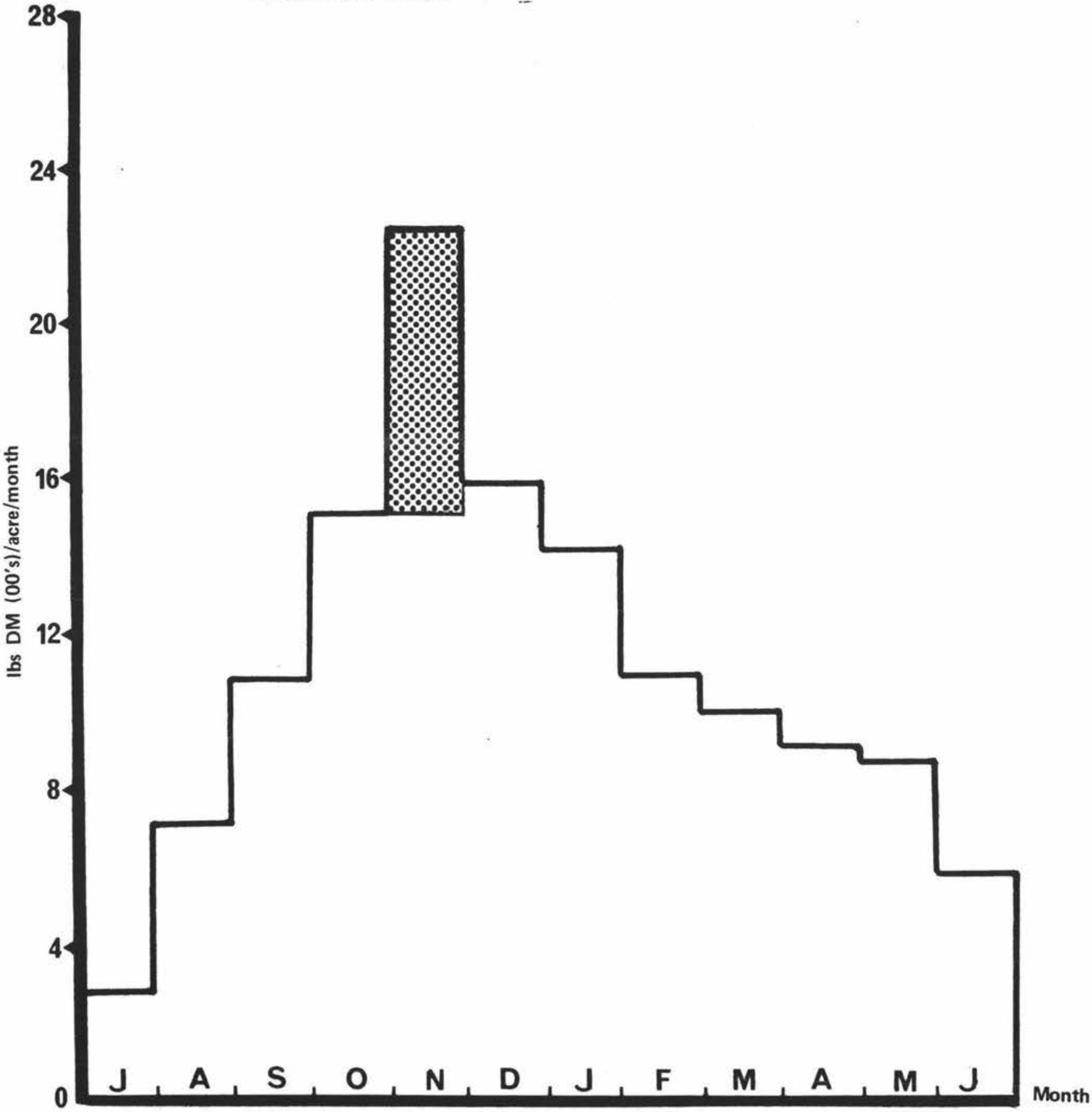
1/ Throughout the discussion of results the pasture allocated to grazing animals is referred to as pasture supply. Pasture consumption would imply that the amount supplied has been adjusted for utilisation losses, but this has not been done; see Table 4.5 for assumed losses.

FIGURE 6.1 GRAZING MANAGEMENT AND CONSERVATION PRACTICES, AND RESULTING MONTHLY DRY MATTER SUPPLY AT 1.5 COWS/ACRE IN THE 'SELF-CONTAINED PLAN.



Area grazed (% of total area)											
43.9	65.4	73.9	81.6	47.2	55.4	69.8	62.3	67.8	69.9	62.3	51.7
Average length of spell (weeks)											
7.6	9.5	6.5	5.6	5.8	5.3	6.0	6.3	6.2	6.5	6.4	7.1
Area closed for silage (% of total area)											
		5.8	20.9								
Area closed for hay (% of total area)											
			14.0								

FIGURE 6.2 GRAZING MANAGEMENT AND CONSERVATION PRACTICES, AND RESULTING MONTHLY DRY MATTER SUPPLY AT 1.5 COWS/ACRE IN THE 'HAYBUYING' PLAN.



Area grazed (% of total area)

J	A	S	O	N	D	J	F	M	A	M	J
33.9	59.4	72.5	85.1	59.7	67.8	66.7	65.4	67.8	69.9	64.7	52.7

Average length of spell (weeks)

J	A	S	O	N	D	J	F	M	A	M	J
7.8	10.2	7.7	5.4	5.5	5.2	6.3	6.4	6.2	6.4	6.4	7.0

Area closed for silage (% of total area)
24.5

FIGURE 6.3 AVERAGE DAILY FEED SUPPLY TO EACH LACTATING COW AT 1.5 COWS/ACRE IN THE 'SELF CONTAINED' PLAN.

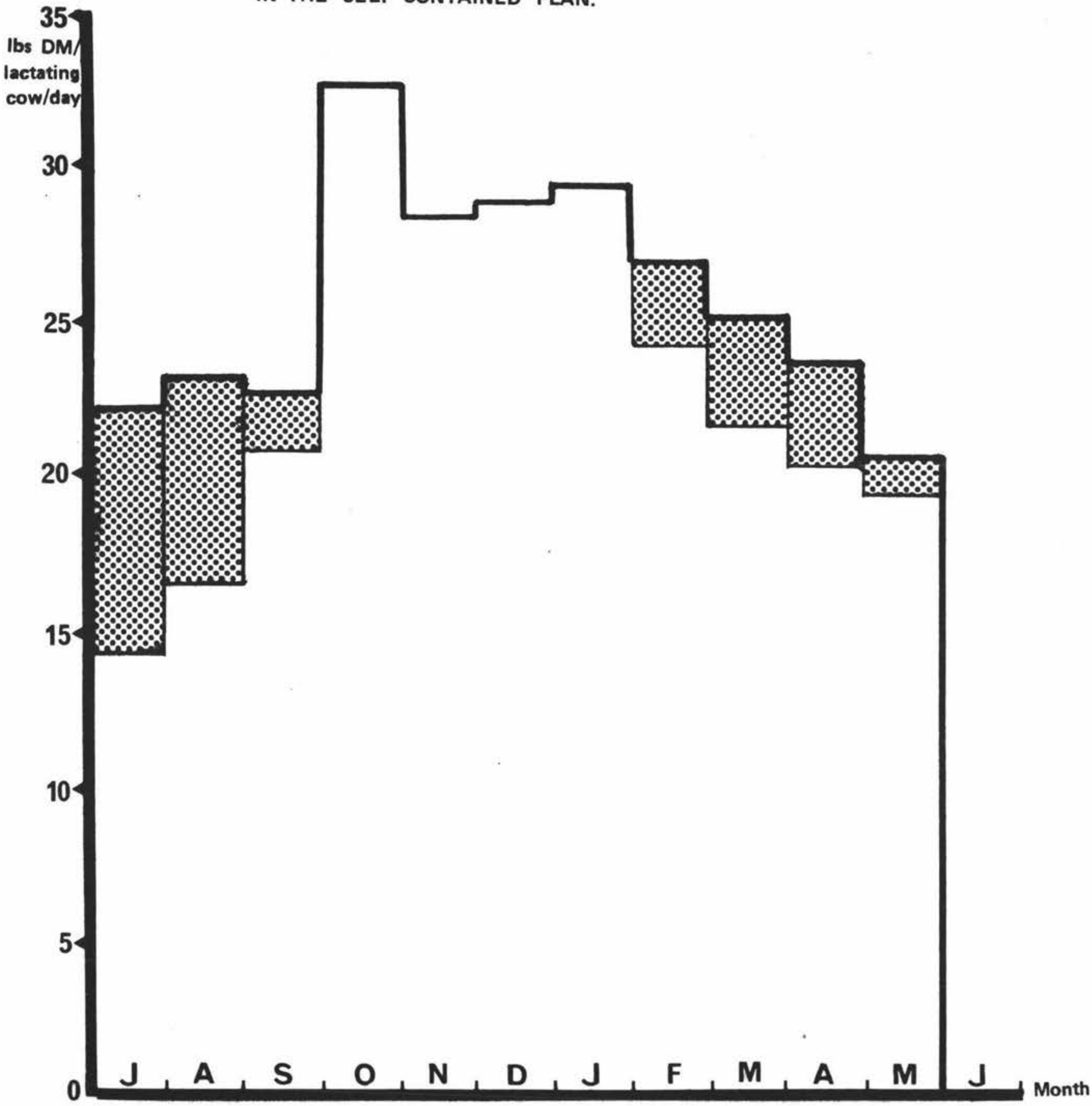


TABLE 6.9 AVERAGE DAILY FEED SUPPLY TO EACH DRY COW AT 1.5 COWS/ACRE IN THE 'SELF–CONTAINED' PLAN.

	May	June	July	August
		(lbs DM/dry cow/day)		
Pasture	11.8	12.9	5.4	11.5
Hay	–	–	12.4	6.1
TOTAL	11.8	12.9	17.8	17.6

FIGURE 6.4 AVERAGE DAILY FEED SUPPLY TO EACH LACTATING COW AT 1.5 COWS/ACRE IN THE 'HAYBUYING' PLAN.

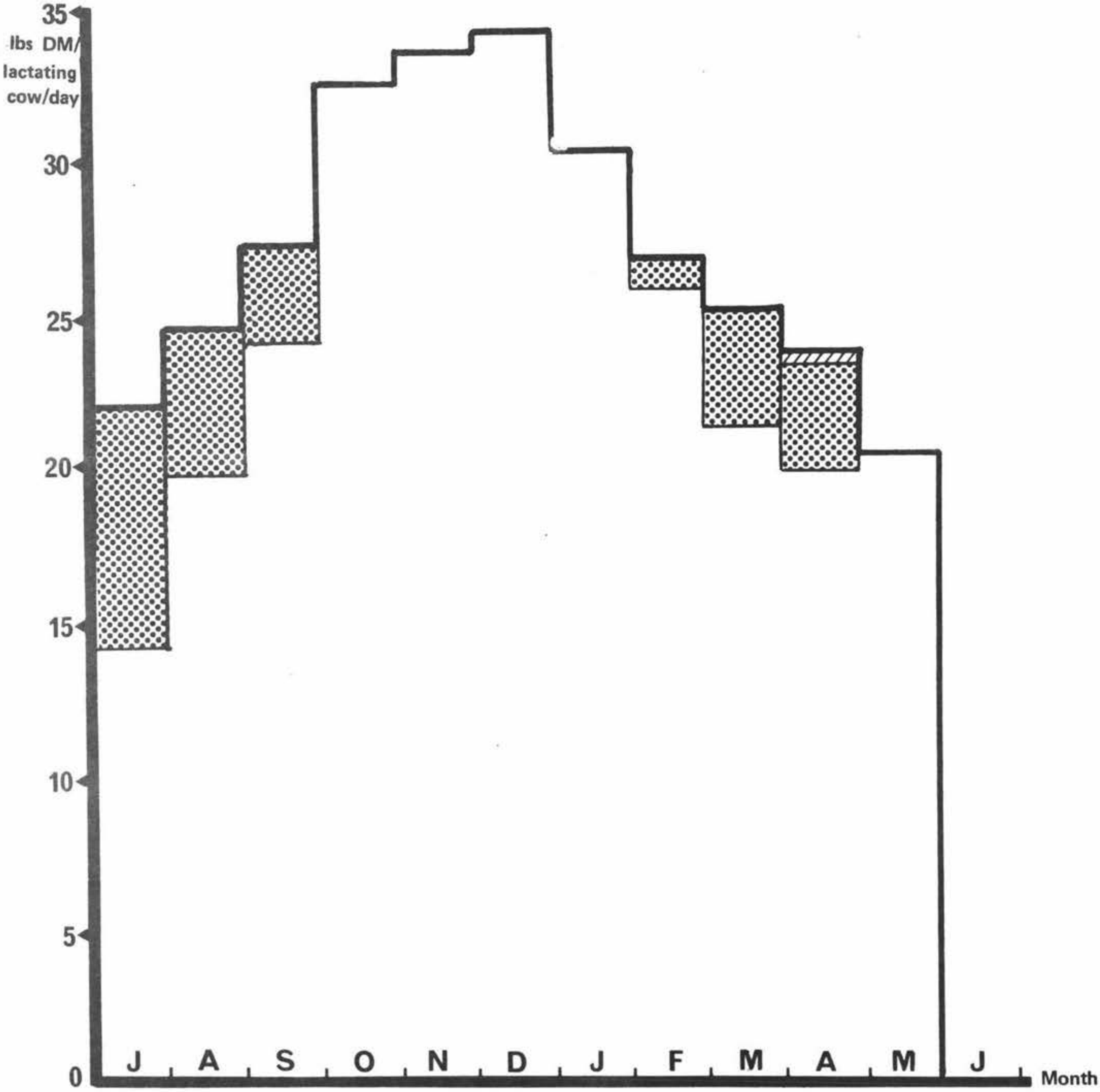


TABLE 6.10 AVERAGE DAILY FEED SUPPLY TO EACH DRY COW AT 1.5 COWS/ACRE IN THE 'HAYBUYING' PLAN.

	May	June	July	August
		(lbs DM/dry cow/day)		
Pasture	11.8	12.9	3.2	–
Hay	–	–	15.2	21.0
TOTAL	11.8	12.9	18.4	21.0

FIGURE 6.5 AVERAGE DAILY BUTTERFAT PRODUCTION/COW AT 1.5 COWS/ACRE IN THE 'SELF-CONTAINED' PLAN.

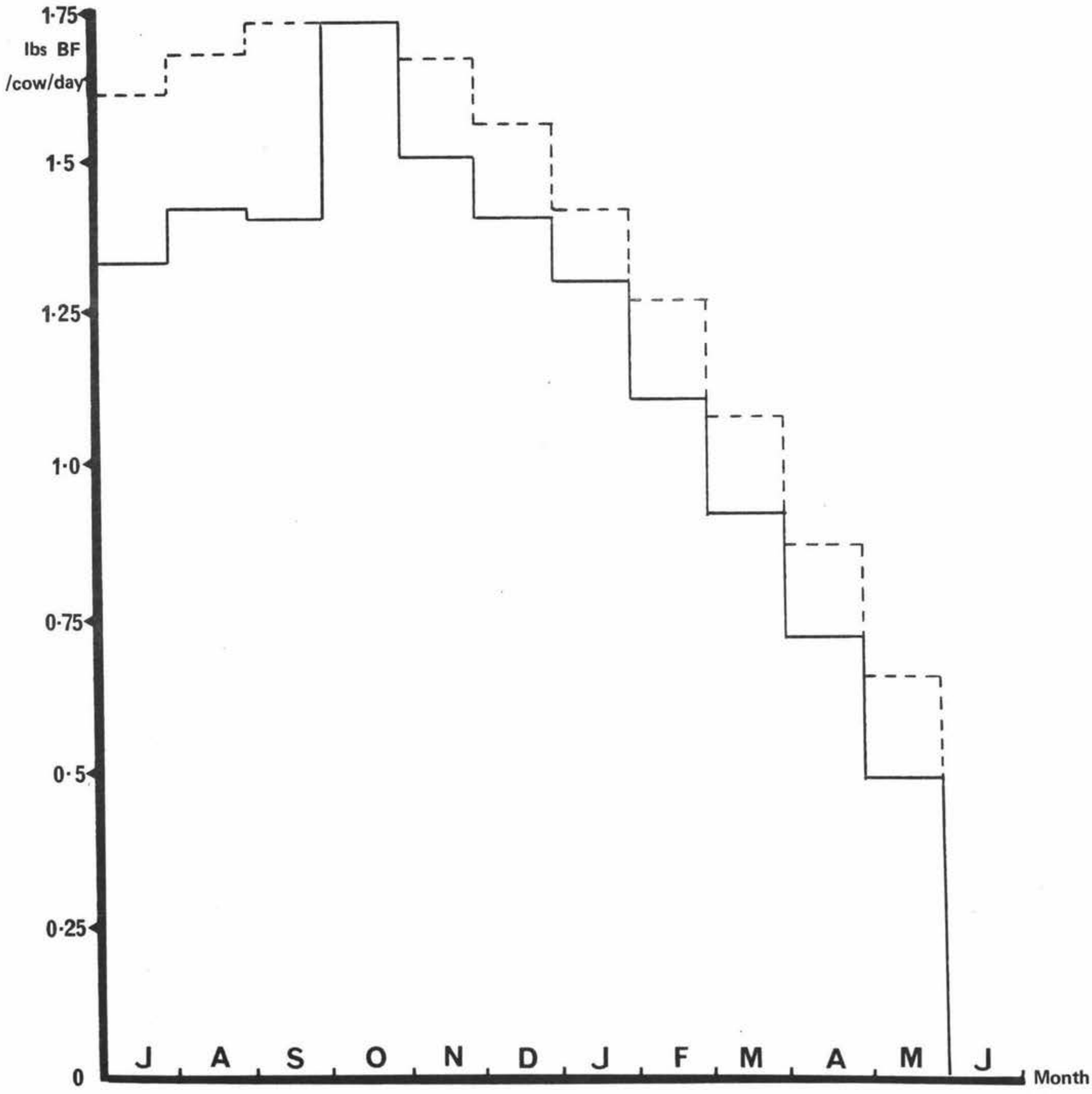
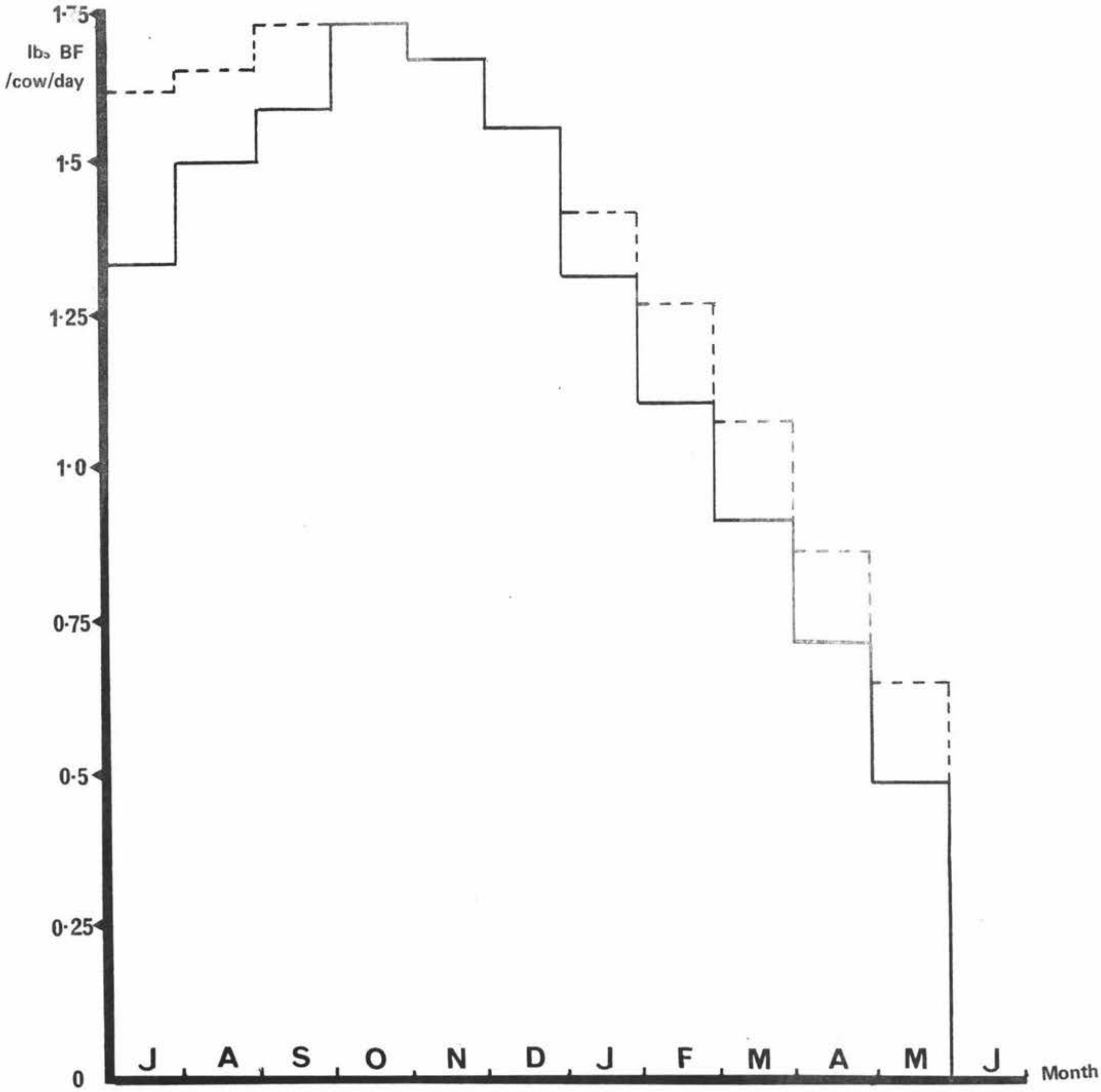


FIGURE 6.6 AVERAGE DAILY BUTTERFAT PRODUCTION/COW .5 COWS/ACRE IN THE 'HAYBUYING' PLAN.



In the 'hay-buying' plan, additional hay is fed to the dry cows in July and August. This permits a slower grazing rotation to be followed over this period. The resulting longer spelling of pasture provides higher dry matter yields when grazed in August and September and this increases intake and butterfat production in each month. In the 'hay-buying' plan, the release of land previously closed for hay production makes extra pasture available for grazing in November and December resulting in increased butterfat production over this period. Similar amounts of silage are fed to the lactating cows in early lactation in each plan, but slightly less silage is fed in late lactation in the 'hay-buying' plan. Similar grazing management practices occur between January and June resulting in similar amounts of pasture supplied over this period in each plan.

6.7.2 'Hay-buying' and 'Nitrogen' plans

The grazing management and conservation practices, together with the resulting dry matter production for the 'Nitrogen' plan at 1.5 cows/acre are contained in Table A6.3, Appendix 6, which also supplied information on N activities included in the optimum plan. The system of grazing management, N use and pasture conservation practices followed are summarised in Table 6.11. The resulting monthly supply of pasture and N produced grass, together with hay and silage production are illustrated in Figure 6.7. The monthly allocation of feed to lactating and dry cows is contained in Figure 6.8 and Table 6.12. Monthly butterfat production is illustrated in Figure 6.9.

In comparing the 'Nitrogen' and 'hay-buying' management plans, it can be seen that in the 'Nitrogen' plan, N is applied to the total area closed for silage in September. However, the closing of an area of land for silage in September, and a small area for hay production in October, results in slightly less area available for grazing over the October/November/December period. An application of N to pasture in September provides additional feed in October. This enables the cows to be fully fed in this month on a smaller area of land while pasture growth on land to be grazed in November and December is 'spelled'. The result is sufficient pasture to maintain maximum intake and butterfat production in both months.

TABLE 6.11 GRAZING MANAGEMENT AND CONSERVATION PRACTICES AT 1.5 COWS/ACRE IN THE 'NITROGEN' PLAN

	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Area grazed (% of total area)	38.8	65.6	75.4	79.8	55.3	65.3	76.7	62.5	67.8	73.7	56.9	38.4
Average length of spell (weeks)	9.6	9.9	6.9	5.4	5.8	5.4	6.2	5.9	6.2	6.4	6.2	7.6
Area to which N is applied for grazing (% of total area)	34.4	19.6	10.2	-	-	-	-	-	-	41.3	11.3	-
Area closed for silage (% of total area)	-	-	5.3	17.9	-	-	-	-	-	-	-	-
Area to which N is applied for silage (% of total area)	-	-	5.3	-	-	-	-	-	-	-	-	-
Silage produced by N (lbs DM)	-	-	-	-	48.0	-	-	-	-	-	-	-
Area closed for hay (% of total area)	-	-	-	2.4	-	-	-	-	-	-	-	-

FIGURE 6.7 TOTAL PASTURE ALLOCATED FOR GRAZING AND CONSERVATION IN EACH MONTH AT 1.5 COWS/ACRE IN THE 'NITROGEN' PLAN.

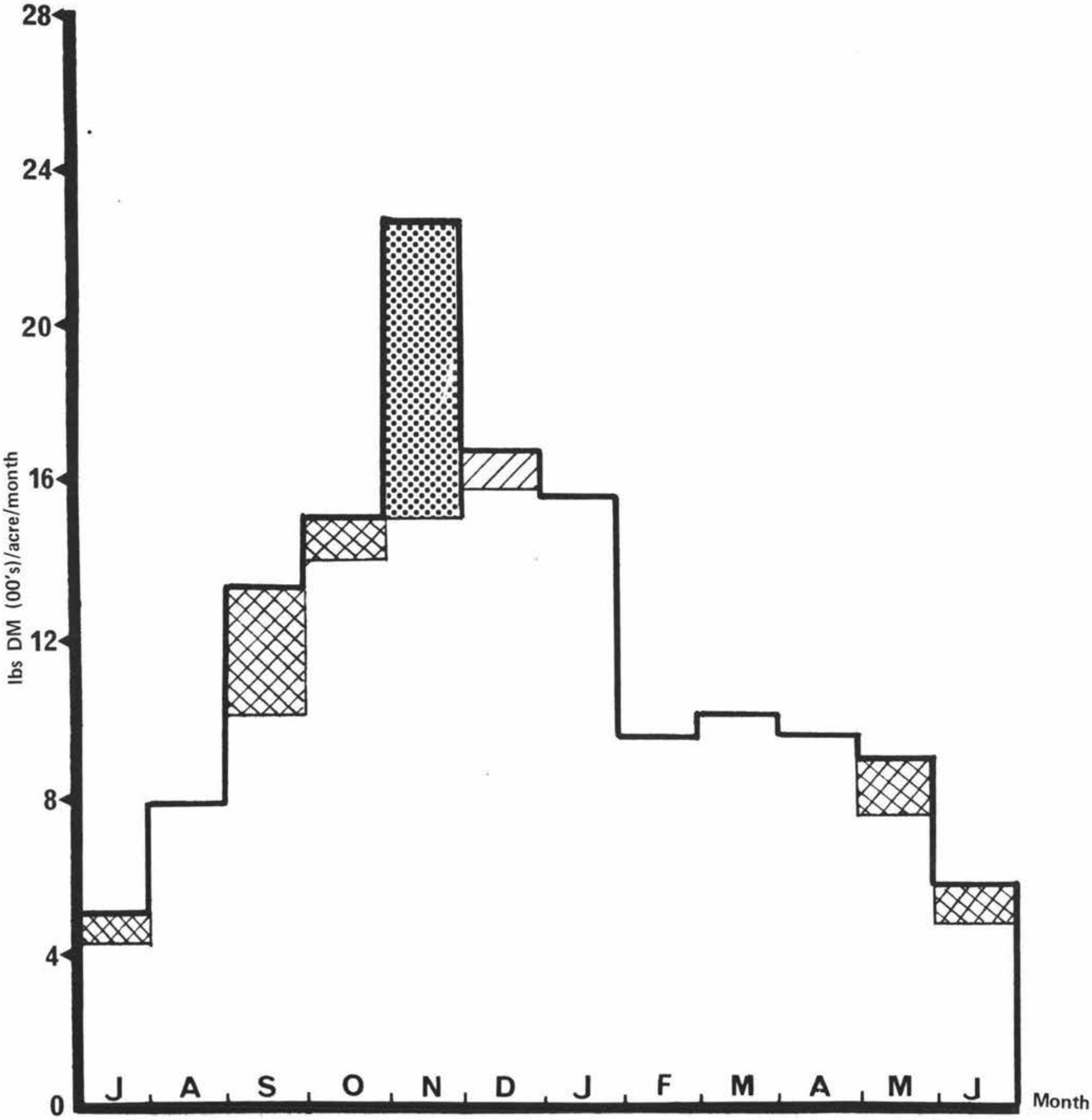


FIGURE 6.8 AVERAGE DAILY FEED SUPPLY TO EACH LACTATING COW AT 1.5 COWS/ACRE IN THE 'NITROGEN' PLAN.

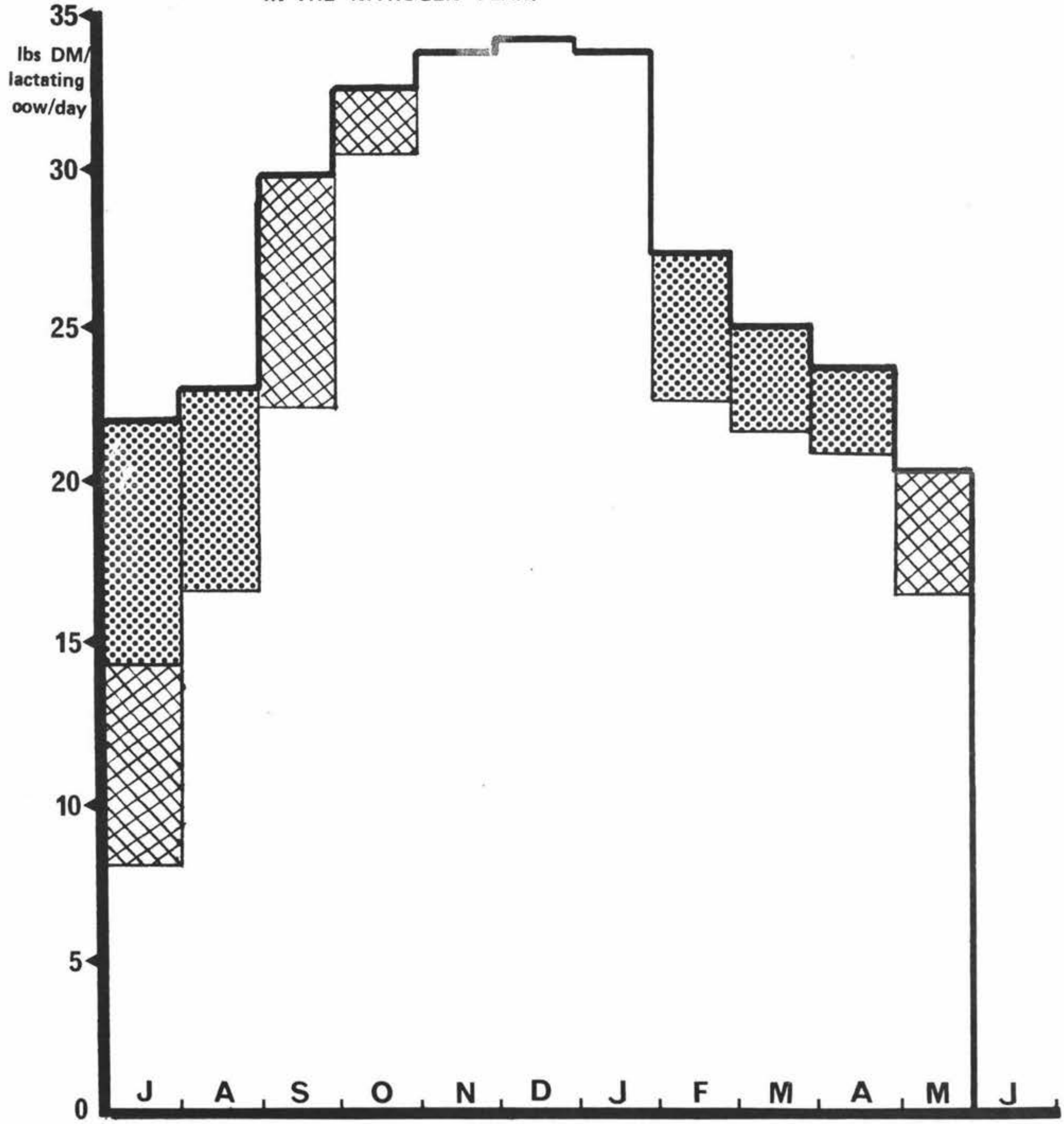
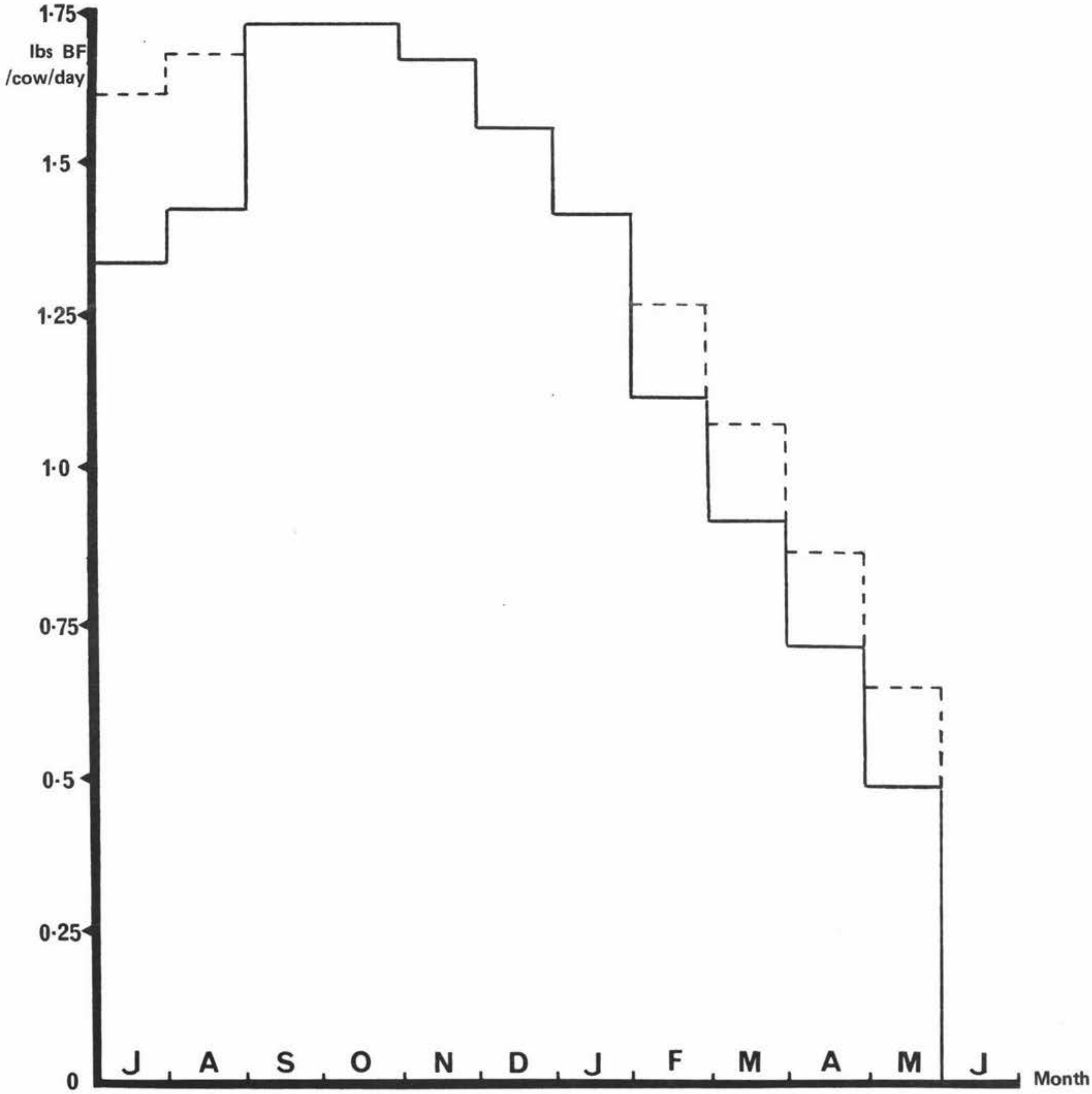


TABLE 6.12 AVERAGE DAILY FEED SUPPLY TO EACH DRY COW AT 1.5 COWS/ACRE IN THE 'NITROGEN' PLAN.

	May	June	July	August
		(lbs DM/dry cow/day)		
Pasture	11.8	10.8	8.8	14.2
N. produced grass	–	2.1	–	–
Hay	–	–	8.0	2.8
TOTAL	11.8	12.9	16.8	17.0

FIGURE 6.9 AVERAGE DAILY BUTTERFAT PRODUCTION/COW AT 1.5 COWS/ACRE IN THE 'NITROGEN' PLAN.



N fertiliser is, therefore, used to allow similar silage requirements to those in the 'hay-buying' plan to be met from a reduc d area of land. N fertiliser thus enables silage production to be maintained and hay output increased to replace more expensive purchased hay, without prejudicing butterfat production over the spring-early summer period.

In January, a greater area is grazed in the 'Nitrogen' plan so that the cows are fully fed, but this causes February pasture supply to be reduced and additional silage is fed in this month.

Similar areas of pasture spelled for approximately the same length of time are grazed in March and April. The grazing rotation is slowed down and less pasture is supplied in May and June so that pasture can be conserved for late winter-early spring. N produced grass from April applications is used to maintain intake over this period. Increased areas of pasture are grazed in July, August and September and the longer spelling of pasture grazed in July and August, as a result of the slower rotation over May and June, provides increased pasture supply in each month. In July and August, because less hay is available, additional pasture is fed to the dry cows. In July, lactating cow intake is maintained at the same level as in the 'hay-buying' plan by N produced grass. In August, because of the additional pasture fed to the dry cows, pasture available to the lactating cows is less than in the 'hay-buying' plan and, although additional silage is fed, dry matter intake and butterfat production are slightly reduced. N is applied to pasture grazed in July and August to ensure that feed is available to fully feed the cows in September.

6.8 COMPARISON BETWEEN DIFFERENT SYSTEMS OF GRAZING MANAGEMENT AT 2.0 COWS/ACRE

6.8.1 'Self-contained' and 'hay-buying' plans

The grazing management and conservation practices, together with the resulting dry matter production for the 'self-contained' and 'hay-buying' plans are contained in Tables A6.4 and A6.5 of Appendix 6, and are summarised in Figures 6.10 and 6.11 respectively. The monthly allocation of feed to lactating and dry cows is contained in Figure 6.12 and Table 6.13 for the 'self-contained' plan, and Figure 6.13 and Table 6.14 for the 'hay-buying' plan. Monthly butterfat production is illustrated in Figure 6.14 for the 'self-contained' plan and Figure 6.15 for the 'hay-buying' plan.

Similar areas of pasture spelled for approximately the same length of time are grazed in February, March and April in both plans.

In the 'self-contained' plan all cows are 'dried off' on the 30 April. In the 'hay-buying' plan, however, only 20 percent of the herd is dried off on this date, the remainder of the herd continue to be milked until the end of May [1/]. Consequently, in the 'hay-buying' plan, a greater area of pasture is grazed in May. In the 'hay-buying' plan, purchased hay allows a slower rotation to be followed between June and October. Slightly more hay is fed to the dry cows in June, July and August. Consequently, slightly more pasture is fed to the lactating cows in July and August. However, effective dry matter intake and butterfat production in July and August remain the same as in the 'self-contained' plan, as purchased hay is used to replace expensive meal feeding in both months. In September, silage is used to replace meal feeding, and effective dry matter intake and butterfat production is again similar to the 'self-contained' plan.

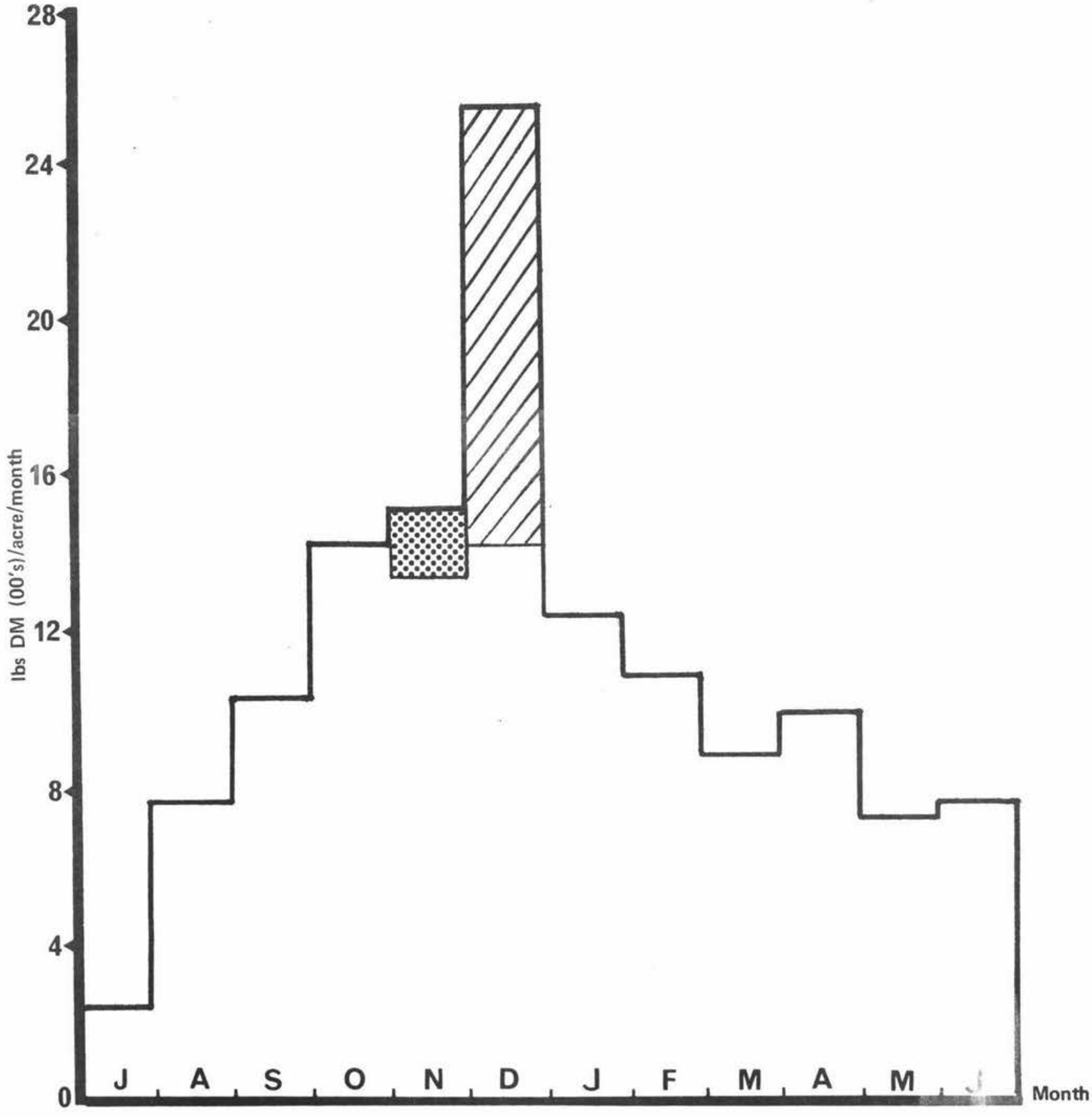
In the 'hay-buying' plan, longer spelling of pasture grazed in October increases the amount of pasture fed to the cows in this month and results in increased butterfat production compared with the 'self-contained' plan. The release of land previously closed for hay production makes extra pasture available for grazing in November, December and January so that dry matter intake and butterfat production are both raised over this period. Also, large amounts of purchased hay are used to substitute for small quantities of meal and silage and to raise intake and butterfat production levels in the second half of lactation.

6.8.2 'Hay-buying' and 'Nitrogen' plans

The grazing management and conservation practices, together with resulting dry matter production for the 'Nitrogen' plan, are contained in Table A6.6 of Appendix 6, as is information on the N activities included in the optimum plan. The system of grazing management, N use and pasture conservation practices followed, are summarised in Table 6.15. The resulting monthly supply of pasture and N produced grass, together with hay and silage production, is illustrated in Figure 6.16. The monthly allocation of feed to lactating and dry cows is contained in Figure 6.17 and Table 6.16. Monthly butterfat production is illustrated in Figure 6.18.

1/ This is the standard lactation pattern assumed in the model although provision is made for drying off all the cows in April if it is more economic to do so. May feed supply in this latter case is used for maintenance.

FIGURE 6.10 GRAZING MANAGEMENT AND CONSERVATION PRACTICES, AND RESULTING MONTHLY DRY MATTER SUPPLY AT 2.0 COWS/ACRE IN THE 'SELF–CONTAINED' PLAN.



Area grazed (% of total area)

J	A	S	O	N	D	J	F	M	A	M	J
34.8	65.2	80.5	86.6	47.3	49.9	67.8	69.4	62.8	76.8	55.3	6[illegible].1

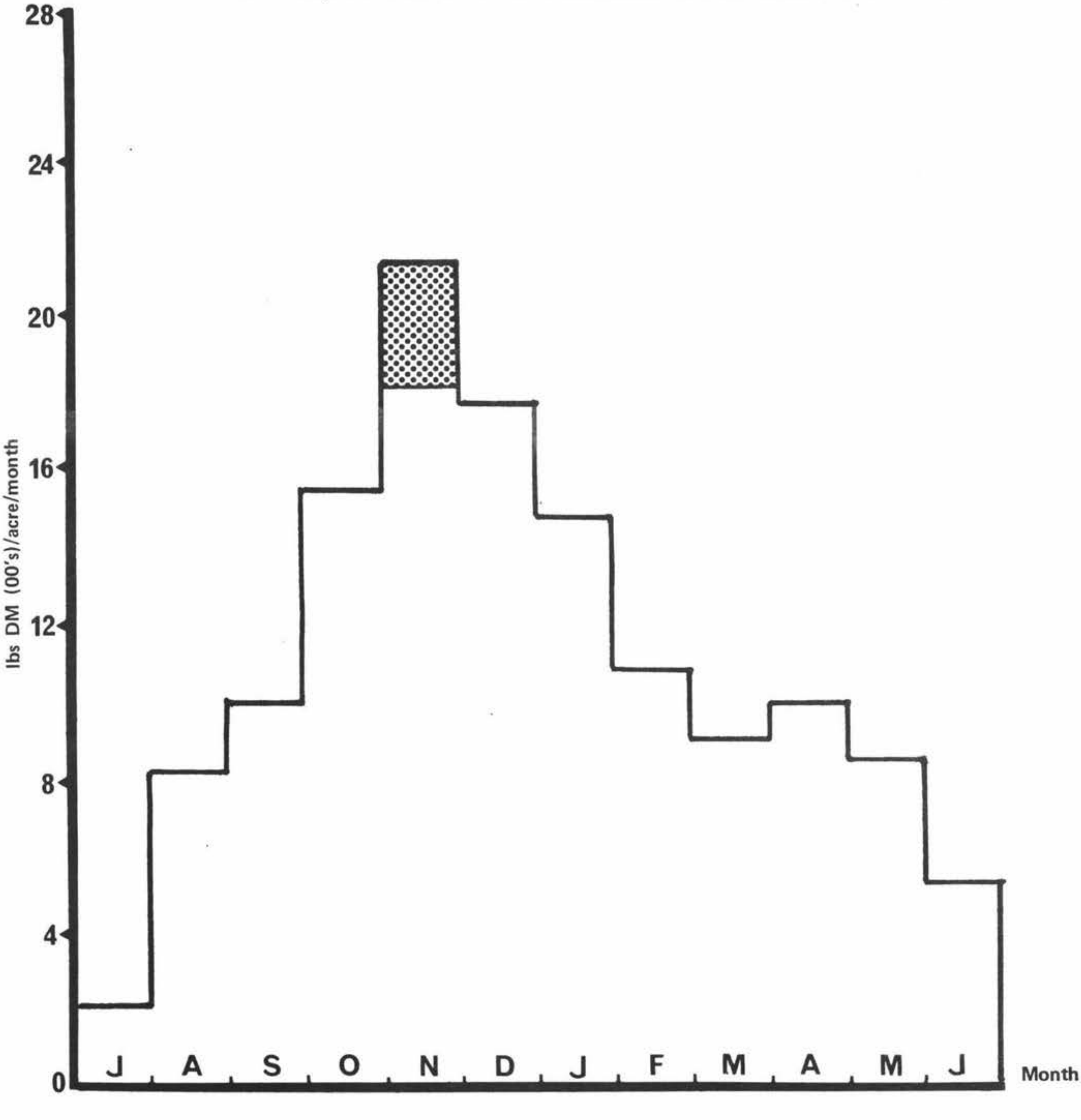
Average length of spell (weeks)

J	A	S	O	N	D	J	F	M	A	M	J
7.0	9.6	6.3	5.0	6.1	6.0	5.8	6.1	5.9	6.4	6.2	7.3

Area closed for silage (% of total area)
5.5

Area closed for hay (% of total area)
28.0

FIGURE 6.11 GRAZING MANAGEMENT AND CONSERVATION PRACTICES AND RESULTING DRY MATTER SUPPLY AT 2.0 COWS/ACRE IN THE 'HAYBUYING' PLAN.



	J	A	S	O	N	D	J	F	M	A	M	J
Area grazed (% of total area)	20.6	63.6	67.5	85.0	67.9	66.2	70.8	66.2	63.0	77.4	65.3	48.1
Average length of spell (weeks)	10.9	11.0	7.7	5.6	5.8	5.7	6.3	6.3	6.0	6.4	6.1	6.7
Area closed for silage (% of total area)				11.2								

FIGURE 6.12 AVERAGE DAILY FEED SUPPLY TO EACH LACTATING COW AT 2.0 COWS/ACRE IN THE 'SELF–CONTAINED' PLAN.

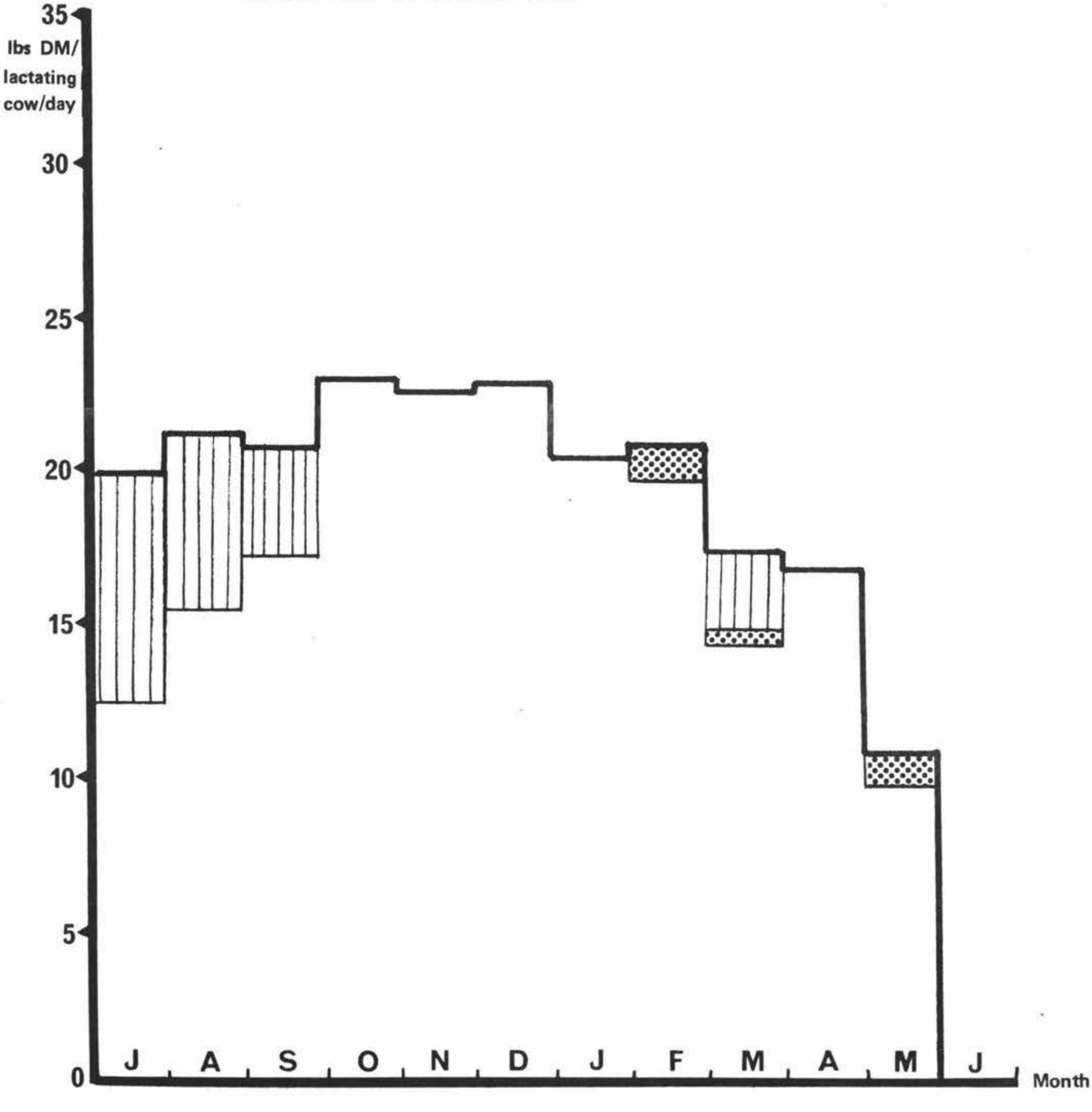


TABLE 6.13 AVERAGE DAILY FEED SUPPLY TO EACH DRY COW AT 2.0 COWS/ACRE IN THE 'SELF–CONTAINED' PLAN.

	May	June	July	August
		(lbs DM/dry cow/day)		
Pasture	11.8	12.9	1.6	3.7
Hay	–	–	17.3	16.0
TOTAL	11.8	12.9	18.9	19.7

FIGURE 6.13 AVERAGE DAILY FEED SUPPLY TO EACH LACTATING COW AT 2.0 COWS/ACRE IN THE 'HAYBUYING' PLAN.

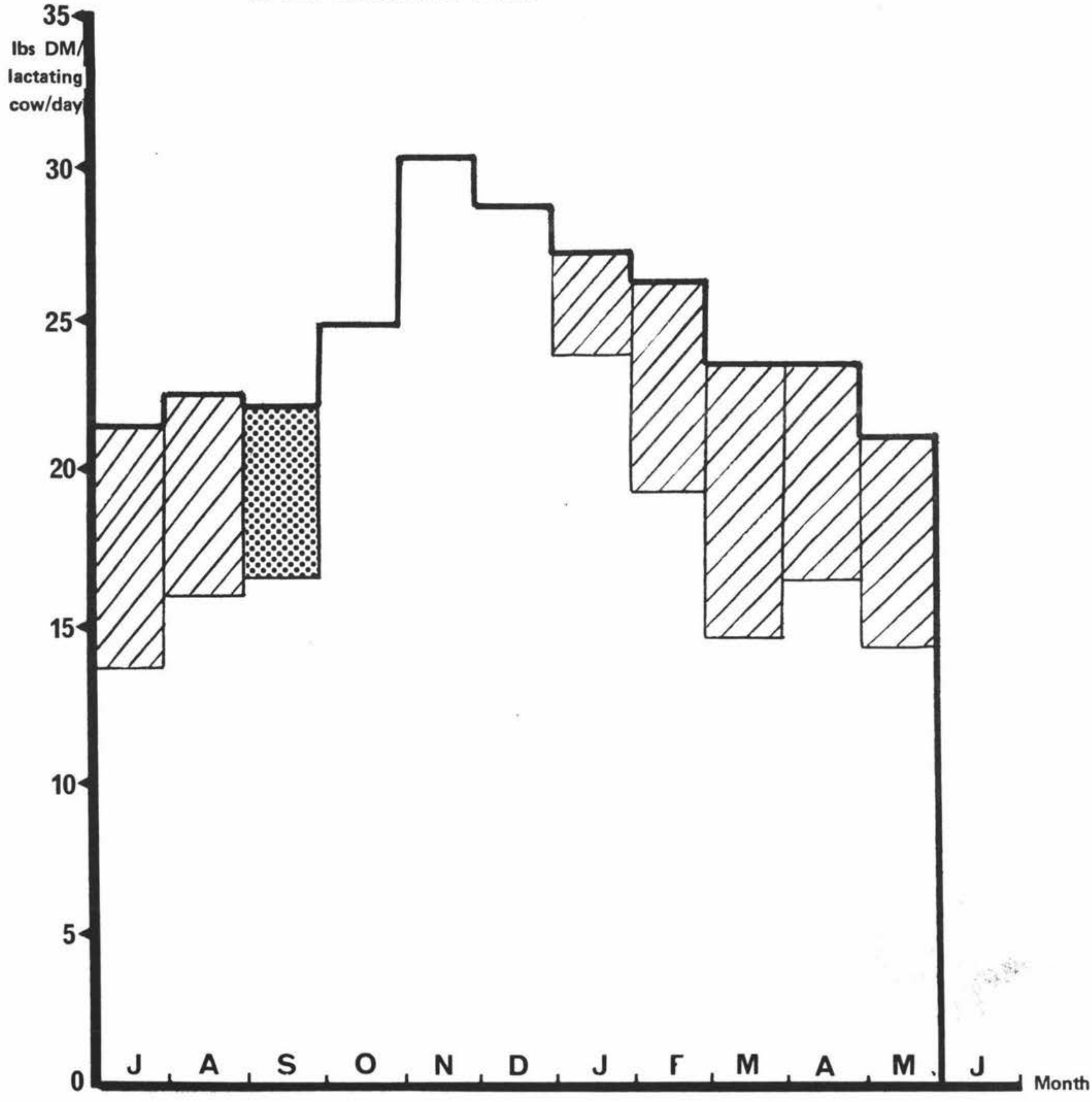


TABLE 6.14 AVERAGE DAILY FEED SUPPLY TO EACH DRY COW AT 2.0 COWS/ACRE IN THE 'HAYBUYING' PLAN.

	May	June	July	August
		(lbs DM/dry cow/day)		
Pasture	11.8	8.8	–	–
Hay	–	5.0	19.3	21.0
TOTAL	11.8	13.8	19.3	21.0

FIGURE 6.14 AVERAGE DAILY BUTTERFAT PRODUCTION/COW AT 2.0 COWS/ACRE IN THE 'SELF–CONTAINED' PLAN.

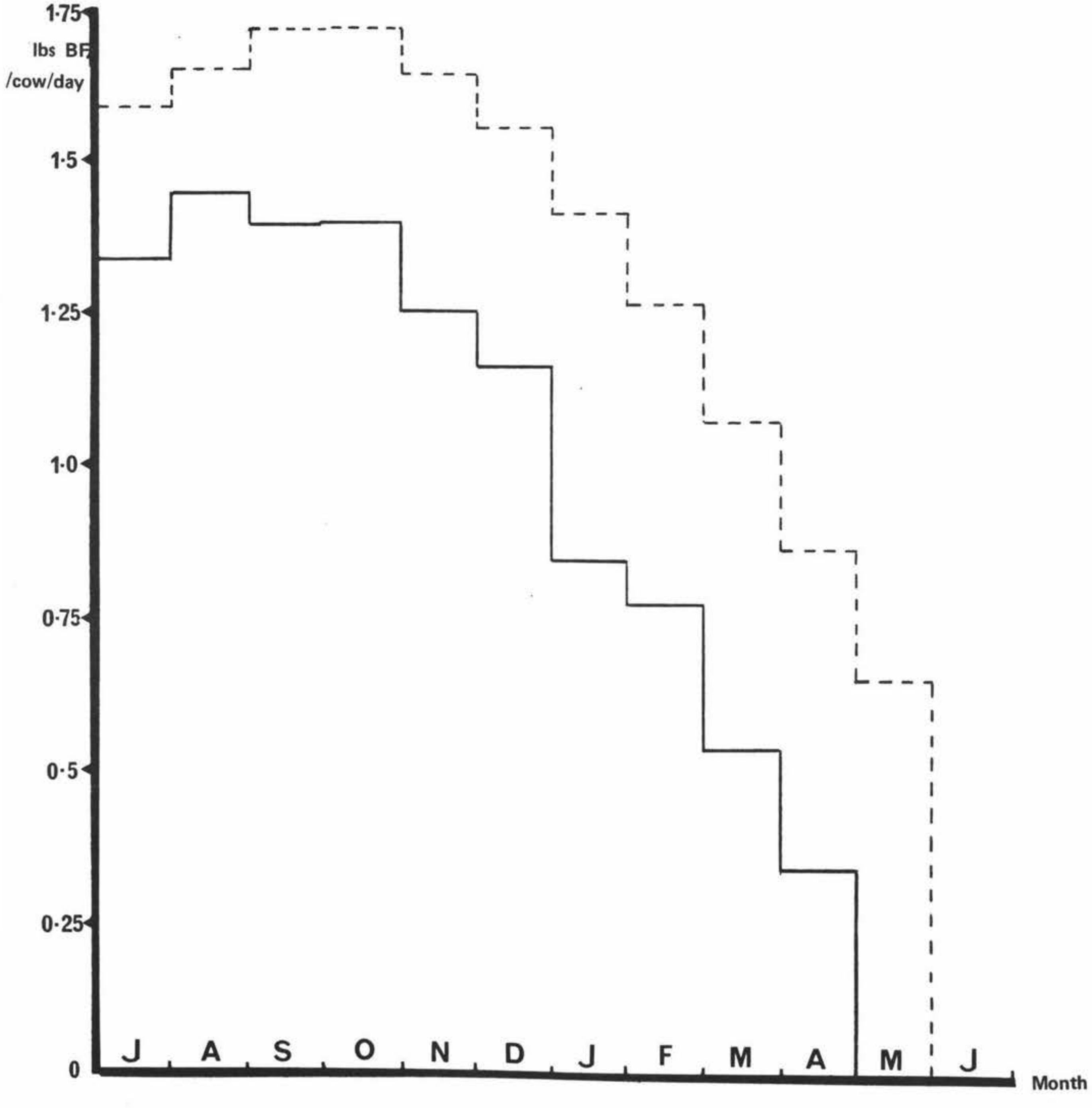


FIGURE 6.15 AVERAGE DAILY BUTTERFAT PRODUCTION/COW AT 2.0 COWS/ACRE IN THE 'HAYBUYING' PLAN.

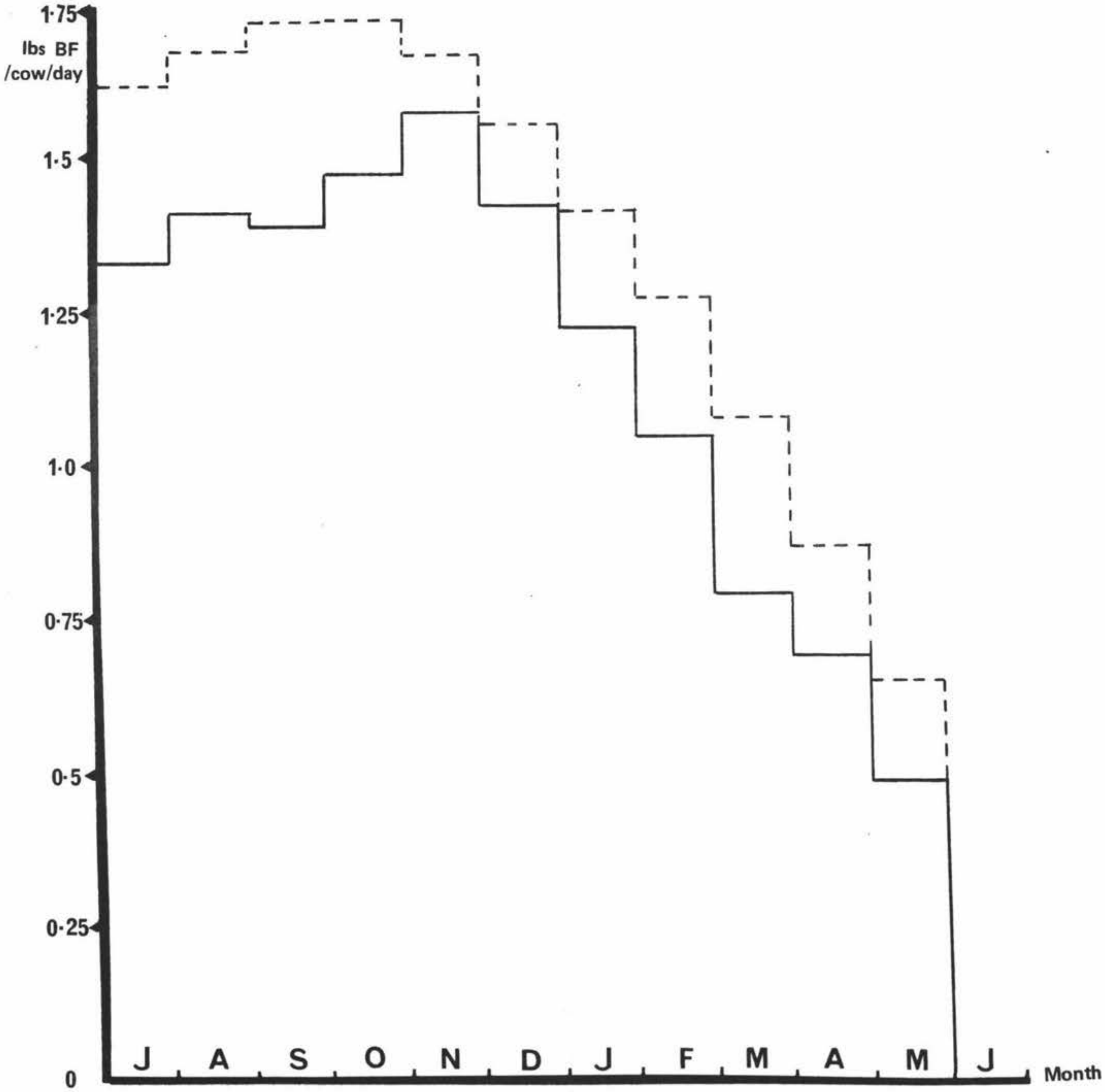


TABLE 6.15 GRAZING MANAGEMENT AND CONSERVATION PRACTICES AT 2.0 COWS/ACRE IN THE 'NITROGEN' PLAN

	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Area grazed (% of total area)	32.5	67.5	71.1	76.9	59.4	66.2	72.0	71.7	64.8	86.9	56.9	43.2
Average length of spell (weeks)	9.3	10.1	7.0	5.6	5.8	5.6	6.2	5.9	5.7	6.1	5.9	7.6
Area to which N is applied for grazing (% total area)	32.5	67.5	50.2	47.2	-	-	-	-	-	86.9	12.8	-
Area closed for silage (% of total area)	-	-	8.7	12.9	-	-	-	-	-	-	-	-
Area to which N is applied for silage (% of total area)	-	-	8.7	12.9	-	-	-	-	-	-	-	-
Silage produced by N (lbs DM)	-	-	-	-	171	-	-	-	-	-	-	-

FIGURE 6.16 TOTAL PASTURE ALLOCATED FOR GRAZING AND CONSERVATION IN EACH MONTH AT 2.0 COWS/ACRE IN THE 'NITROGEN' PLAN.

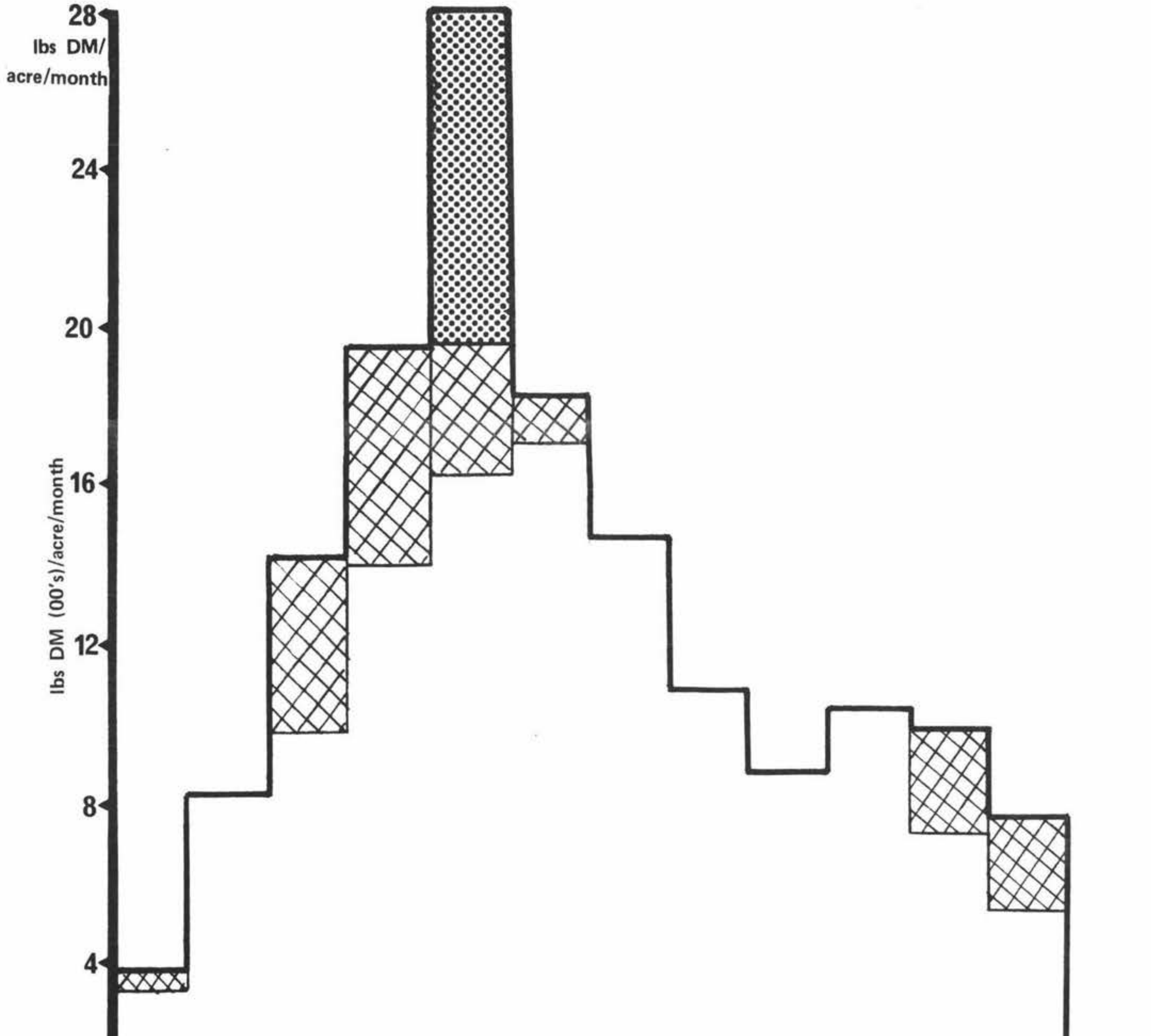


FIGURE 6.17 AVERAGE DAILY FEED SUPPLY TO EACH LACTATING COW AT 2.0 COWS/ACRE IN THE 'NITROGEN' PLAN.

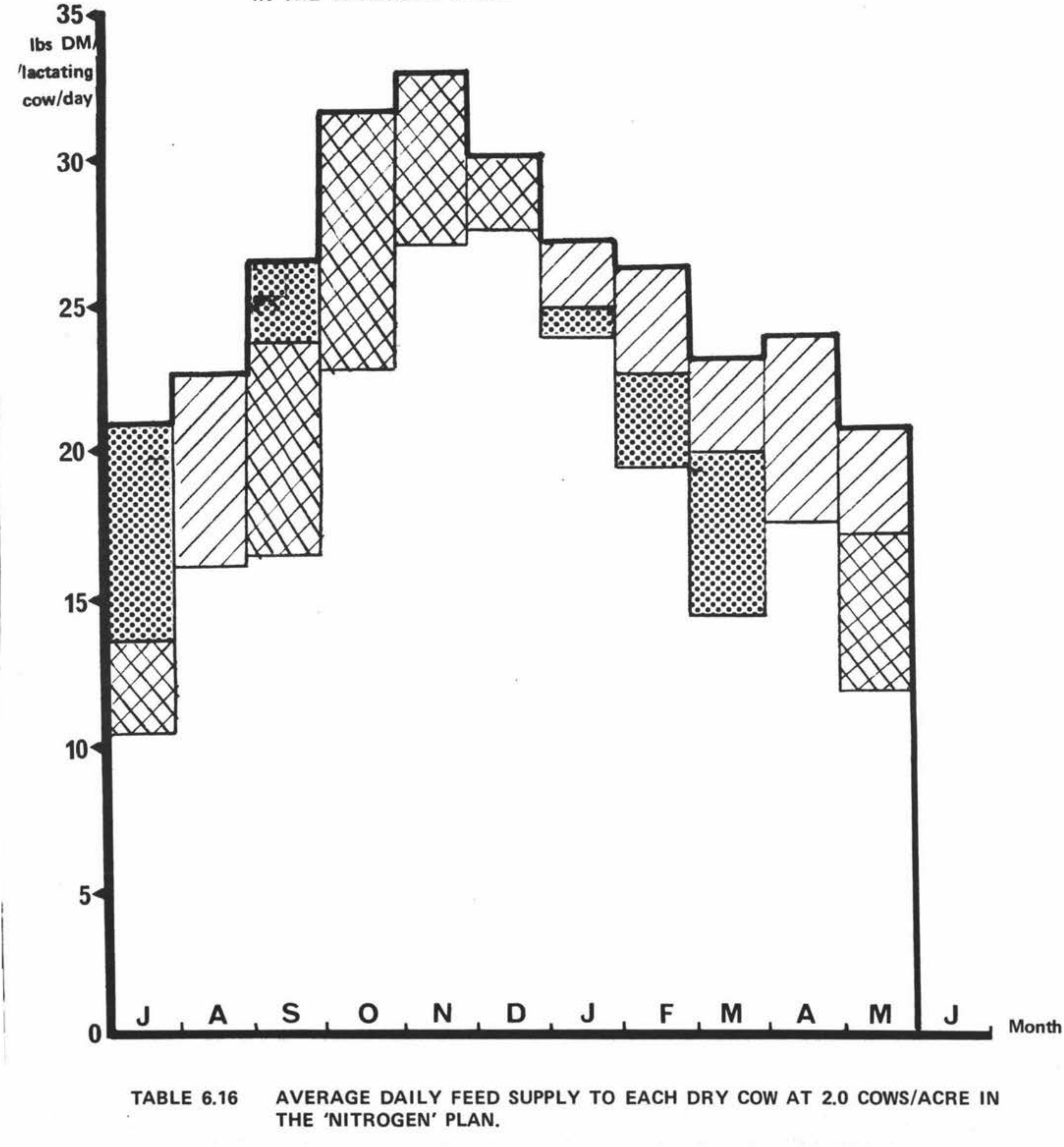
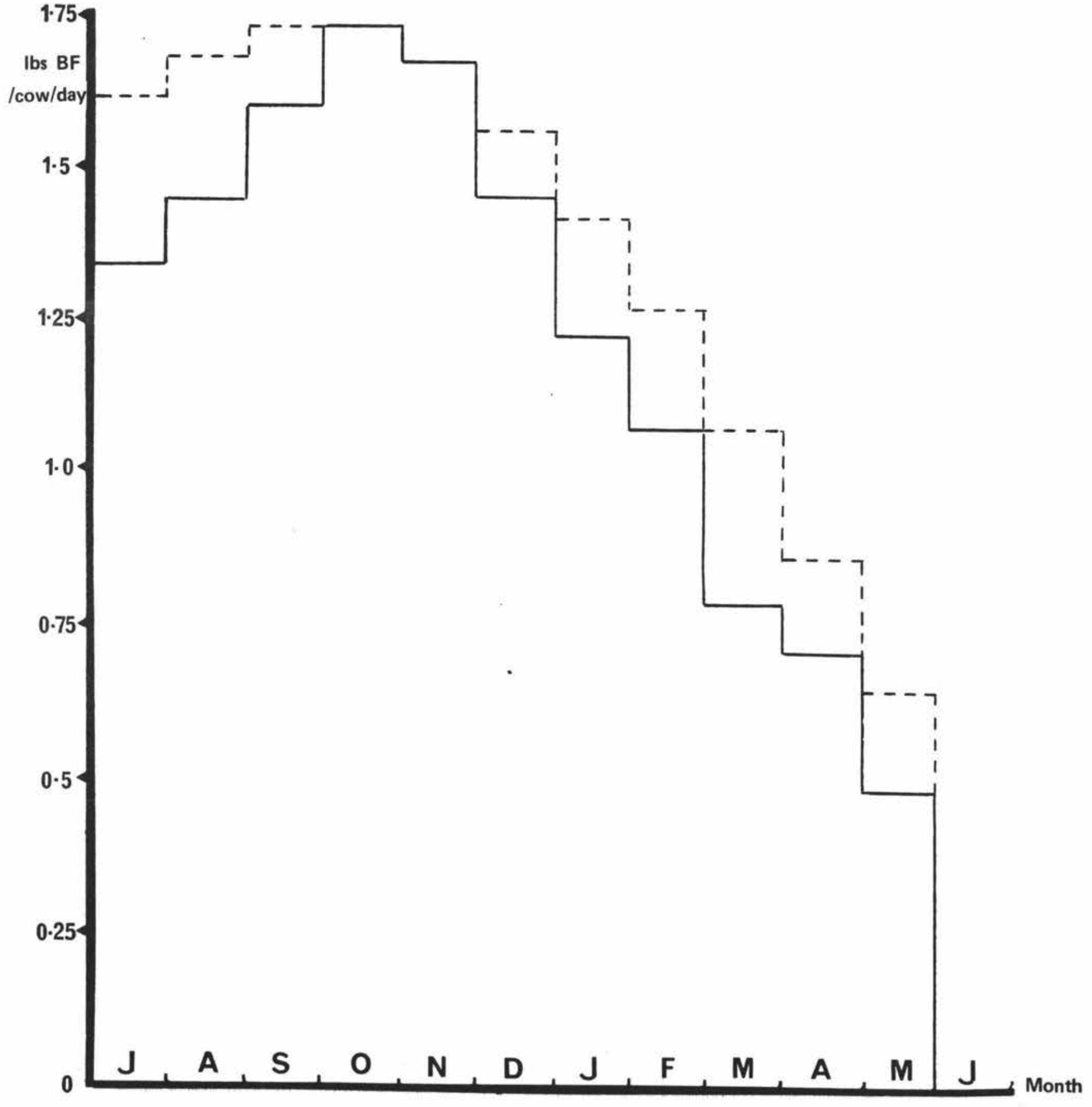


TABLE 6.16 AVERAGE DAILY FEED SUPPLY TO EACH DRY COW AT 2.0 COWS/ACRE IN THE 'NITROGEN' PLAN.

	May	June	July	August
		(lbs DM/dry cow/day)		
Pasture	11.8	8.8	3.4	–
N. produced grass	–	4.1	–	–
Hay	–	–	14.9	21.0
TOTAL	11.8	12.9	18.3	21.0

FIGURE 6.18 AVERAGE DAILY BUTTERFAT PRODUCTION/COW AT 2.0 COWS/ACRE IN THE 'NITROGEN' PLAN.



The major management differences between the 'hay-buying' and 'Nitrogen' plans are as follows:

In the 'Nitrogen' plan, application of N to pasture in July and August permits silage feeding in September to be replaced and dry matter intake and butterfat production to be considerably increased. In October and November, the area available for grazing is reduced because additional land is closed in September and October for silage production. This enables silage requirements to be met by taking a minimum amount of land out of the grazing rotation in October and November. N fertiliser is also used to increase intake and allow a slow grazing rotation to be followed while silage paddocks are out of the rotation. This allows pasture to be spelled for longer periods which in turn results in increased pasture and butterfat production. Consequently, N applications between July and October result in 32.8 lbs additional butterfat/acre in the September/October/November period. This represents approximately 90 percent of the difference in butterfat production between the 'Nitrogen' and 'hay-buying' plans. A late October application of N is also responsible for extra pasture supply in December. Total DM intake and butterfat production in January, February and March are similar in both plans but considerable substitution of silage for hay, as a milking feed supplement, occurs in the 'Nitrogen' plan.

As less hay is purchased in the 'Nitrogen' plan, it is necessary to apply N to large areas in April to meet feed requirements over the winter/early spring period. Consequently, the area grazed in April is slightly increased resulting in a small increase in pasture supply to lactating cows in this month. N is applied to all areas grazed in April. A slower rotation is then followed over May and June so that pasture can be conserved for the winter-early spring period. N produced grass is used in May to maintain intake at a similar level to that in the 'hay-buying' plan, while in June it is used to replace hay fed to the dry cows. N is also applied to pasture in May.

In July, N produced grass and silage are used to replace hay fed to the milking cows. The extra area grazed in this month also supplies additional pasture to meet the dry cow requirements. In August, similar amounts of pasture and hay are fed to the lactating cows for both plans. Dry cow requirements in August are met by hay in both plans.

TABLE 6.17 SUMMARY OF RESULTS

Stocking Rate:		1.0	1.2	1.5	1.7	2.0
BF/cow (lbs)						
(i)	Self-contained	399.4	392.9	356.2	310.6	272.0
(ii)	Hay-buying			373.6	366.1	341.6
(iii)	Nitrogen			379.3	374.2	360.1
BF/acre (lbs)						
(i)	Self-contained	399.4	471.5	534.3	528.0	544.0
(ii)	Hay-buying			560.4	622.4	683.1
(iii)	Nitrogen			569.0	636.1	720.2
Net Revenue/acre ($)						
(i)	Self-contained	123.6	140.0	155.5	152.4	131.8
(ii)	Hay-buying			157.8	163.2	165.4
(iii)	Nitrogen			159.7	168.5	173.6

Notes: (a) BF at 30c/lb, N fertiliser at 10c/lb N.

(b) Hay purchases and N application were not profitable at 1.0 and 1.2 cows/acre.

CHAPTER 7

FERTILISER MAINTENANCE REQUIREMENTS OF PASTURE

7.1 INTRODUCTION

In previous chapters the profitability of N fertiliser use has been discussed without reference to the productivity level of the pasture. The optimum economic rate of N application will be determined by the distribution of pasture production throughout the year, and the total amount of pasture produced. As plant nutrients other than N affect pasture growth and possibly N response, analysis of the economics of N use cannot be separated from a consideration of total fertiliser use. Discussion in this chapter is confined to Phosphorus (P), Potassium (K) and Sulphur (S) maintenance requirements of pasture [1].

7.2 SULPHATE MAINTENANCE REQUIREMENTS

The sulphate group (SO_4^-) is only weakly retained on the soil colloids and is not fixed, except perhaps where there is accumulation of organic matter, and its effectiveness as a fertiliser is reduced by its leaching through the soil profile to beyond the reach of plant roots [2]. For the purpose of this study it is assumed that the quantity of superphosphate that will meet soil phosphate requirements, will also meet the sulphate requirement of the soil.

7.3 POTASSIUM MAINTENANCE REQUIREMENTS

Most New Zealand soils were well supplied with potassium in their original state. Under intensive dairy farming conditions, the losses of this nutrient can be considerable and many soils have become K deficient [3].

While significant quantities of K may be lost through the sale of farm products, losses of K in urine represent the major drain on soil reserves as ten percent of K deposited in a urine patch may be leached [4].

K fixation may occur in many New Zealand soils [5] but insufficient experimental work has been conducted to determine the extent of loss from this process.

1/ That is, the amount of fertiliser required to maintain constant soil availability levels of these major plant nutrients.

2/ Sanders (1967).

3/ During (1967).

4/ Elliot (1961).

5/ Sanders (1967).

The importance of adequate soil K supply in maintaining high pasture production levels is well recognised, but there is insufficient experimental information available to calculate the K maintenance requirements of pasture, as emphasis in the past has largely centred on the phosphate requirements of soils 1/. Consequently, only phosphate requirements are calculated in this chapter.

7.4 PHOSPHATE MAINTENANCE REQUIREMENTS

Most New Zealand soils are phosphate deficient and are unable to sustain high producing pasture species without the addition of phosphates.

Figure 7.1 presents a simplified grasslands phosphorus nutrient cycle. The P maintenance requirement of any soil will be related to the level of pasture production, losses from leaching and inorganic and organic fixation, and removal of P in animal products sold off the farm, or excrements voided outside the grazing area.

7.4.1 Phosphate fixation and pasture production

The level of phosphate fixation is the major factor determining the effectiveness of phosphate topdressing on New Zealand soils and, therefore, it governs the application rate and cost of phosphate topdressing to attain a required level of available soil P. On the basis of field trials and laboratory studies on the rate and severity of phosphate fixation 2/, the major soil groups of New Zealand can be placed into four categories 3/. Within each category, Karlovsky (Ibid.) establishes relationships on an annual basis between:-

(a) Phosphorus output and total dry matter production of pasture.

(b) Phosphorus input and P output.

P input refers to all P returned to the soil and includes fertiliser and the P in dung and decomposed herbage. P output refers to the P in the pasture produced. The relationship between P input and P output provides a measure of the amount of P fixed or leached from the soil at different rates of input.

1/ Karlovsky (1966).

2/ Karlovsky (1966).

3/ High, medium, low and very low P-fixing soils.

FIGURE 7.1 A SIMPLIFIED PHOSPHORUS CYCLE

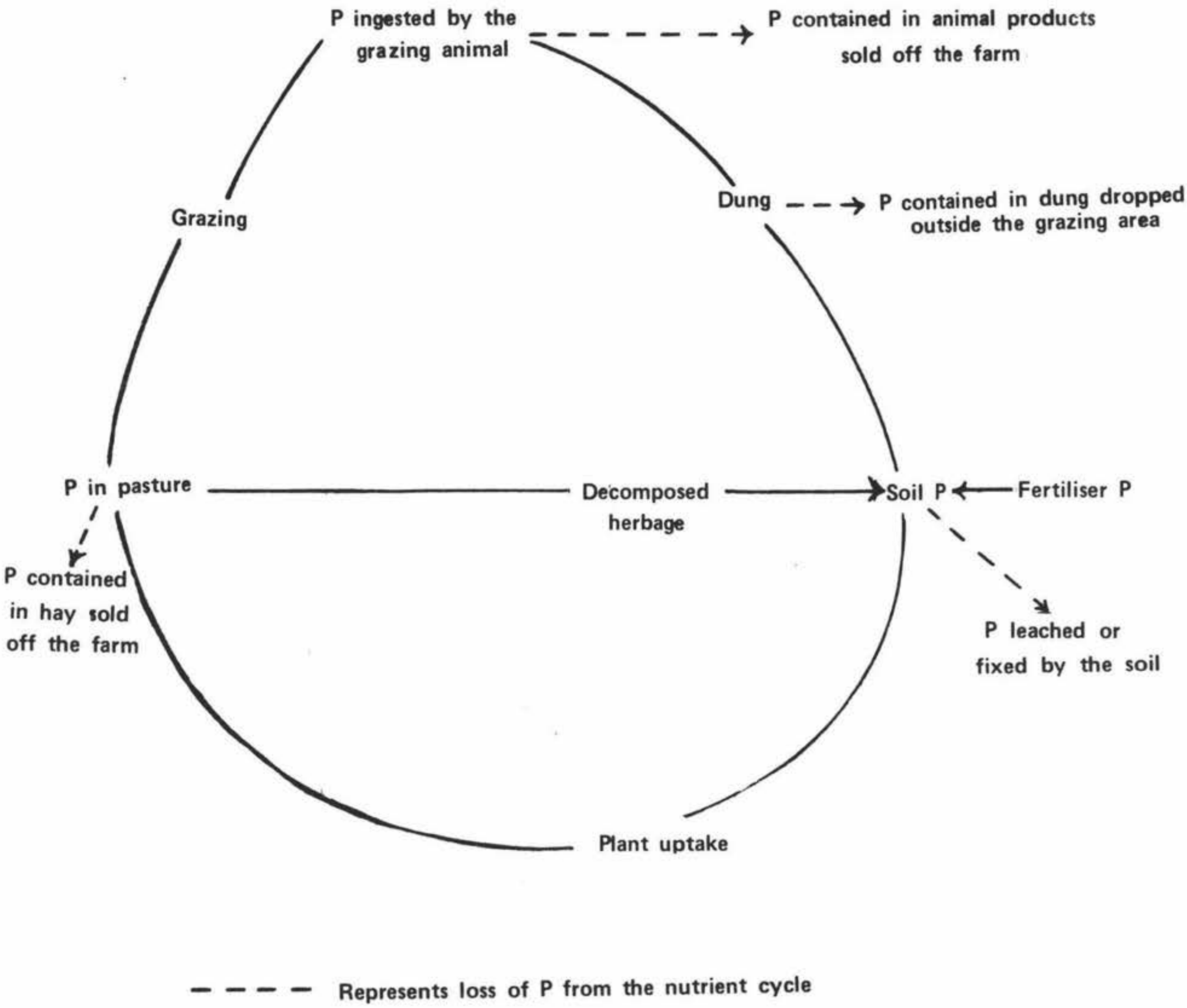


Figure 7.2 shows these two relationships for medium fixing soils [1/] with high pasture production potential [2/].

Curve OB shows the relationship between P output and total dry matter production of pasture. Curve OA shows the relationship between P input and P output. For example: To maintain a steady pasture production level of 13,000 lbs DM/acre/year, (or a P output of 49 lbs P/acre/year), 82 lbs P input is required on medium fixing soils.

7.4.2 Removal of phosphorus from the grazing area

(i) Hay Sold: It is assumed that in $1\frac{1}{2}$ tons of dry matter, P equivalent to 1 cwt of superphosphate is removed [3/].

(ii) Animal Products: The sale of 450 lbs of butterfat or 1,400 lbs of live stock also represents a P loss to the farm equivalent to 1 cwt of superphosphate [4/].

(iii) It is assumed that ten percent of dung is excreted outside the grazing area and thus the P it contains is lost from the cycle.

7.5 EXPERIMENTATION

The model developed in this study can be used to investigate animal production resulting from any specified level of pasture production and stocking rate. Using the outlined assumptions concerning P fixation and loss from the grazing area, the amount of P fertiliser required to maintain equilibrium for any specified level of pasture production, the grazing management system and stocking rate can be assessed. At any specified level of stocking rate, the relationships between P input, P output and pasture production can be used to gain some idea of the most profitable level of phosphate [5/] application.

1/ Yellow grey earths in the Manawatu could be expected to fall into this category. (Fife - pers. comm.).

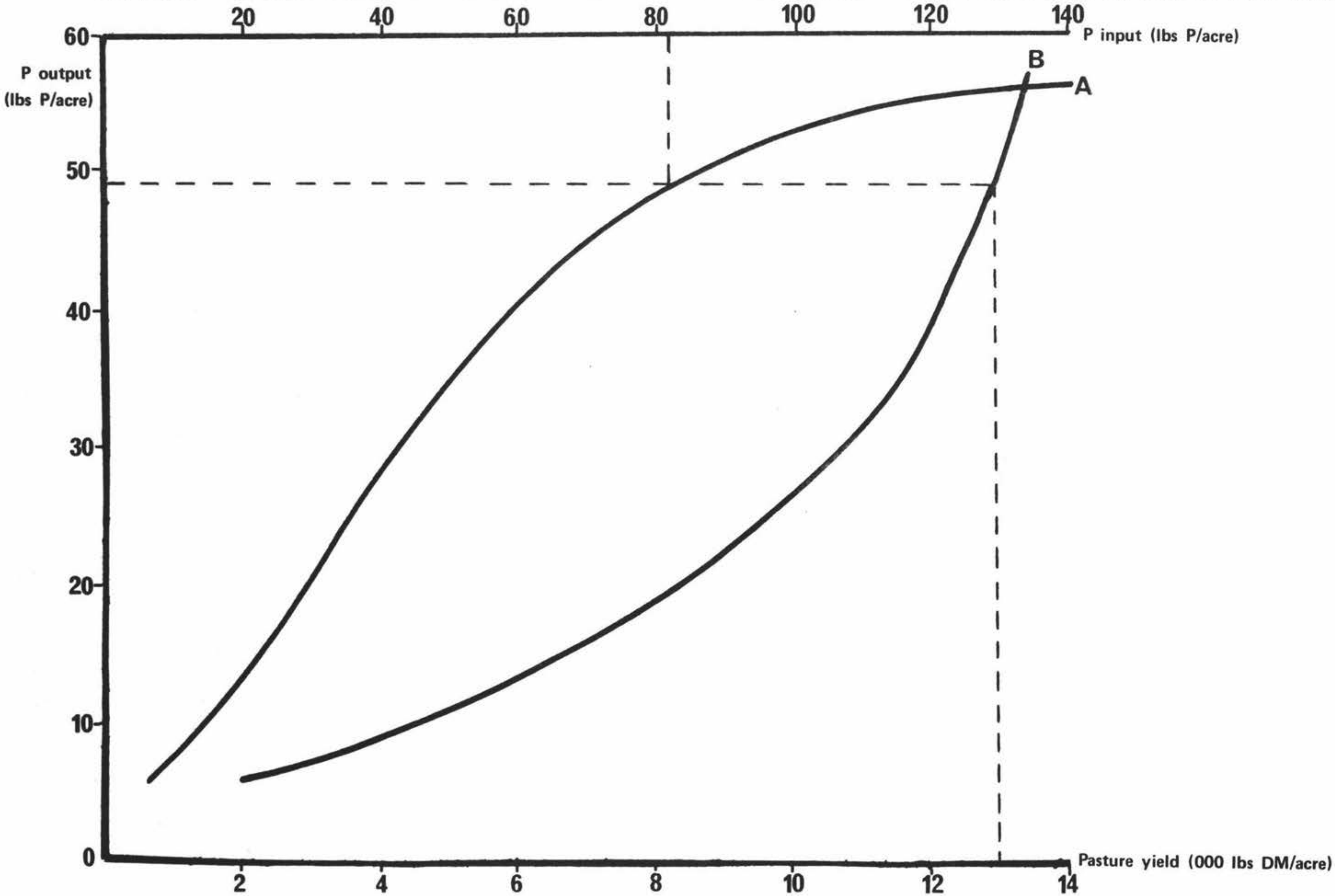
2/ Karlovsky (1966).

3/ Elliot (1961).

4/ Hodgson (1949).

5/ That is the amount of fertiliser required to maintain constant soil availability levels of these major plant nutrients.

FIGURE 7.2 THE RELATIONSHIPS BETWEEN PASTURE YIELD AND P OUTPUT, AND P OUTPUT AND P INPUT ON MEDIUM–FIXING SOILS



7.6 ASSUMPTIONS

As is demonstrated in Chapter 4, the grazing management/pasture production interaction contained within the model determines to a large extent the total annual pasture production. Programming for arbitarily chosen potential pasture production levels was accomplished by altering the pasture production input/output coefficients of each pasture production activity, in the model, by a fixed proportion. This assumes that pasture production throughout the year is similarly affected by changes in fertiliser application rate. This assumption was based on discussions with farmers in the Levin/Otaki area, who had increased fertiliser usage in recent years. Most had observed a general rise in pasture productivity throughout the year, rather than specific seasonal effects.

The response to nitrogen was also reduced in a similar manner as no experimental work has been conducted in New Zealand on N response under varying soil availability levels of phosphate. Experimental reports merely indicate that these levels should be 'adequate' for satisfactory responses.

The model, as used in deriving the results presented in Chapter 6, had a potential pasture production level, without N, of approximately 13,000 lbs DM/year. The input/output coefficients of the model were altered, as described above, to give potential pasture production levels of 12,000 and 11,000 lbs DM/year.

In Figure 7.2, a maximum P output of 56 lbs P/acre/year is required at a maximum pasture yield of 13,500 lbs DM/acre/year. No information could be found on changes in P output as the ceiling pasture production level is increased by the use of N fertiliser. It was, therefore, assumed that the total P output, in plans where N contributes to total yield, is related only to the level of pasture production excluding that contributed by N fertiliser. This assumes that N causes a P 'dilution effect' in pasture.

The assumption was also made that continuous applications of phosphate do not reduce phosphate fixation. Sufficient fieldwork has not been completed to verify this assumption 1/.

1/ Karlovsky (1966).

The analysis requires that the farmer be aware of fertility transfers 1/ occurring within the farm as a result of his management practices. Precautions must be taken to ensure that areas of the farm receive nutrients according to their needs.

The rates of fertiliser calculated apply to the maintenance dressings required to sustain pasture production at a specified level. These rates may be quite different to that necessary to raise pasture productivity from one level to another, but pasture development situations have not been considered in this study.

7.7 RESULTS

Table 7.1 shows annual feed resource organisation and butterfat production at one cow/acre for pasture production levels of approximately: 13,000, 12,000, and 11,000 lbs DM/acre 2/. Table 7.2 summarises results at 1.5 cows/acre for pasture production levels of approximately: 13,000 and 12,000 lbs DM/acre 3/.

The calculation of P maintenance requirements is explained in Appendix 7 and the P requirements for each plan are presented in Tables 7.3 and 7.4. Finally, net profitability resulting from the different levels of pasture production and fertiliser usage at each stocking rate chosen, is presented in Tables 7.5 and 7.6.

7.7.1 1.0 cow per acre

At a stocking rate of one cow per acre, at lower pasture production levels, there is a marked reduction in the amount of hay sold and an increase in the amount of silage produced and fed to the cows. Slight reductions in dry matter supply to cows caused small depressions in butterfat production. It was not profitable to apply N at any of the pasture production levels selected at this stocking rate.

1/ Such transfers may occur with practices such as feeding and making hay on different areas of the farm.

2/ Plans X(1), Y(1) and Z(1) respectively. Plan X(1) corresponds to the optimal plan for 1.0 cows/acre for the model as used in Chapter 6; this is the 'self-contained' plan.

3/ Plans X(1.5) and Y(1.5) respectively. Plan X(1.5) corresponds to the optimal plan for 1.5 cows/acre for the model as used in Chapter 6; this is the 'Nitrogen' plan.

TABLE 7.1 FEED ORGANISATION AND BUTTERFAT PRODUCTION AT 1 COW/ACRE

	PLAN		
	X(1)	Y(1)	Z(1)
	(lbs DM/acre)		
Total Pasture Produced for Grazing	10,918	10,535	10,021
Silage Production	162	338	583
Hay Production	1,874	1,154	471
TOTAL	12,954	12,027	11,075
Hay Sold	1,805	1,064	358
Net DM Available to the Grazing Animal	11,149	10,963	10,717
BUTTERFAT PRODUCTION (lbs/acre)	399.4	394.3	386.2

TABLE 7.2 FEED ORGANISATION AND BUTTERFAT PRODUCTION AT 1.5 COWS/ACRE

	PLAN	
	X(1.5)	Y(1.5)
	(lbs DM/acre)	
Total pasture Produced for Grazing	12,380	11,415
Silage Production	708	776
Hay Production	92	-
TOTAL	13,180	12,191
Hay Purchased	250	554
Grass for Grazing Produced by N	725	1,127
Silage Produced by N	48	194
TOTAL DM Available to the Grazing Animals	14,203	13,066
Amount of N Applied for Grazing (lbs N)	58.4	91.0
Amount of N Applied for Silage (lbs N)	2.7	3.8
TOTAL N USE*	61.1	94.8
BUTTERFAT PRODUCTION		
(lbs BF/acre)	569.0	564.4
(lbs BF/cow)	379.3	376.3

* This is the amount of N used on an 'average' acre, but does not necessarily represent the <u>rate</u> of use/acre

TABLE 7.3 PHOSPHORUS MAINTENANCE REQUIREMENTS AT 1 COW/ACRE

Source of P Loss/acre	Amount of P Loss/acre PLAN X(1)	Y(1) (lbs P/acre)	Z(1)
Animal Products Sold off the Farm	11.5	11.4	11.2
Dung Voided Outside the Grazing area	2.9	2.0	1.5
Hay Sold off the Farm	6.2	3.5	1.2
P Fixed from the Soil	33.0	16.0	12.0
TOTAL LOSS	53.6	32.9	25.9
Superphosphate Maintenance Requirement (cwt)	4.8	2.9	2.3

TABLE 7.4 PHOSPHORUS MAINTENANCE REQUIREMENTS AT 1.5 COWS/ACRE

Source of P Loss/acre	Amount of P Loss/acre PLAN X(1.5)	Y(1.5) (lbs P/acre)
Animal Product	16.5	16.4
Dung Voided Outside the Grazing area	2.8	2.1
Hay Purchased	-.8	-1.8
P Fixed	36.0	17.5
TOTAL LOSS	54.5	34.2
Superphosphate Maintenance Requirement (cwt)	5.0	3.0

TABLE 7.5 COSTS AND RETURNS AT 1 COW/ACRE

	PLAN		
	X(1)	Y(1)	Z(1)
		($/ acre)	
REVENUE			
Butterfat Sales*	119.82	118.28	115.86
Hay Sales	13.53	7.98	2.69
Total Revenue	133.35	126.26	118.55
EXPENSES			
Silage Production	.40	.85	1.47
Hay Production	9.37	5.78	2.34
Superphosphate**	9.60	5.80	4.60
Total Expenses	19.37	12.43	8.41
Net Revenue	113.98	113.83	110.14

* Return on butterfat 30c/lb.

** Price of superphosphate assumed to be $2/cwt applied.

Source: Manawatu fertiliser merchants

TABLE 7.6 COSTS AND RETURNS AT 1.5 COWS/ACRE

	PLAN	
	X(1.5)	Y(1.5)
	($/acre)	
REVENUE		
Butterfat Sales	170.7	169.33
EXPENSES		
Silage Production	1.88	3.44
Hay Production	.45	-
Hay Purchased	2.50	5.54
Nitrogen (Grazing)	5.84	9.10
Nitrogen (Silage)	.27	.38
Superphosphate	10.00	6.00
Total Expenses	20.94	24.46
Net Revenue	149.76	144.87

A reduction in the phosphatic fertiliser maintenance requirements of pasture by 1.9 cwt. superphosphate/acre in plan Y(1) compared to plan X(1), enables reduced revenue from smaller butterfat and hay sales to be offset. However, a reduction in net profits 1/ occurs at an annual pasture production level of 11,000 lbs DM/acre, plan Z(1).

Therefore, at a stocking rate of one cow/acre, the application of approximately 3 cwt. superphosphate/acre/year appears necessary to maintain a pasture production level of approximately 12,000 lbs DM/acre/year, (on medium fixing soils), and achieve satisfactory per acre returns. Little economic advantage is to be gained from the application of higher rates of fertiliser in an attempt to raise pasture productivity above this level, unless butterfat returns exceed 30 cents per pound and a reliable market for hay is available.

7.72 <u>1.5 cows/acre</u>

At an annual pasture production level of 12,000 lbs DM/acre/year at 1.5 cows/acre, plan Y(1.5), it is profitable to apply additional N fertiliser and purchase more hay so that annual feed supply is maintained at approximately the same level as in plan X(1.5). The cost of purchased hay and N necessary to increase animal consumption levels completely eliminates any economic advantage from lower superphosphate costs. Therefore, at a stocking rate of 1.5 cows/acre, it appears profitable to apply 5 cwt. of superphosphate/acre on medium fixing soils.

7.8 SUMMARY AND CONCLUSIONS

It is assumed, in this analysis, that apart from additional losses of phosphate due to increased butterfat sales, the use of N fertiliser does not affect P maintenance requirements. This may be an unrealistic assumption but no information is available to determine whether this is so 2/. Consequently, it was decided to disregard P fertiliser costs in the model. However, as is indicated in this chapter, P fertiliser requirements will change with different management systems at any

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1/ Net profits are re-defined in this chapter only. It now is a measure of revenue from butterfat and hay sales, less hay and silage production costs, purchased hay and N fertiliser costs, and also the costs of superphosphate requirements.

2/ R.H. Jackman (pers. comm.), D.S.I.R., Palmerston North.

specified stocking rate, so that plans described in Chapters 6 and 8 may not be 'optimal' because all variable costs at each stocking rate have not been taken into account.

The results presented in this chapter indicate that at higher stocking rates, the use of N fertiliser will depend largely on the level of pasture productivity. The economics of N fertiliser use cannot be completely resolved without further information on interactions that occur between all major plant nutrients and pasture growth.

CHAPTER 8

THE EFFECTS OF ECONOMIC AND PHYSICAL UNCERTAINTY ON OPTIMAL FEED RESOURCE ALLOCATION

8.1 INTRODUCTION

Farm plans are formulated in an environment of economic and climatic uncertainty. An attempt is made in this chapter to determine how optimal feed resource allocation should change with different economic conditions and to find a management plan that performs best over a range of possible future N and butterfat prices. Possible procedures for incorporating the effects of climatic uncertainty into a Linear Programming study are also discussed. The model assumes the same pasture response relationships as used in Chapter 6.

8.2 THE EFFECTS OF ECONOMIC UNCERTAINTY

8.2.1 Experimentation

The Linear Programme output analyses provide information on the range of prices or costs over which the optimum solution remains stable. Lattimore (1970) uses this information to derive normative 1/ beef and butterfat supply functions. However, the section of the output analyses providing this information in the present study required an additional 1.5 hours of computing time per solution. Therefore, the procedure adopted was to derive optimum plans corresponding to a combination of three butterfat prices: (30, 40 and 50 cents per pound), and two N prices: (5 and 10 cents per pound), for each of two stocking rates: (1.5 and 2.0 cows/acre). While many optimum plans may exist between the particular price combinations selected, the author considered that with limited time and computing facilities, the 12 solutions provided sufficient information to determine the effects of price changes on optimal feed resource allocation.

8.2.2 Results: Stocking rate of 1.5 cows/acre

Optimal plans resulting from changes in butterfat and/or N price are summarised in Table 8.1.. The annual distribution of feed supplies to lactating and dry cows is summarised in Table 8.2.

1/ Normative policies refer to those that should be adopted if the objective function is to be maximised.

TABLE 8.1 SUMMARY OF PLANS RESULTING FROM PARAMETRIC PRICE A ALYSIS AT 1.5 COWS/ACRE

P_N(c/lb)	10	10	10	5	5	5
P_{BF}(c/lb)	30	40	50	30	40	50
PLAN	A	B	C	D	E	F
(1) ANNUAL DM SUPPLY			(lbs DM/acre)			
Pasture Supply for Grazing	12,380	12,244	12,306	12,091	12,053	12,034
Pasture Produced by N for Grazing	725	1,012	1,198	1,667	1,734	1,766
Silage Production	708	795	716	644	550	558
Silage Produced by N	48	69	50	99	122	111
Hay Production	92	92	103	295	425	425
Purchased Hay	250	462	470	-	-	-
Total DM Supply	14,203	14,674	14,843	14,796	14,884	14,894
Total Effective DM Supply	14,078	14,506	14,685	14,698	14,766	14,776
(2) N FERTILISER USAGE* (lbs N)						
N Applications for Grazing	58.4	80.0	107.6	154.0	162.8	164.6
N Applications for Silage	2.7	3.9	2.8	5.8	7.7	6.7
Total (lbs N)	61.1	83.9	110.4	159.8	170.5	171.3
(3) BF PRODUCTION						
(lbs BF/acre)	569.0	582.0	587.4	588.0	590.2	590.3
(lbs BF/cow)	379.3	388.0	391.6	392.0	393.5	393.5
(4) NET REVENUE ($/acre)	159.7	217.2	275.5	165.1	223.7	282.7

* See Table 6.6, p.74, for comments concerning the actual rate of N usage per acre.

TABLE 8.2 SUMMARY OF STOCK FEEDING AT 1.5 COWS/ACRE

P_N(c/lb)	10	10	10	5	5	5
P_{BF}(c/lb)	30	40	50	30	40	50
PLAN	A	B	C	D	E	F
(1) LACTATING COWS			(lbs DM/cow)			
Silage	504	576	511	495	448	446
Hay	-	-	-	-	-	-
N Produced Pasture	420	578	677	989	1,034	1,055
Pasture	7,523	7,573	7,649	7,361	7,402	7,389
Total DM Supply	8,447	8,727	8,837	8,845	8,884	8,890
Total Effective DM Supply	8,413	8,695	8,815	8,823	8,869	8,875
(2) DRY COWS						
Hay	228	369	382	196	282	282
N Produced Pasture	63	97	122	122	122	122
Pasture	731	590	555	700	633	633
Total DM Supply	1,022	1,056	1,059	1,018	1,037	1,037
Total Effective DM Supply	972	972	972	972	972	972
(3) TOTAL Annual DM Supply	9,469	9,783	9,896	9,863	9,921	9,927
TOTAL Annual Effective DM Supply	9,385	9,667	9,787	9,795	9,841	9,847

(a) Constant butterfat price, reduced N price 1/

As the price of N is reduced, there is a considerable increase in the amount of N applied to pasture for grazing. Although less silage is produced by plans derived at a N price of 5c per lb., N applications to silage areas are also increased. More hay is produced in these plans, but total hay fed to the dry cows in reduced as hay is not purchased. Remaining dry cow requirements are met by additional pasture and N produced grass. Lactating cows receive less silage and extra hay production means that less pasture is available for grazing. However, N produced grass is used to increase lactating cow intake and butterfat production.

(b) Constant N price, increased butterfat price 2/

At a N price of 10c per lb, higher butterfat prices result in increasing quantities of N applied to pasture for grazing. Additional hay is also purchased and this is fed to the dry cows. Additional N produced grass is fed partly to the dry cows but is mainly used to increase lactating cow intake and butterfat production.

At a N price of 5c per lb, N usage is such that at all butterfat prices cows are well fed and per cow production levels are extremely high. Consequently, increased butterfat price results in only small increases in N use, animal intake and butterfat output.

8.2.3 Results: Stocking rate of 2.0 cows/acre

Optimal plans resulting from changes in butterfat and/or N price are summarised in Table 8.3. The annual distribution of feed supplied to lactating and dry cows is summarised in Table 8.4.

(a) Constant butterfat price, reduced N price

As the price of N is reduced, the amount of N applied to pasture for grazing is almost doubled at each butterfat price. Silage production and the amount of N applied to silage areas also increase. Hay is not produced in any plan but the amount of hay purchased is reduced at the lower N price as hay feeding

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1/ For example, comparison of plans A and D.

2/ For example, comparison of plans A and B.

TABLE 8.3 SUMMARY OF PLANS RESULTING FROM PARAMETRIC ANALYSIS AT 2.0 COWS/ACRE

P_N(c/lb)	10	10	10	5	5	5
P_{BF}(c/lb)	30	40	50	30	40	50
PLAN	G	H	I	J	K	L
(1) ANNUAL DM SUPPLY			(lbs DM/acre)			
Pasture Supply for Grazing	12,562	12,694	12,695	12,377	12,426	12,539
Pasture Produced by N for Grazing	2,007	2,284	2,297	3,001	3,040	3,195
Silage Production	674	416	405	752	654	472
Silage Produced by N	171	128	124	191	180	143
Hay Production	-	-	-	-	-	-
Purchased Hay	2,446	2,780	2,784	1,554	1,906	2,098
Total DM Supply	17,860	18,302	18,305	17,875	18,206	18,447
Total Effective DM Supply	17,371	17,810	17,816	17,554	17,853	18,086
(2) N FERTILISER USAGE* (lbs N)						
N Applications for Grazing	148.6	177.8	179.2	305.8	324.3	355.3
N Applications for Silage	10.8	8.4	8.2	12.1	12.1	9.4
Total (lbs N)	159.4	186.2	187.4	317.9	336.4	364.7
(3) BF PRODUCTION						
(lbs BF/acre)	720.2	735.2	735.5	728.7	741.1	747.4
(lbs BF/cow)	360.1	367.6	367.8	364.4	370.6	373.7
(4) NET REVENUE ($/acre)	173.6	246.3	319.9	184.8	258.5	332.9

* See Table 6.6, p.74, for comments concerning the actual rate of N usage per acre.

TABLE 8.4 SUMMARY OF STOCK FEEDING AT 2.0 COWS/ACRE

P_N(c/lb)	10	10	10	5	5	5
P_{BF}(c/lb)	30	40	50	30	40	5[illegible]
PLAN	G	H	I	J	K	L
(1) LACTATING COWS			(lbs DM/cow)			
Silage	423	272	265	472	417	308
Hay	677	915	915	408	584	680
N Produced Pasture	882	1,020	1,027	1,364	1,383	1,461
Pasture	5,859	5,868	5,863	5,642	5,666	5,723
Total DM Supply	7,841	8,075	8,080	7,886	8,050	8,172
Total Effective DM Supply	7,713	7,933	7,936	7,805	7,954	8,071
(2) DRY COWS						
Hay	546	475	468	369	369	369
N Produced Pasture	122	122	122	137	137	137
Pasture	422	480	485	547	547	547
Total DM Supply	1,090	1,077	1,075	1,053	1,053	1,053
Total Effective DM Supply	972	972	972	972	972	972
(3) TOTAL Annual DM Supply	8,931	9,152	9,155	8,939	9,103	9,223
TOTAL Annual Effective DM Supply	8,685	8,905	8,908	8,777	8,926	9,043

to both dry and lactating cows is reduced. The remaining dry cow requirements are met by pasture and a slight increase in N produced grass. Because additional pasture is fed to the dry cows and extra silage is produced, the amount of pasture fed to the lactating cows at the lower N price is slightly reduced. However, additional silage is fed and N produced grass is used to increase intake and butterfat production.

(b) Constant N price, increased butterfat price

As the butterfat price is increased, the amount of N applied to pasture for grazing and the amount of hay purchased both increase. However, both silage production and the amount of N applied to silage areas are reduced. Identical dry cow feeding policies are followed for each butterfat price at a N price of 5c per lb. At a N price of 10c per lb, additional pasture substitutes for hay, for feeding the dry cows, as butterfat price is increased. For each N price, increased butterfat return results in less silage fed to the lactating cows. However, the increased feeding of both hay and N produced grass increase intake and butterfat production.

8.2.4 Planning under economic uncertainty

The parametric analyses discussed indicate optimal feed resource allocation for a given set of economic conditions. They therefore direct necessary adjustments to any optimal plan if profits are to remain a maximum following a change in the butterfat/N price relationship. Such adjustments frequently involve considerable changes in hay and silage production, N use and grazing management.

As product prices experience wide between-year variations, farmers' inability to predict these prices until well into the production season, may result in a sub-optimal plan being used. This could result in net profits being substantially below the maximum. If probability information on each price combination was available, the expected profit from each plan could be calculated and the plans compared. This would provide some idea as to the most acceptable plan over a longer planning period than a year.

To test this approach, the net profit from all twelve plans was recalculated using each combination of butterfat price and N cost used in the parametric analysis. The results for a stocking rate of 1.5 cows/acre are presented in Table 8.5, and for 2.0 cows/acre, in Table 8.6. As the prediction of future butterfat prices and N costs alone would have been a major study, for the purposes of this project, an equal probability of occurrence has been assigned to all butterfat/N price combinations used.

The most notable feature of the results presented in Tables 8.5 and 8.6 is that only small reductions in net profit occur with the sub-optimal plans, despite widely differing feed resource organisation. Therefore, while the butterfat/N price combination will greatly affect actual net profits obtained, several near optimal plans exist, despite the price relationships used.

The average net profit per plan, under the assumption that each BF/N price is equally likely, is also shown in Tables 8.5 and 8.6. At 1.5 and 2.0 cows/acre, the plans giving maximum average net profit are 'D' and 'I' respectively.

The grazing management and conservation practices, together with resulting dry matter production for plans D and I, are contained in Tables A6.7 and A6.8, Appendix 6. Information on the nitrogen activities included in these plans are also supplied in Tables A6.7 and A6.8. The system of grazing management, N use and pasture conservation practices followed are summarised in Table 8.7 for plan D, and Table 8.8 for plan I. The resulting monthly supply of pasture and N produced grass, together with silage and hay production, is illustrated in Figures 8.1 and 8.2 1/. The monthly allocation of feed to lactating and dry cows is contained in Figure 8.3 and Table 8.9 for plan D and Figure 8.4 and Table 8.10 for plan I. Monthly butterfat production is illustrated in Figures 8.5 and 8.6.

1/ Figures 8.1 through 8.4 can be interpreted using the fold-out Key in Appendix 8.

TABLE 8.5 NET PROFIT/ACRE OF PLANS A TO F AT EACH BF/N PRICE COMBINATION (1.5 COWS/ACRE)

BF/N PRICE (c/lb)	A	B	C	D	E	F
	PLAN ($/acre)					
BF = 30, N = 10	159.7	159.0	158.1	157.1	156.2	156.2
BF = 40, N = 10	216.6	217.2	216.8	215.9	215.2	215.2
BF = 50, N = 10	273.5	275.3	275.5	274.6	274.2	274.2
BF = 30, N = 5	162.7	163.2	163.6	165.1	164.7	164.7
BF = 40, N = 5	219.7	221.4	222.3	223.9	223.7	223.7
BF = 50, N = 5	276.5	279.5	281.0	282.6	282.7	282.7
AVERAGE NET PROFIT	218.1	219.3	219.6	219.7	219.5	219.5

TABLE 8.6 NET PROFIT/ACRE OF PLANS G TO L AT EACH BF/N PRICE COMBINATION (2.0 COWS/ACRE)

BF/N PRICE (c/lb)	G	H	I	J	K	L
	PLAN ($/acre)					
BF = 30, N = 10	173.5	172.8	172.8	168.9	167.6	165.2
BF = 40, N = 10	245.6	246.3	246.3	241.8	241.7	239.9
BF = 50, N = 10	317.6	319.8	319.9	314.7	5.8	314.7
BF = 30, N = 5	181.5	182.1	182.1	184.8	34.4	183.5
BF = 40, N = 5	253.5	255.6	255.7	257.7	258.5	258.1
BF = 50, N = 5	325.5	329.1	329.2	330.6	32.6	332.9
AVERAGE NET PROFIT	249.6	250.9	251.0	249.8	250.1	249.1

TABLE 8.7 GRAZING MANAGEMENT AND CONSERVATION PRACTICES AT 1.5 COWS/ACRE IN PLAN 'D'

	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Area grazed (% of total area)	41.9	80.7	91.1	77.3	49.6	60.8	74.5	72.0	58.1	78.0	67.0	32.4
Average length of spell (weeks)	9.5	9.3	4.8	5.0	5.8	5.7	6.5	5.8	6.3	6.2	5.9	7.7
Area to which N is applied for grazing (% total area)	41.9	80.7	29.6	5.9	-	-	-	-	-	78.0	67.0*	-
Area closed for silage (% of total area)	-	-	11.5	10.3	-	-	-	-	-	-	-	-
Area to which N is applied for silage (% of total area)	-	-	11.5	-	-	-	-	-	-	-	-	-
Silage produced by N (lbs DM/acre)	-	-	-	-	99.0	-	-	-	-	-	-	-
Area closed for hay (% of total area)	-	-	-	7.7	-	-	-	-	-	-	-	-

* .047 acres receive 100 lbs N/acre in May

TABLE 8.8 GRAZING MANAGEMENT AND CONSERVATION PRACTICES AT 2.0 COWS/ACRE IN PLAN 'I'

	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Area grazed (% of total area)	36.0	64.0	81.2	74.7	64.5	69.9	66.5	64.5	70.5	99.6	47.7	42.7
Average length of spell (weeks)	10.2	10.0	6.7	5.4	5.4	6.0	6.5	6.3	6.1	5.4	5.3	7.6
Area to which N is applied for grazing (% of total area)	36.0	64.0	70.4	52.1	-	-	-	-	-	99.6	36.3	-
Area closed for silage (% of total area)	-	-	10.9	5.4	-	-	-	-	-	-	-	-
Area to which N is applied for silage (% of total area)	-	-	10.9	5.4	-	-	-	-	-	-	-	-
Silage produced by N (lbs DM/acre)	-	-	-	-	124.0	-	-	-	-	-	-	-

FIGURE 8.1 TOTAL PASTURE ALLOCATED FOR GRAZING AND CONSERVATION IN EACH MONTH AT 1.5 COWS/ACRE IN PLAN 'D'.

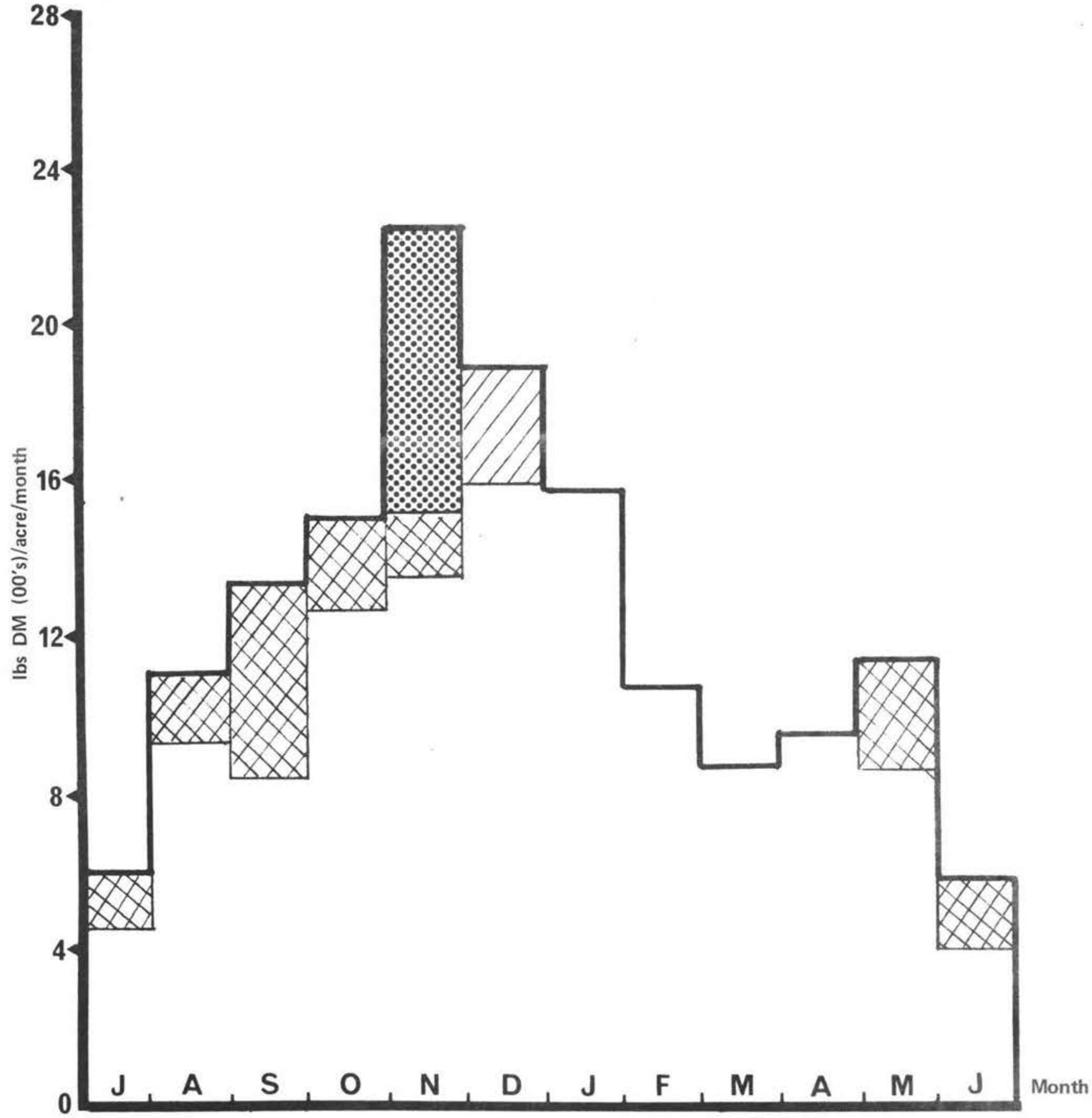


FIGURE 8.2 TOTAL PASTURE ALLOCATED FOR GRAZING AND CONSERVATION IN EACH MONTH AT 2.0 COWS/ACRE IN PLAN 'I'.

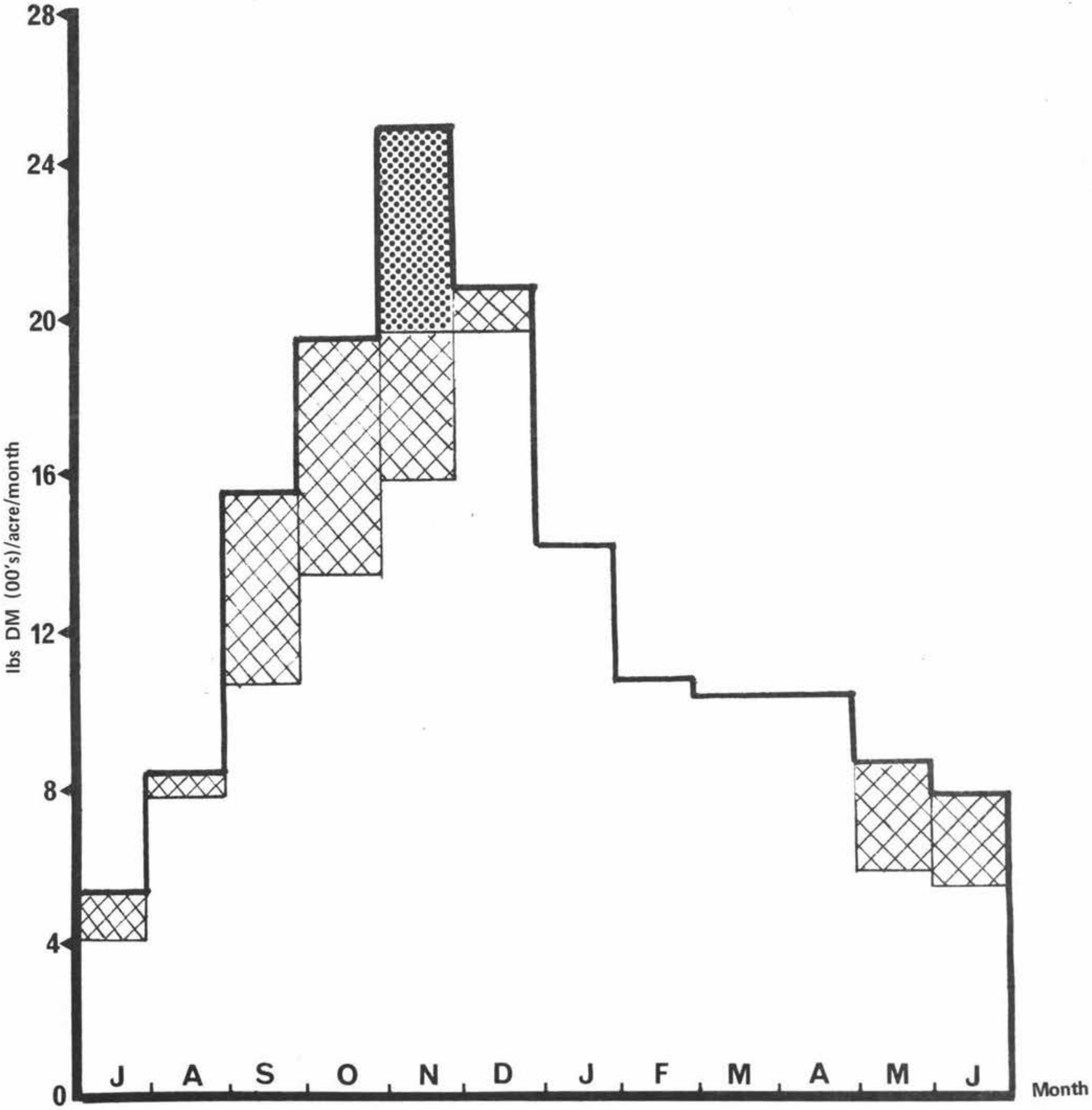


FIGURE 8.3 AVERAGE DAILY FEED SUPPLY TO EACH LACTATING COW AT 1.5 COWS/ACRE IN PLAN 'D'.

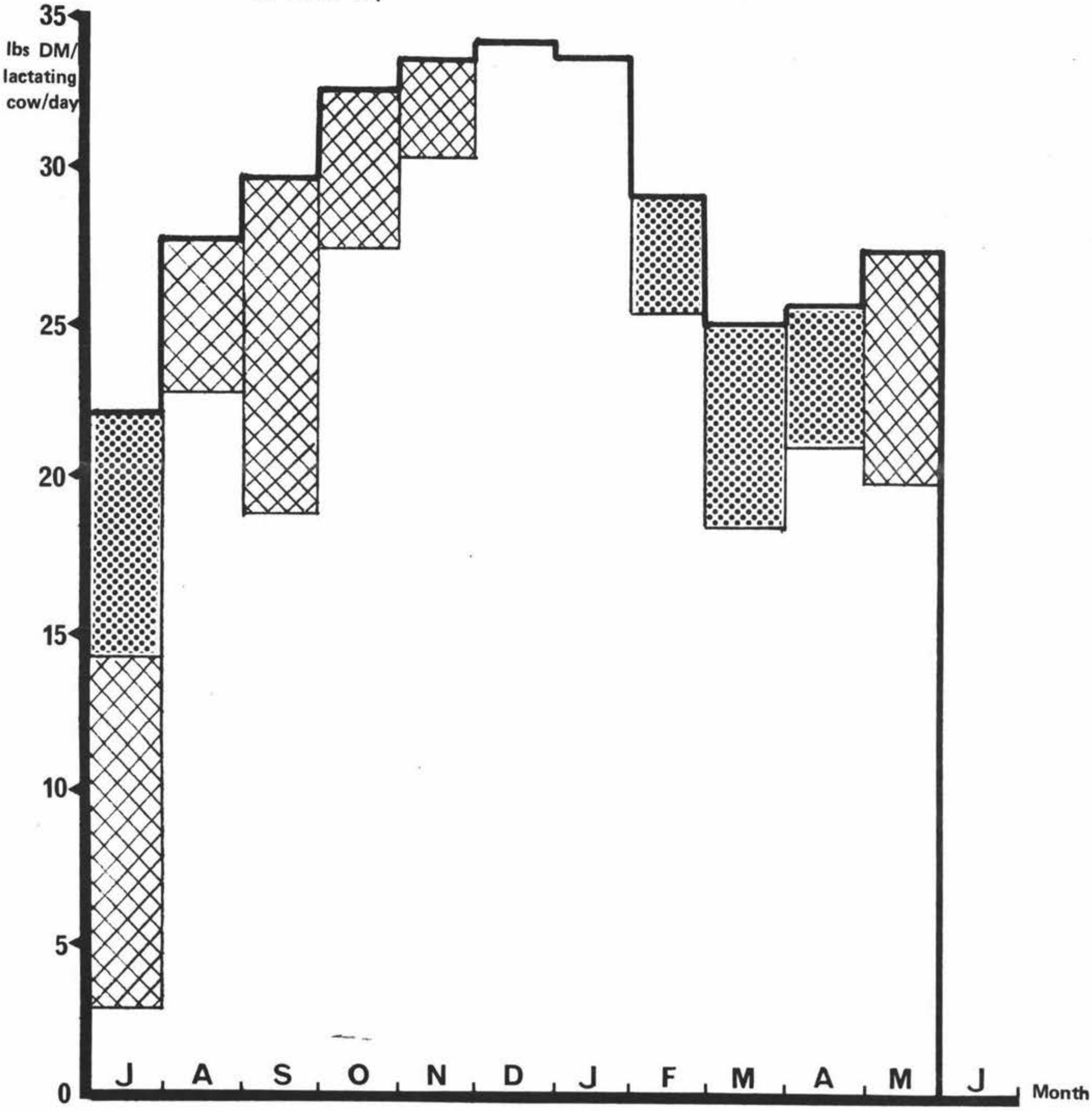


TABLE 8.9 AVERAGE DAILY FEED SUPPLY TO EACH DRY COW AT 1.5 COWS/ACRE IN PLAN 'D'.

	May	June	July	August
		(lbs DM/dry cow/day)		
Pasture	11.8	8.8	11.5	8.8
N. produced grass	–	4.1	–	–
Hay	–	–	4.7	9.9
TOTAL	11.8	12.9	16.2	18.7

FIGURE 8.4 AVERAGE DAILY FEED SUPPLY TO EACH LACTATING COW AT 2.0 COWS/ACRE IN PLAN 'I'.

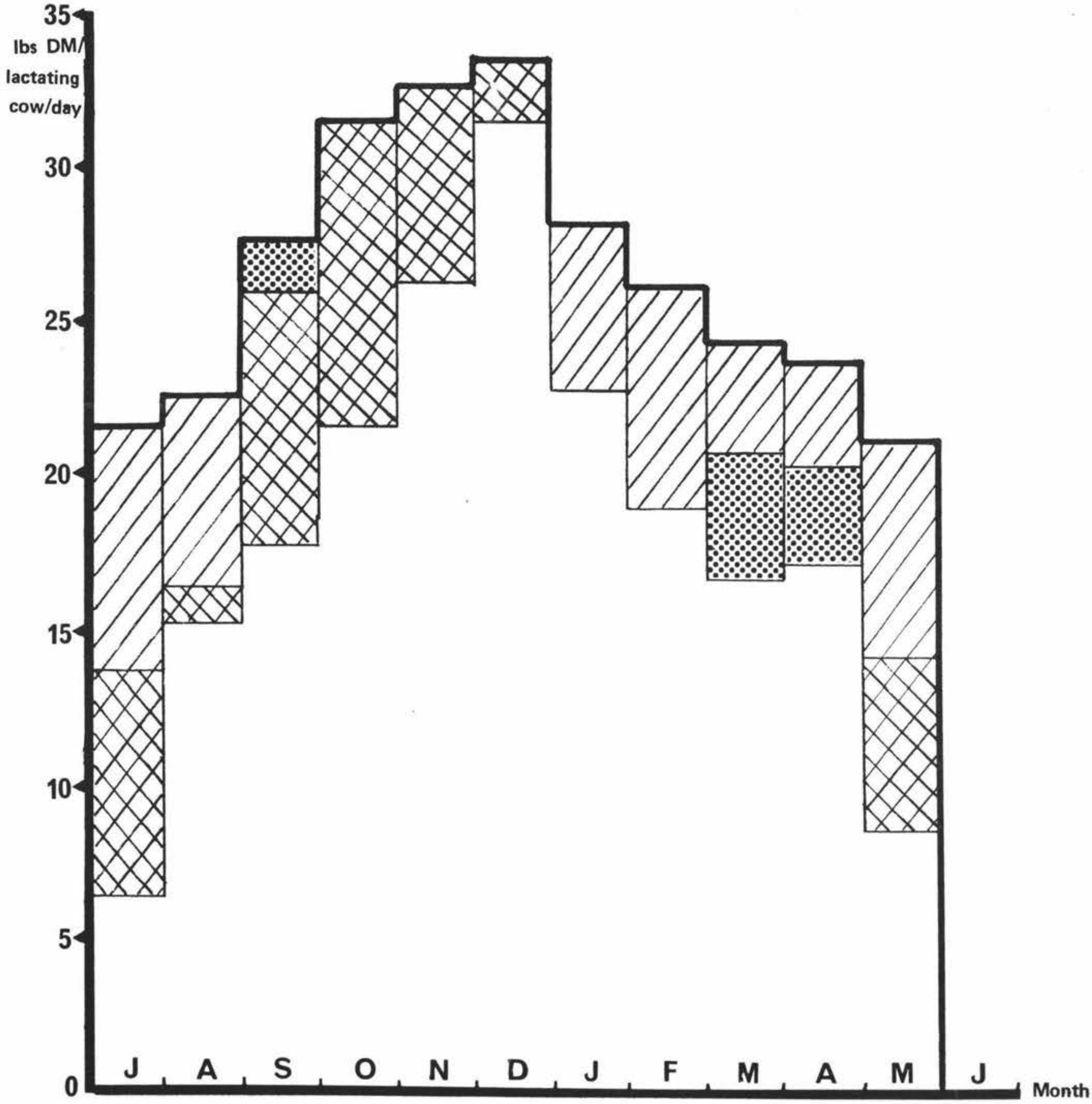


TABLE 8.10 AVERAGE DAILY FEED SUPPLY TO EACH DRY COW AT 2.0 COWS/ACRE IN PLAN 'I'.

	May	June	July	August
		(lbs DM/dry cow/day)		
Pasture	11.8	8.8	5.9	–
N. produced grass	–	4.1	–	–
Hay	–	–	11.6	21.0
TOTAL	11.8	12.9	17.5	21.0

FIGURE 8.5 AVERAGE DAILY BUTTERFAT PRODUCTION/COW AT 1.5 COWS/ACRE IN PLAN 'D'.

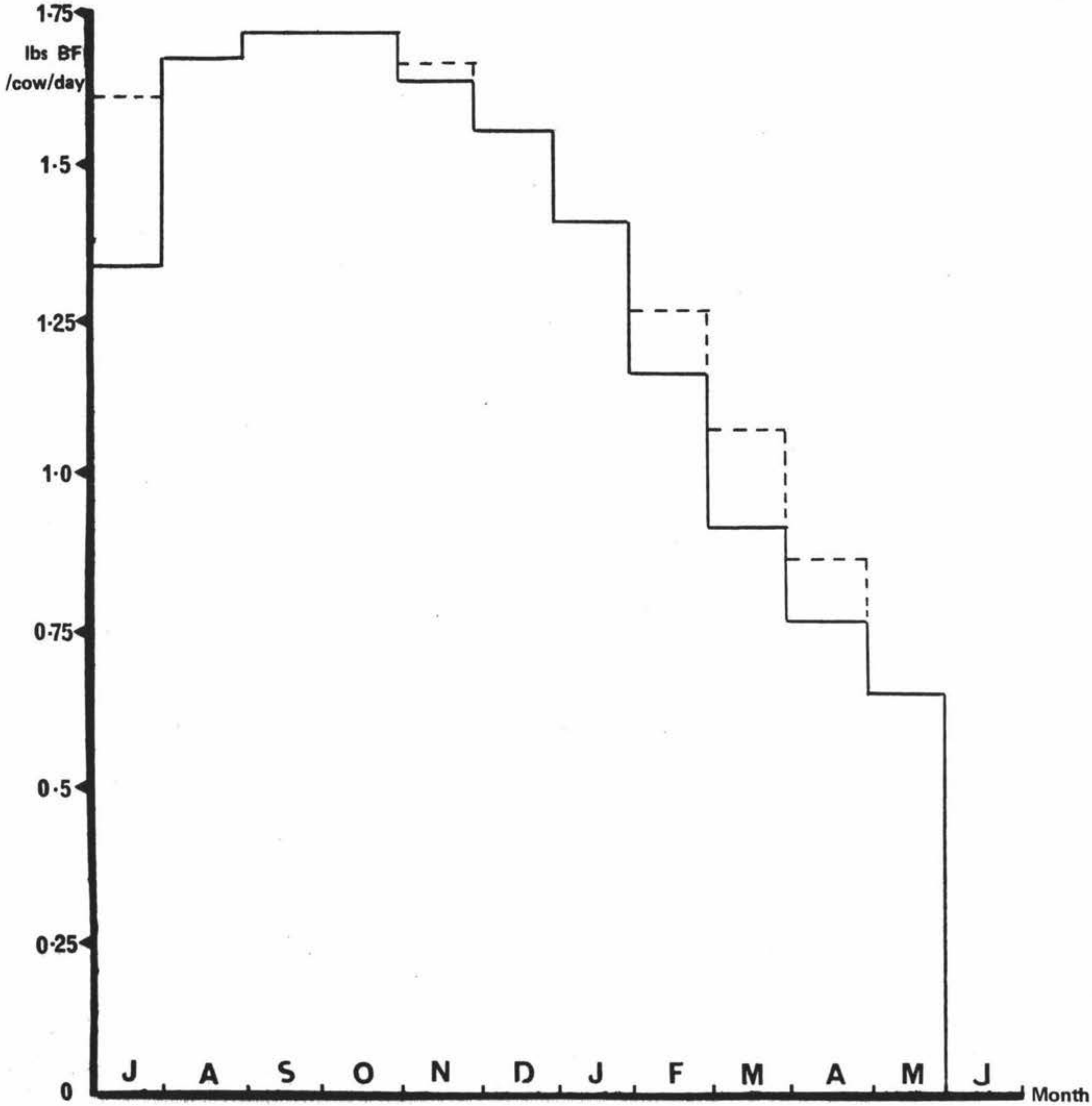
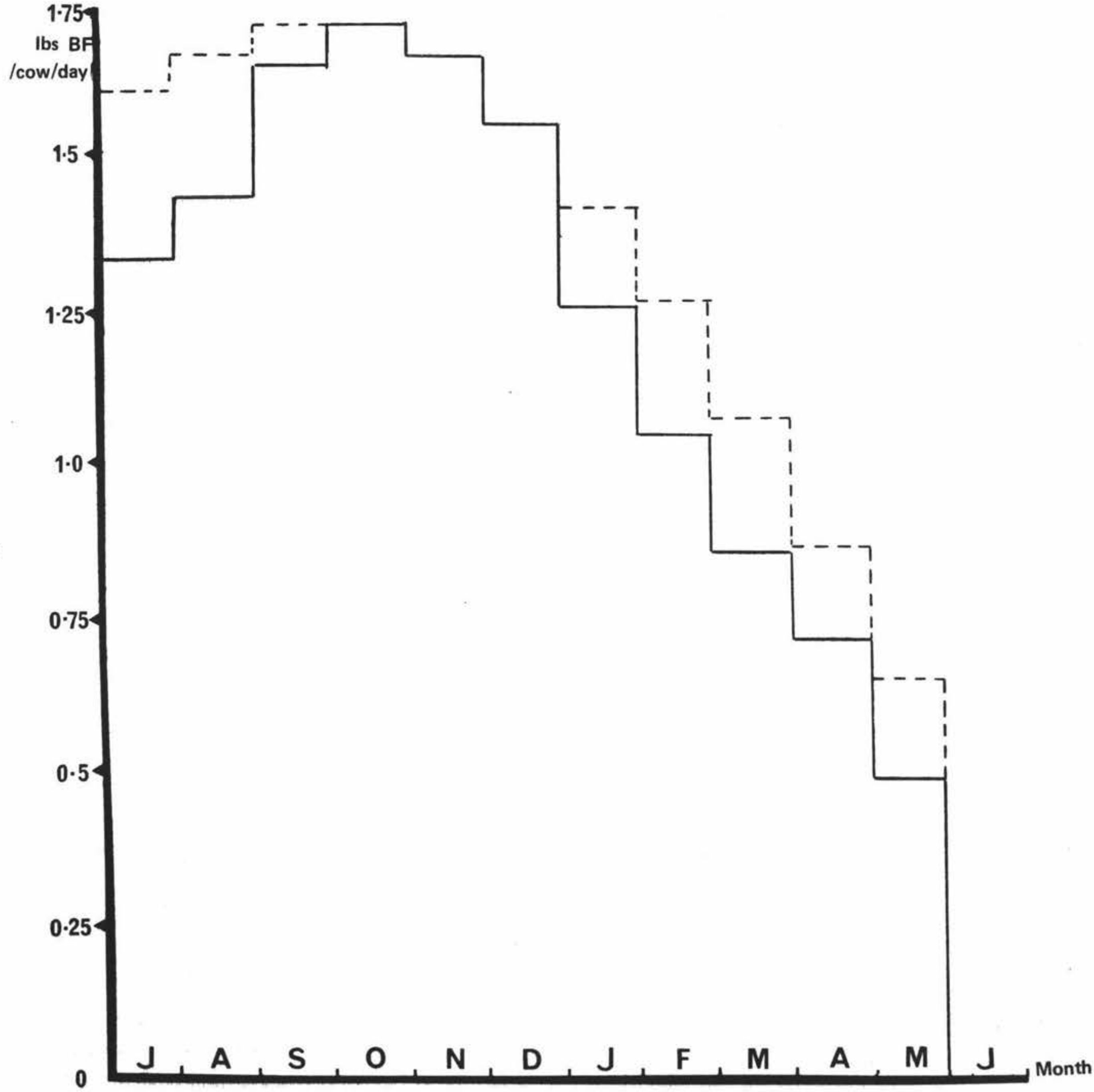


FIGURE 8.6 AVERAGE DAILY BUTTERFAT PRODUCTION/COW AT 2.0 COWS/ACRE IN PLAN 'I'



8.2.5 Comparison of management practices: Plan A and Plan D at 1.5 cows/acre 1/

In plan D, a greater area of land is closed in September for silage production, and also in October for hay production. Consequently, less land is available for grazing over the October to January period. However, heavier applications of N in the August/September/October period provide additional feed in October and November. This enables the cows to remain fully fed in both months on a smaller area of pasture while pasture growth on land to be grazed in December and January "gets away". Consequently, cows are also fully fed in December and January. As N fertiliser price is reduced therefore more N is used to maintain the amount of silage produced and also enables dry cow hay requirements to be produced instead of being purchased without prejudicing butterfat production over the late spring/ early summer period.

In February, a greater area of land is grazed supplying more pasture in this month, but this is at the expense of pasture supply in March and more silage is required at this stage to maintain intake at the same level as in plan A.

For N produced grass to be of economic value over the winter period, N must be applied in April/early May for a worthwhile response to be obtained. Once N has been applied to all areas grazed in this period, demand for additional dry matter in the winter requires that either a greater area be grazed over the Autumn period and N applied following grazing or some areas of pasture grazed in Autumn receive a double dressing 2/. In plan D, both possibilities occur. The area grazed is increased and all this area receives 50 lbs N/acre, except for 4.7 percent of the total area in May which receives 100 lbs N/acre. This pasture is then grazed between May and August. Additional pasture supplied in April, as a result of the extra area grazed, is used, together with additional silage, to increase intake and butterfat production. The extra area

1/ Plan A is optimal for the 30:10, BF:N price combination and has been discussed, in detail, in Section 6.7. A comparison of plans A and D therefore focuses attention on the differences in management practice 'required' by a 5c/lb drop in the price of N at a 30c/lb BF price. However, the main point of this section, and the next, is to illustrate the nature of the detail on the 'where', 'how' and 'why' questions, relating to the differences in net revenue per acre presented in Tables 8.1 and 8.3, that can be obtained from the model used in this study.

2/ That is, receive 100 lbs N/acre.

grazed in May, together with N produced grass resulting from early April N application, provides sufficient feed to fully feed the cows over this period. In June, a slower rotation is followed so that pasture can be conserved for July and August. N produced grass is used in June to maintain intake. A faster rotation is followed over the July/August period. In July, because less hay is available, additional pasture is fed to the dry cows. Additional N produced grass is supplied to the lactating cows with a similar amount of silage to that fed in plan A so that intake and butterfat production in this month are the same for both plans. In August, extra hay is fed to the dry cows in plan D. This enables additional pasture to be supplied to the lactating cows. The extra area grazed in August also supplies more pasture and this, together with N produced grass, which replaces silage feeding, enables the cows to be fully fed in this month.

All the areas grazed in July and August receive N fertiliser applications following grazing.

In September, large areas of land are grazed as the faster July/ August rotation results in pasture that has been spelled for a shorter period of time being available. N applications in July and August are used to ensure that the cows are fully fed in this month.

8.2.6 Comparison of management practices : Plan G and Plan I at 2.0 cows/acre 1/

At a higher butterfat price, plan I, it becomes more economical to substitute purchased hay for silage as a milking feed supplement and use the additional pasture to increase butterfat production. N is applied to all areas closed for silage in both plans. In plan I, the amount of land closed in September is slightly increased. However, a smaller area is closed in October so that less total silage is produced. N is applied to a slightly greater area in July so that intake and butterfat production can be increased in September while the amount of silage fed to the cows is reduced. Purchased hay is used to substitute for silage feeding to the lactating cows in July, January and February, although the amount of silage fed in March and April is increased.

1/ Plan G, discussed in detail in Section 6.8, corresponds to the optimal plan for the 30 : 10, BF : N price combination. This comparison therefore focuses attention on 'required' management changes due to an increase in BF price to 50c/lb, at 2.0 cows/acre.

By increasing the area closed for silage production in September, slightly less area is available in plan I for grazing in October. Increased application of N fertiliser to pasture in September allows intake to be maintained at the maximum level in both October and November. Additional pasture is available for grazing in November and December because of the reduced area closed for silage in October. Increased pasture supply in December, together with the N response from an October application of N enables the cows to be fully fed in this month also.

In plan I, N is applied to a greater area in April and May. The grazing rotation is slowed down over May and June so that additional pasture can be conserved for July and August. In May, additional N produced grass and hay is fed to the lactating cows to maintain intake at a similar level to that in plan G. Similar amounts of pasture and N produced grass are also fed in June. The extra pasture produced in plan I enables the amount of hay fed to the dry cows in July to be reduced and intake and milk production in August to be slightly raised.

8.3 THE EFFECTS OF PHYSICAL UNCERTAINTY

Owing to variability in the physical performance of farming systems, plans computed on the basis of average patterns of pasture growth and N response will be infeasible or at least suboptimal in some, or all, years.

8.3.1 Variability in N response

As discussed in Chapter 3, experimentation with N fertilisers in New Zealand has been characterised by widely differing results. While climatic effects are likely to be of major importance in explaining this variation, it is generally acknowledged that other factors such as pasture characteristics and soil conditions are important. Through limited experimental design and insufficient experimentation, quantitative data on the effects of these factors is not available.

By successively reducing N response input/output coefficients in the model, total N use in the optimal plans will diminish and eventually the 'hay-buying' plans discussed in Section 6.4 will be obtained. The actual plan to be recommended under specific field conditions will depend largely on the response to N that can be obtained under those conditions. Until quantitative information is available on all the major factors affecting N response, these recommendations cannot be supplied.

8.3.2 Climatic variability

As considerable fluctuations in pasture growth and N response occur from year to year owing to climatic variability, it is difficult to identify a truly optimal policy. The net profit indicated by a solution based on pasture growth coefficients averaged through time, will be higher than the profit which can actually be achieved. Generally the losses sustained as a result of unfavourable climatic conditions are not fully offset by an equivalent gain in seasons of above average pasture yield.

Of special importance in this study is the effect of climatic uncertainty at critical periods of the year, particularly late winter and early spring. No fully acceptable procedure for incorporating the effects of climatic variability is available when LP is used as the systems research technique.

McFarquhar (1960) suggests a method that, if used in the present study, would involve increasing feed requirements in critical periods as a form of insurance [1]. But, as Hardaker (1967) notes, there is no ready means of assessing what degree of insurance should be allowed for a particular coefficient. If requirements are increased too much, the solution may be unnecessarily restricted and profits may fall short of the optimal level, while too little insurance may result in an infeasible plan in a bad season.

Consequently, possible procedures that involved changing pasture growth and N response input/output coefficients to represent the effects of fluctuating climatic factors, (particularly temperature over late winter/early spring), were investigated. For example, in Figure 8.7 five growth curves will be affected, for any percentage growth reduction considered, for some 'critical' period of interest. The first problem is to establish the effect on each individual growth curve.

It could be assumed that for each individual growth curve:

(a) The effect on growth during the restricted period is the same, irrespective of the stage of growth.

(b) Growth rate following the 'critical' period in which growth rate slumps is not affected, as demonstrated in Figure 8.8.

1/ The analagous situation is found under practical farming conditions where a farmer deliberately understocks.

FIGURE 8.7 GROWTH CURVES AFFECTED BY ADVERSE WEATHER CONDITIONS.

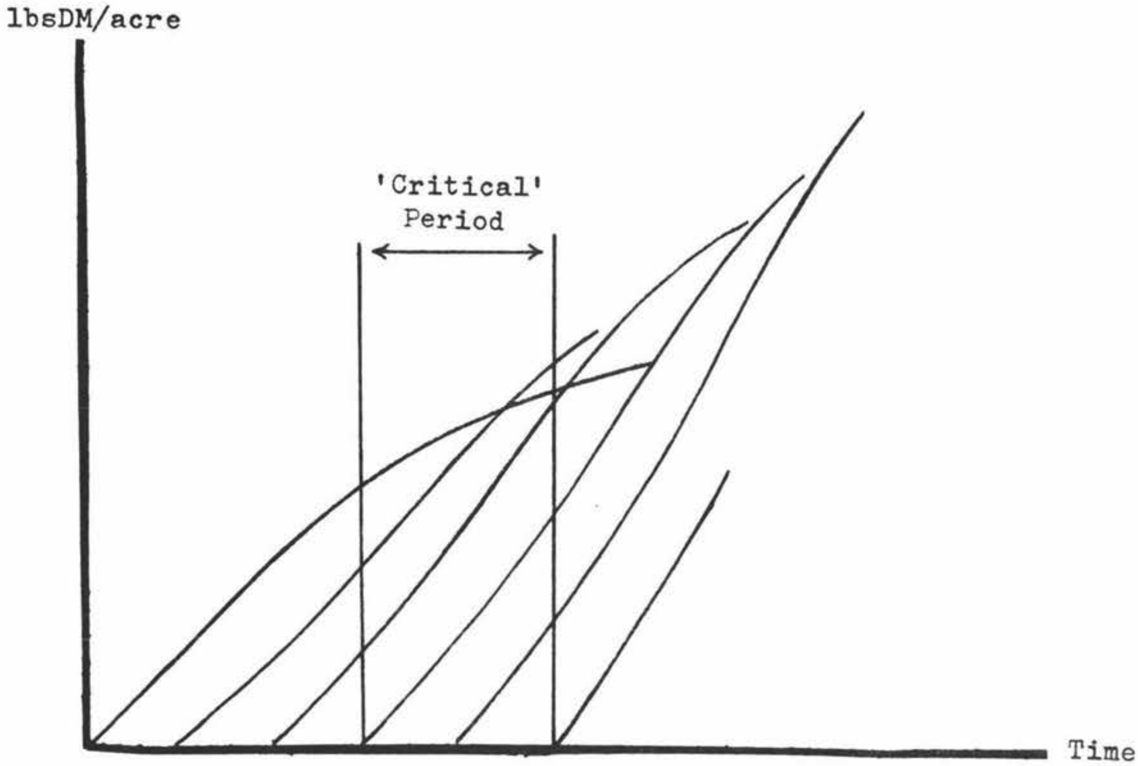
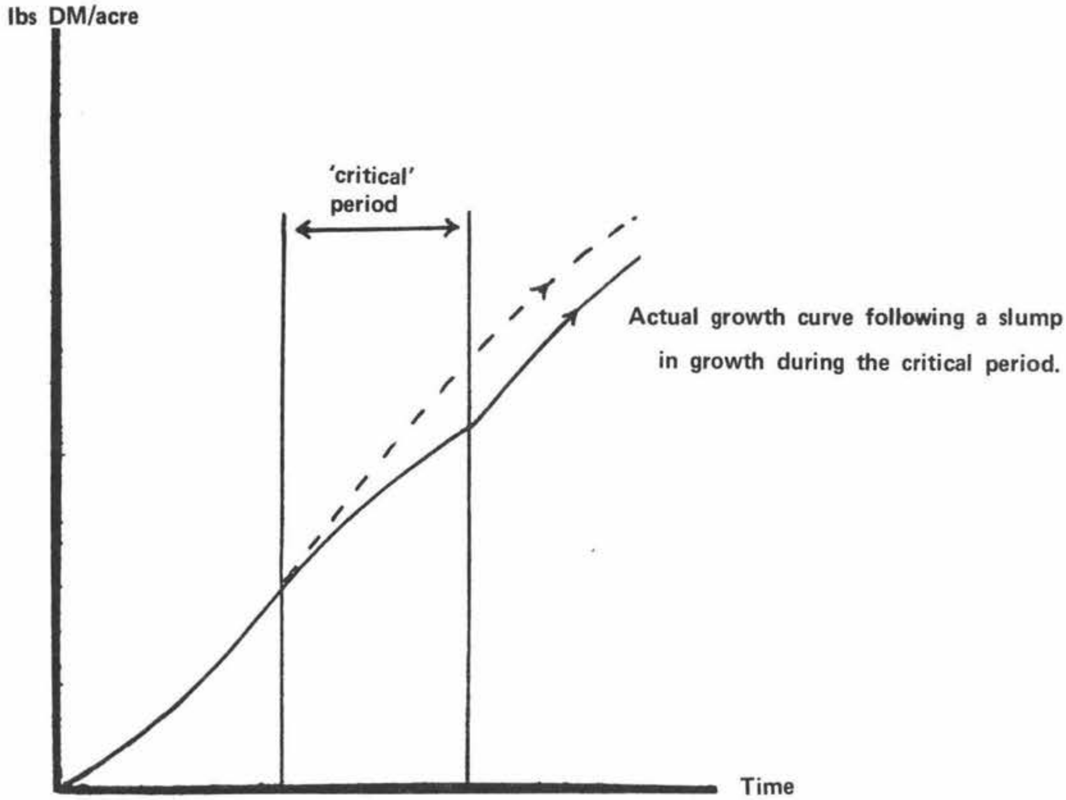


FIGURE 8.8 THE EFFECTS OF A SLUMP IN GROWTH UPON THE SHAPE OF EACH INDIVIDUAL GROWTH CURVE.



The effect of temperature change on N response is not known. Crofts (1966) demonstrated that grass and clover growth will continue until soil temperature at 4" depth is 41^{o}F. However, growth is limited below 48^{o}F because of temperature effects on legume and organic N availability.

Assuming that information on pasture growth and N response/soil temperature relationships was available, several methods may have potential for the inclusion of climatic variability effects into farm planning, using linear programming.

Gunn and Silvey (1967) suggests a method that involves identifying an optimal policy, based on average pasture yields. Ex ante strategies 1/, which will be followed in feed surplus of deficit periods, are then selected 2/. The effect of applying the chosen strategy in conjunction with the general policy identified by the LP is then determined for a number of different pasture yield situations. By constructing a probability distribution of grass yields, the expected profit of a general policy can be determined.

Several problems arose concerning the application of this approach to the present study.

(a) It was impossible to locate satisfactory data on pasture yield,collected under field conditions for a number of years, that could be analysed for yield variation.

(b) No automatic procedure exists for identifying a policy which would yield a higher expected profit. These plans must be selected intuitively, although familiarity with the system and observations on the results may provide a guide to profitable adjustments. However, the time involved in computing worthwhile solutions would have been prohibitive with available facilities.

A possible extension of this approach, applicable to the present study, would be to use an auxilary LP model in conjunction with that described.

1/ Such strategies included:-
- (a) Forage cannot be carried over from one year to the next.
- (b) Forage cannot be sold, and livestock numbers cannot be adjusted to meet temporary changes in the feed situation.
- (c) A predetermined strategy must be followed when there is a choice between alternative uses for forage such as current consumption or conservation.

2/ LP in specific yield situations would not be suitable as it presupposes a degree of foreknowledge on the part of the farmer.

The levels of the LAND USE activities associated with the optimal plan for an average season would be used to determine pasture supply for any specified conditions of growth. These pasture supply figures for any specified conditions of growth therefore correspond to the pattern of defoliation, (grazing management), associated with the optimal plan for an average season. The use of these supplies in the optimal average season plan, i.e., as hay, silage or grazing, would then be ignored and the total pasture supplies, associated with the specified conditions of growth, entered into the B column of the second model. Purchased and conserved feed products then enter the matrix of the second model as competitive feed activities in each production period. The second model could therefore be used to determine the optimal allocation of feed resources, for any specified growing conditions, subject to the constraint that the basic defoliation pattern associated with the optimal average season plan is used. In periods where there is feed surplus in comparison with the average season, additional pasture could be consumed or conserved and offered as a supplement in later periods. In periods of feed deficit, say in the spring, areas saved for hay and/or silage in the average season, may be 'opened up' and used for grazing without violating the original defoliation pattern. Such a course of action could be at the expense of supplement feeding later in lactation and would only occur if profitable.

Such a procedure would offer a general grazing management policy with recommendations concerning feed conservation and stock feeding practices that should be followed under specific pasture growth conditions. A problem still exists, however, in identifying a general policy to test for profitability over a number of years. Possibly a useful procedure may be to combine this approach with that used in Section 6.7 to find a plan which is stable under a range of climatic conditions. This would involve the generation of several LP plans, each plan providing the optimum management system for each specific pasture yield considered. Maximum expected profits resulting from each plan, when that management system is followed for all pasture yield situations considered, could then be calculated by applying probability data on pasture yields. The plan resulting in maximum expected profits could then be selected.

Obviously, these various methods of incorporating the effects of weather variability would have required more analytical information, available time, and more extensive computer facilities than were available during the course of this study. The discussion does serve to illustrate, however, that linear programming does offer some potential for incorporating the effects of weather uncertainty into farm planning.

8.4 SUMMARY

Results presented in this chapter give some indications as to the profitability of N fertiliser use at stocking rates of 1.5 and 2.0 cows/acre, under various assumptions about BF and N prices. Unfortunately, time did not permit a comparison of 'Nitrogen' plans with 'self-contained' and 'hay-buying' plans at different BF prices. A detailed comparison of two plans for each stocking rate is also presented in order to illustrate the nature of the information obtained on management adjustments from the model used in this study. Tables 8.9 and 8.10 summarise the information on N use and net revenue per acre for 1.5 and 2.0 cows/acre, at different BF and N prices, as presented in Tables 8.1 and 8.3 respectively. These levels of N use are high and raise questions concerning the variability of actual responses to N at different times of the year and in different years. Section 8.3 discusses some of the problems in this area and the potential for incorporating an analysis of the effects of yield uncertainties using linear programming as the modelling technique.

TABLE 8.9 N USE AND NET REVENUE/ACRE AT 1.5 COWS/ACRE

	BF Price (c/lb)		
	30	40	50
	Net Revenue/acre ($)		
10c/lb N	159.7	217.2	275.5
5c/lb N	165.1	223.7	282.7
Difference	5.4	6.5	7.2
	lbs N used		
10c/lb N	61.1	83.9	110.4
5c/lb N	159.8	170.5	171.3
Difference	98.7	86.6	60.9

TABLE 8.10 N USE AND NET REVENUE/ACRE AT 2.0 COWS/ACRE

	BF Price (c/lb)		
	30	40	50
10c/lb N	173.6	246.3	319.9
5c/lb N	184.8	158.5	332.9
Difference	11.2	12.2	13.0
	lbs N used		
10c/lb N	159.4	186.2	187.4
5c/lb N	317.9	336.4	364.7
Difference	158.5	150.2	177.3

CHAPTER 9

LIMITATIONS OF THE STUDY

9.1 INTRODUCTION

This chapter outlines some of the more important limitations of the study. A scarcity of experimental data and limited computing facilities may have imposed limitations on the realism of the model. The number of alternative management systems that could be developed and compared was also limited by these factors.

9.2 EXPERIMENTATION

Experimentation with systems models is largely a cyclical procedure. Analysis of the solution to the management problem obtained for one set of circumstances, provides information that can be used in the process of formulating the next set of conditions for which a solution is required. The value of the approach lies in conducting a large number of experiments on which recommendations can be based. Utilising the full potential of this technique, with large models, requires sophisticated computer hardware which was not available for the present study. The short-term nature of the N response largely dictated the model size that was necessary, as small time intervals had to be defined. This resulted in a matrix size approaching the limit for available computing facilities, and three to four hours of computing time was generally required for a solution. Consequently, the amount of experimentation conducted in the time available was small in relation to that required to fully examine the problem. The analysis of each solution also required several hours with a desk calculator, and it is recommended that software procedures for direct output analysis be prepared in future major 'systems' studies.

9.3 DEFICIENCIES IN AVAILABLE INFORMATION

The most serious problem to overcome in building a realistic grazing model is the lack of suitable information on basic structural relationships.

One component of the systems model used in this study required estimates of butterfat output per cow, for various levels of feed intake, at different stages of lactation. However, published experimental data from which this relationship could be estimated was particularly deficient.

It is possible that the synthesised relationships used in this study are adequate, in the sense that the resultant model reacts in much the same way as a real system would to changes in its structure or in managerial policies, (Dent and Anderson, 1971). If this is not the case, then further analysis of past trials, or further trials with a range of feed intake restrictions at different stages of lactation, will be required to supply the information on inter-relationships between intake, butterfat production, animal liveweight changes and stage of lactation.

Quantitative information on factors affecting pasture growth and utilisation was also deficient, and this imposed limitations on the realism of the model. Furthermore, many of the pasture growth relationships available were obtained from mowing trials. Bryant and Parker (1971) question the validity of extrapolating the results from mowing trials to field conditions because:-

> '...... the conditions imposed on a pasture by a self-contained grazing system are quite different to those in a mowing or simulated grazing situation.'

If it is true, as Bryant and Parker suggest, that agronomists are, in general, unable to predict the outcome and explain the results of self-contained grazing systems by using standard agronomic research techniques, then it is likely that past results of agronomic research are of limited value when applied to the problem of devising practical farming systems. In this situation, research is required to devise treatments for plot experiments that more effectively simulate pasture growth relationships under actual grazing management systems.

The design of grazing management studies on a field scale should involve considerable communication and co-operation between synthesist and analyst, so that scarce and costly research facilities can be most efficiently allocated and the maximum amount of useful information obtained. By experimenting with, and validating, models of farm production systems, it should readily be determined whether the body of analytical knowledge built up is adequate and what further research is required.

9.4 LIMITATIONS OF GRAZING MANAGEMENT RECOMMENDATIONS DERIVED FROM THE RESULTS

A significant feature of the grazing management pattern followed at all stocking rates in this study, is the spelling of pasture for long periods throughout the year. This appears to contradict recommendations made by Bryant and Parker (1971) based on a grazing interval experiment conducted at Ruakura. In this experiment, a comparison was made of production from four farmlets over two seasons in which a 12 and 24-day rotation were carried out at each of two stocking rates 1/. It was found that at the lower stocking rate the shorter of the two rotations resulted in the greatest pasture growth, and despite more incomplete utilisation of available pasture at each grazing, animal intake and production was higher. At 2.0 cows/acre little difference in pasture availability or animal productivity occurred between the treatments. Over the summer, pasture was Paspalum dominant under all treatments, but the possibility of results being applicable only to this type of pasture is discounted by Bryant and Parker:-

> 'Other similar experiments have been conducted on pasture devoid of Paspalum with similar effects on butterfat production.' 2/

In order to compare the grazing management systems described by Bryant and Parker with those developed in this study, consider a highly simplified representation of a grazing system.

$$A_t - I_t = S_t$$

$$S_t + G_t = A_{t+k}$$

Where A_t = pasture availability at time t.

I_t = pasture intake at time t.

S_t = grazing severity at time t.

G_k = pasture growth after k days 3/.

By 'fixing' grazing frequency, pasture availability and grazing severity are determined within the system, as animal intake in relation to pasture availability will determine grazing severity. The four experimental treatments used in the grazing interval trial did in fact represent four different grazing frequency/severity combinations.

Where the grazing interval is fixed throughout the year, lax grazing will occur in times of abundant feed supply, and in feed deficit periods grazing is severe. In practice, a farmer will vary the area

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1/ 1.67 and 2 cows/acre.

2/ Source not stated.

3/ Factors affecting pasture growth are discussed in Chapter 3.

allocated for grazing each day as pasture availability fluctuates throughout the year. Inter-relationships between factors that influence the farmer in making a decision as to what area should be allocated to the animals at a particular grazing are extremely complex and difficult to evaluate.

At any particular grazing a farmer must attempt to assess the amount of pasture available on the farm. He then 'fixes' an area to be grazed so that a certain level of intake will occur. The area allocated will be influenced by a number of factors. For example, rationing of available feed must take into account likely future animal demands and pasture growth, and feed availability at subsequent grazings.

Similar decisions to those made by the farmer are made in the grazing model used in this study. Grazing severity is fixed in each period and an area of pasture is allocated according to future pasture growth, and present and future animal demands. However, decisions made by farmers are influenced by uncertainty about the future, whereas a non-stochastic system is assumed in the model. This is a major limitation and emphasises the need to incorporate stochastic variables, (particularly for pasture growth), into grazing management models when available information and computing facilities allow this to be done.

Several important relationships exist in actual grazing systems that have not been included in the model.

A relationship between intake and availability of pasture has not been incorporated. As is discussed in Chapter 4:

$$I_t = f(A_t)$$

As $A_t - I_t = S_t$, grazing severity will also be affected by this relationship.

There is also little information on the effects of different levels of grazing severity at different times of the year on future pasture production potential. As is discussed in Chapter 3, considerable changes in pasture composition can occur which will affect both annual pasture yield and the seasonal distribution of pasture growth. Consequently, the effects of varying grazing height could not be investigated in this study, but with information on interactions between grazing frequency, season, grazing severity and pasture production, a grazing model could provide useful information for establishing experimental treatments to be tested under field conditions.

9.5 ALTERNATIVE MANAGEMENT SYSTEMS

The model is limited in its ability to generate and explore the profitability of alternative management systems that may prove economically competitive to the systems based on early calving and N use described in the study.

9.5.1 Grazing systems based on later calving

A feature of the results presented is that at stocking rates above and including 1.5 cows/acre, even with heavy applications of N fertiliser, the cows are not fully fed in early lactation. The problem of maintaining adequate feed supply to cows calved in July/August over this period has been experienced under field conditions at Ruakura. There, experiments in recent years have consistently shown at high stocking rates, (1.67 and 2 cows/acre), considerable increases in animal productivity can be achieved by a change to later calving. The milk production level of September calved cows in the first three months of lactation is consistently 12-20 percent higher, and this is associated with increasing pasture intake and liveweight gain. During the remainder of lactation, cows continue to out-produce earlier calved identical twins despite lower feed intake, by drawing on body reserves 1/.

At Ruakura, July/August calvers achieved their peak intake in November/December. However, September calved cows, which commence lactating about the onset of spring growth, have a more abundant feed supply in early lactation and reach a peak intake at a relatively earlier stage. This gives better correspondence between peak levels of intake and butterfat production 2/. The causes of differences in post calving intake patterns cannot be fully explained, and may not be a reflection of increased pasture availability alone. Hutton (1971) suggests that significantly better prepartum feeding may contribute to some of the productive advantage associated with September calving. Because of the relative ease with which both prepartum and early lactation feed requirements can be met, later calving at high stocking rates, (say, above 1.5 cows/acre), is recommended in areas not prone to summer drought, (such as at Ruakura).

Unfortunately, a lack of quantitative information concerning differences in animal production relationships occurring when a change

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1/ Hutton (1971).

2/ Hutton (pers. comm.).

is made to later calving, required that 'experimentation' in this study had to be confined to a consideration of feed resource organisation for 'early' calved cows only.

In the model, fixed 'dry' cow requirements must be met, so that adequate prepartum feeding levels are ensured. Because there was insufficient information to quantify the relationships between restricted feeding in early lactation and subsequent production potential, only small depressions in intake below the maximum in early lactation were permitted. Not allowing carryover effects may have indirectly accounted for the apparent shortage of feed in early lactation. In terms of the production relationships specified in the model, it was uneconomic to provide sufficient feed to satisfy maximum intake. If carryover effects had been included, the extra penalty incurred as a result of prejudiced production potential later in lactation would increase the value of pasture supplied in this period and may well have resulted in full feeding in early lactation.

Obviously, the economies of N use cannot be satisfactorily resolved until there is accurate information available on the value of feed supply in early lactation. This would allow the elimination of the minimum intake restrictions used in the model and incorporation of relationships relating feed intake in any period to milk production potential later in lactation. It will also be necessary to establish the reliability of this method of feed supply as all experimentation was conducted assuming a non-stochastic system.

Severe feed shortages also exist in the summer and autumn period at higher stocking rates. A change to 'later' calving under the pasture growth assumptions made in the study would cause these feed supply difficulties to occur relatively earlier in lactation. As N cannot be successfully used to stimulate pasture growth in the summer period, other sources of feed supply must be considered.

9.5.2 Grazing systems based on irrigation

Irrigation may offer considerable potential for raising and stabilising the level of pasture production over this summer/autumn period. Elliot (1966) discusses the results of experimentation with irrigation at Rukuhia Soil Research Station where irrigation has raised pasture productivity by 3,500 lbs DM/acre on average 1/, at a cost of approximately 1clb DM. In the period January to March inclusive, the standard deviation

1/ From 16 years of data collection.

from the mean yield of irrigated plots was 6.6 percent while that from unirrigated plots was 52 percent [1/].

The possibility of including irrigation activities in the present study was considered. However, while sufficient information is available on technical factors relating to spray irrigation use, suitable agronomic information on pasture responses is not as readily available.

Alternatively, specialist crops with greater summer potential than pasture, such as maize for silage production, or lucerne, may prove economically competitive to the use of irrigation for the production of additional feed over the summer period.

9.5.3 Grazing systems based on irrigation and later calving

Irrigation and later calving together may offer considerable potential for raising butterfat productivity levels at high stocking rates by ensuring that animals remain well fed throughout lactation. Later calving would replace the need for late winter applications of N and irrigation would supply summer feed and also enable the lactation length of later calving cows to be extended by ensuring abundant feed supply in Autumn.

However, it appears that clover dominance caused by irrigation may result in reduced pasture growth over the late autumn/winter/early spring period [2/]. Therefore, late summer/autumn applications of N fertiliser may still have a role to play in stimulating grass growth and thus increase total pasture yield over this period.

The author visited two farms in the Levin/Otaki area, where satisfactory responses to N are also being obtained in the summer period by using irrigation water to apply urea to pasture.

Therefore, many alternative grazing management systems may prove economically competitive to the system developed in this study. Given the necessary information, however, profitability comparisons could be made. This would indicate potentially profitable management systems that could be tested for feasibility under field conditions.

1/ 11 years' data.

2/ Ball (pers. comm.).

9.6 LIMITATIONS OF THE RESULTS CONCERNING N USE

As mentioned previously, the comparisons made in this study, between alternative management systems at a given stocking rate, have been limited in part by the amount of time and money available for experimenting with the model. Management systems were considered for five stocking rates: 1.0, 1.2, 1.5, 1.7 and 2.0 cows/acre. At a BF price of 30c/lb and a N price of 10c/lb., N use was only profitable at stocking rates of 1.5 cows/acre and above. Although both BF and N prices were varied in Chapter 8, only stocking rates of 1.5 cows/acre and above were considered. At these stocking rates considerable use is made of N fertiliser. For a stocking rate of 1.5 cows/acre, N use varies between 61 and 171 lbs N depending on BF and N prices, (Table 8.1). The corresponding range of N use at 2.0 cows/acre is 159 to 365 lbs N, (Table 8.3).

The margin of net profit per acre from using, versus not using, N fertiliser is limited to comparisons between the plans presented in Chapter 6, i.e., at a BF price of 30c/lb and a N fertiliser price of 10c/lb N. In a comparison of the 'Nitrogen' and 'hay-buying' plans, this margin ranges from $2.10/acre at 1.5 cows to $8.20 at 2.0 cows/acre, (Table 6.16). At a BF price of 30c/lb, these margins correspond to 7.0 and 27.3 lbs BF/acre, (or, 4.7 and 13.6 lbs BF/cow), for each stocking rate respectively. Any unplanned reduction in N response would result in some erosion of these margins. Given sufficient time, the model could have been used to explore the effects of unplanned responses to N. For example, it would be possible to use the model to predict the outcomes, associated with any given grazing management system, under different pasture response situations.

A feature of the results described in Chapters 6 and 8 is that N fertiliser use enables a reduction in the level of hay feeding to the dry cows at 1.5, 1.7 and 2.0 cows/acre. This practice is economical because, as shown in Appendix 2, the pasture response to a mid-April application of 50 lbs N/acre, followed by eight weeks spell, is 660 lbs DM/acre. At a N price of 10c/lb, dry matter provided in the winter in this way costs less than 1c/lb DM which is the price assumed in the model for purchased hay. However, the reliability of this method of providing winter feed must be questioned. Dry autumn conditions following N application or a cold early winter period may result in considerably less dry matter being supplied in practice.

The use of large quantities of N at 2.0 cows/acre means that some grazing areas will receive high annual rates of N. This raises the possibility of severe depressions in clover growth and subsequent changes in pasture regrowth characteristics. Research work has yet to define the conditions under which this will occur, and so 'slumping' effects have been disregarded in the model. Consequently, the value of N at high stocking rates may have been over-estimated.

Also at high stocking rates, cows are largely dependent on N produced grass for adequate consumption levels in early lactation. Should the actual N response under field conditions be less than expected, some carryover effects may result. Given the appropriate information on the nature of these carryover effects, the model could be used to explore the effects of variation in N response. However, this further emphasises the limitations that are imposed on the recommendations that can presently be made, (at least on the basis of results presented in this study), concerning the profitability of N use.

9.7 SUMMARY

The limitations of this study have been presented in light of the aim of the study; which was to provide recommendations concerning the profitability of N fertiliser use in factory supply dairy production systems.

Recommendations that can be made from this study are likely to be severely limited by the lack of experimentation with the model. It is clear that there exist a large number of alternative management systems which could be compared under different assumptions about economic variables. In addition, it was not possible to compare alternative management systems where physical factors, such as pasture growth rate at any time, were treated as stochastic variables. Also, it was not possible to consider alternative management strategies at different stages of the production process, where the current situation is known but future outcomes are uncertain.

A major part of this study was concerned with specification and synthesis of the inter-relationships involved in an animal/grazing production system using LP as the modelling technique. Data limitations and the consequent limitations on experimentation with the model, have been stressed.

It should be stated, however, that the limitations of this particular systems modelling study, refer explicitly to the stated problem of investigating the economics of N fertiliser use in dairy production systems and the use of LP as the modelling technique. The same limitations may not prove so important for other problems where LP is used, or for this and other problems using alternative modelling techniques.

CHAPTER 10

SUMMARY AND CONCLUSIONS

10.1 INTRODUCTION

Experimentation with real farming systems is likely to be costly and time consuming. By using a model of the system, and experimenting with it, indications of management adjustments that appear to increase potential annual productivity and farm profitability may be obtained. This technique may be a useful complement to physical experimentation and enable limited research resources to be allocated more efficiently. Despite the limitations of the LP model developed in this study, valuable information was gathered on data deficiencies that will restrict the development of more complex realistic models when computing facilities are extended. As well, some useful information on the economics of N fertiliser use was supplied.

10.2 COMPARISON OF THE RESULTS WITH PUBLISHED INFORMATION

Given information about future pasture production, the model organises grazing management to optimally allocate feed resources to the grazing animals throughout the year. It assumes an extremely high level of management and makes no allowance for the inefficiencies, (caused primarily by uncertainty about future events), that normally occur on well-managed farms. However, the results obtained appear realistic when compared with small farm experimental results. For example, the model indicates that an annual production of approximately 530 lbs of butterfat per acre can be achieved by using herbage grown on the farm as the sole feedstuff, (without the use of N fertiliser). This is comparable with actual production levels ranging from 450 - 550 lbs/acre achieved at Ruakura with early calving cows 1/.

The results also appear realistic when compared with actual grazing systems, when feed supplements are purchased. Based on stocking rate experiments at Ruakura, Bryant (1969) summarises per acre feed consumption and butterfat production levels at a stocking rate of 2.0 cows/acre. Data is averaged over a three year period. At Ruakura, pasture production is insufficient to feed the animals adequately at 2.0 cows/acre at all times.

1/ Bryant (1969).

Therefore, an average butterfat production level of 617 lbs/acre required an additional 870 lbs Meal DM/acre and 1,100 lbs of purchased hay DM/acre [1]. Bryant calculates that an additional 6,133 lbs DM/acre over the three year period, (2,044 lbs DM/acre/year), would have resulted in an average yearly intake of 16,600 lbs DM/acre and an average butterfat production level of 720 lbs/acre. Average total intake of purchased supplements each year would equal:-

2,044 + 870 + 1,100 = 4,014 lbs DM/acre

In the 'Nitrogen' plan at 2.0 cows/acre, described in detail in Section 6.8, an annual butterfat production level of 720.2 lbs/acre required a total intake of 16,074 lbs DM/acre of which purchased feed supplements [2] contributed 4,162 lbs DM/acre [3]. The composition of these supplements is as follows:-

N produced grass	1,806
N produced silage	154
Purchased hay	2,201
Total	4,162

The major difference between the Ruakura results and the 'Nitrogen' plan are that the animals in the model are assumed to be slightly more efficient at converting dry matter into butterfat, (22.3 lbs DM/lb butterfat compared with 23.0 lbs DM/lb butterfat at Ruakura), and slightly more pasture is harvested by the grazing animals at Ruakura. Also, the two systems are not strictly comparable because at Ruakura the cows were calved at the onset of the spring flush and had a shorter lactation length than in the model. However, despite these differences, the results from the model did appear sufficiently realistic to use as a basis for examining the economics of N fertiliser use.

10.3 BRIEF SUMMARY OF RESULTS

A comparison between butterfat production levels at different stocking rates in the model, highlights the importance of stocking rate as a major determinant of per acre butterfat production. However, the

1/ One bale of hay is assumed to contain 50 lbs DM.

2/ N produced grass and silage are considered to be purchased feed supplements.

3/ All feed supply figures in Table 6.6 have been corrected for utilisation losses by subtracting 10 percent.

most profitable stocking rate cannot be determined because optimal plans are defined where the revenue from butterfat output and hay sales, less feed costs for any specified stocking rate, is a maximum. Consequently, the resulting net profit figure does not take into account variable costs between different stocking rates.

Table 10.1 summarises the effects of purchased hay and N fertiliser on net profits.

TABLE 10.1 SUMMARY OF THE EFFECTS OF PURCHASED HAY AND N FERTILISER ON NET PROFITS [1/]

Stocking rate	1.0	1.2	1.5	1.7	2.0
			($/acre)		
Net profits from the self-contained plan	123.6	140.0	155.5	152.4	131.8
Increase in net profit contributed by purchased hay	-	-	2.2	10.8	33.5
Further increase in net profits contributed by purchased hay and N fertiliser	-	-	1.9	5.3	8.2
Total net profits	123.6	140.0	159.6	168.5	173.5

At stocking rates of 1.0 and 1.2 cows/acre the efficient organisation of available feed supplies results in high per cow butterfat production levels. Surplus feed is conserved as hay and a large proportion is sold, as only small amounts of conserved grass products are required for the animals in other periods. At 1.0 cows/acre, N activities were not included in the optimal plan, even when the annual pasture production level was 11,000 lbs DM/acre/year. At stocking rates above 1.5 cows/acre pasture growth is insufficient to provide adequate feed for the lactating cows, resulting in marked depressions in per cow butterfat production levels, and a consequent decline in net profits/acre for the 'self-contained' plans.

1/ BF at 30c/lb, N at 10c/lb.

As shown in Table 10.1, purchased hay increases net profits slightly at 1.5 cows/acre and is of considerable value in increasing profitability at higher stocking rates. There are three main ways in which purchased hay contributes to the production of extra butterfat and net profits:

(a) By feeding greater amounts of hay to the dry cows, a slower grazing rotation can be followed over the winter period. The longer spelling of pasture grazed in spring increases dry matter yields at that time, resulting in increased intake and butterfat production.

(b) The release of land previously closed for hay production makes extra pasture available for grazing in late spring and early summer.

(c) Purchased hay is also used as a milking feed supplement at 1.7 cows/acre and particularly at 2.0 cows/acre where large amounts are fed in the second half of lactation to raise intake levels. At 2.0 cows/acre purchased hay is also used to replace expensive meal feeding.

Table 10.1 demonstrates that the use of N fertiliser at stocking rates above and including 1.5 cows/acre will also result in additional net profits.

N is used in three main ways:

(a) Application to pasture in late winter/spring increases pasture intake and butterfat production in the spring and early summer period at each stocking rate.

(b) N is also used to enable silage to substitute for more expensive purchased hay as a milking feed supplement at 1.7 and 2.0 cows/acre 1/. Additional pasture conservation at each stocking rate results in a reduced area being available for grazing over the late spring/summer period. N fertiliser is applied to pasture in late winter and spring, so that a slower grazing rotation can be followed over this period and high pasture yields obtained. Consequently, butterfat production is not reduced as a result of the additional pasture conserved. N fertiliser is also applied to

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1/ Hay is not fed to the lactating cows at 1.5 cows/acre.

silage paddocks to enable silage requirements to be met by taking a minimum area of land out of the grazing rotation.

(c) N fertiliser also enables the amount of hay purchased and fed to the dry cows to be reduced. N is applied in April and May and N produced grass is used to maintain intake over May and June so that pasture can be spelled for the July/August periods. The additional pasture produced is then used to reduce the amount of hay fed to the dry cows over this period. However, as is discussed in Chapter 9, the reliability of this method of providing winter feed can be questioned.

Because of the diminishing pasture response to successive increments of N, it is more profitable to apply N to a greater area of pasture than increase the application rate. Consequently, in nearly all plans, N applications are at a rate of 50 lbs N/acre.

10.4 POSSIBLE EXTENSIONS OF THE PRESENT STUDY

The model used in this study was limited in its capacity to generate alternative management systems for profitability comparisons. To fully evaluate the economics of N use on seasonal supply dairy farms at high stocking rates, it will be necessary to construct models of alternative management systems and compare them with the systems developed in this study. The cost of constructing models for, say, late and early calving may not be warranted if only the profitability of N fertiliser use is examined. However, model development costs may be justified if these systems were extended to study other management problems such as the profitability of irrigation or cropping as a means of supplying high quality feed to lactating cows.

As is discussed in Chapter 9, a lack of published experimental data prevented the effects of varying grazing height on pasture growth from being investigated. However, given the necessary information on interactions between grazing severity, grazing frequency, season and pasture production, a grazing management model may be of considerable value in establishing decision rules that should be followed under field conditions if pasture growth is to be most efficiently allocated to the grazing animals throughout the year. Grazing management recommendations could be expressed in terms of area grazed in each month, or rotation speed around the farm as at present, but with more information provided on minimum grazing height that is advisable in each season if future pasture production is not to be adversely affected. As is discussed in Chapter 8, Brougham (1970) presents similar recommendations, involving grazing frequency and severity based on field plot experiments. Management adjustments that should accompany pasture growth fluctuations within any season may also be possible. However, this will require that pasture availability on grazing areas be estimated with greater accuracy than is possible at present. If a relatively simple device for measuring pasture availability could be developed however, grazing management extension may be able to provide these more detailed recommendations. Given the necessary information, computer modelling does offer considerable potential for making this approach feasible.

A serious limitation of this study is that a non-stochastic system was assumed. While the advantages of LP as an important tool for efficient resource allocation in deterministic studies is well recognised, its usefulness as an aid to decision making in farming systems characterised by extreme climatic uncertainty has often been questioned [1/,2/]. Possible ways in which LP could have been used to incorporate the effects of climatic uncertainty into farm planning are outlined in Chapter 8. Alternative procedures to those described will generally involve the application of some other programming technique and will undoubtedly involve a consideration of simulation. However, as farming systems are extremely complex, it may be necessary to use several programming techniques to realistically incorporate the important characteristics of the system under study; where each technique is used to exploit its advantages for particular aspects of the overall problem. For example, LP can be useful if information on pasture yield variation is available, but field measurements of pasture growth over long periods of time have not been conducted in the Manawatu environment. Wright (1970) has shown that simulation offers considerable potential for providing this information. Another possible approach would be to use LP as a method for selecting grazing management systems that could be tested for long-term profitability, (and feasibility), by subjecting them to randomly selected yearly pasture growth patterns by a simulation model.

1/ Hardaker (1967).

2/ Musgrave (1963).

The use of more realistic systems models in research will become feasible as computer hardware becomes more sophisticated and as research workers become interested in the systems approach and design experiments so that suitable information is provided. During the course of this study, the author was dependent on research workers for estimates concerning the nature of many relationships required in the model. This does, however, emphasise the necessity for a systems research study to be a joint research project, utilising the extensive knowledge of research workers in different specialised areas. If an attempt is made to open up channels of communication between different fields, information on data deficiencies can be efficiently conveyed to those responsible for the research effort. Joint planning of research projects may occur and this would ensure that a maximum amount of useful information would be obtained from the research facilities available. The use of the systems approach in agricultural research therefore, is likely to become more widespread as research workers begin to identify farming problems in a 'systems' framework. This will require the crossing of inter-disciplinary boundaries and more extensive communication between research workers than occurs at present. The extent to which this can be achieved will set the limits on the significance of the contribution that systems research can make to agricultural research in general.

APPENDIX 1

RELATIONSHIP BETWEEN POUNDS DRY MATTER PRODUCTION PER ACRE AND LENGTH OF SPELL FOLLOWING DEFOLIATION

Length of spell (weeks)	2	3	4	5	6	7	8	9	10
Dec.	450	800	1,200	1,500	1,700	1,750	1,800		
Jan.	400	700	1,000	1,300	1,500	1,550	1,600		
Feb.	300	550	850	1,100	1,300	1,450	1,500		
Mar.	250	400	650	900	1,200	1,400	1,500		
Apr.	250	500	800	1,000	1,200	1,300	1,350	1,380	1,400
May	150	300	450	600	800	950	1,000	1,030	1,050
June	150	250	350	500	650	800	950	1,100	1,280
July	200	300	450	650	850	1,100	1,350	1,650	1,900
Aug.	250	450	750	1,150	1,550	2,000	2,400		
Sep.	400	800	1,250	1,750	2,300	2,900	3,350		
Oct.	550	1,050	1,650	2,300	2,950	3,600	4,100		
Nov.	600	1,100	1,600	2,150	2,600	2,900	3,100		

NOTE: 1) Relationships for monthly periods are presented, as these were estimated from published and 'raw' data. Growth relationships for the fortnightly periods used in this study were then extrapolated.

2) Defoliation is assumed to occur at the mid-point of each period.

APPENDIX 2

RELATION SHIP BETWEEN QUANTITY OF NITROGEN APPLIED AND LENGTH OF SPELL FOLLOWING APPLICATION

A 2.1 <u>Response to 50 lbs N/acre</u>

Length of spell (weeks)	Apr.	May	July (lbs DM/acre)	Aug.	Sep.	Oct.
2	260	140	100	250	350	320
3	370	200	170	380	500	470
4	460	240	250	500	650	580
5	540	280	330	600	780	650
6	600	320	420	700	900	700
7	640	340	500	780	1,000	730
8	660	360	600	860	1,060	750
9	680	370	700	920		
10	680	370	800	980		

A 2.2 <u>Response to 100 lbs N/acre</u>

Length of spell (weeks)	Apr.	May	July (lbs DM/acre)	Aug.	Sep.	Oct.
2	400	200	200	450	550	540
3	550	280	320	630	750	670
4	650	340	450	800	950	760
5	750	400	580	930	1,100	840
6	800	450	700	1,040	1,230	890
7	850	480	820	1,130	1,340	920
8	880	500	950	1,200	1,400	950
9	900	510	1,070	1,260		
10	920	520	1,200	1,320		

NOTE: 1) The Nitrogen response relationships for monthly periods, estimated from 'raw' data, are presented pasture responses for fortnightly periods used in the study were extrapolated from these relationships.

2) Nitrogen is assumed to be applied to freshly grazed pasture midway through each period.

3) Nitrogen response is assumed additive to pasture growth over the same period.

APPENDIX 3

THE PASTURE PRODUCTION MODEL

A representation of the LP matrix used for the pasture production model is presented in Figure A 3.1.

A 3.1 ACTIVITIES

$P_1, \ldots, P_n$ are LAND USE activities and refer to one acre of pasture spelled for a specified period of time following grazing.

A 3.2 RESTRAINTS

(a) Feed reconcilation rows $F_1, \ldots, F_m$ ensure that feed demand does not exceed feed supply in any of the specified periods.

(b) LAND restraints $L_1, \ldots, L_m$ ensure that all land is fully utilised throughout the year.

(c) F. PROD is a free row that calculates total amount of DM produced as a result of LAND USE activities chosen by the programme.

A 3.3 INPUT - OUTPUT COEFFICIENTS

a_{ij}, $i = 1, \ldots, m$; $j = 1, \ldots, n$; is the amount of pasture DM/acre supplied by the ith LAND USE activity in the jth production period.

A 3.4 TOTAL GRAZING AREA

It is necessary to include in the model constraints that ensure no more than a specified amount of land is used overall. In this study, total grazing area is constrained to one acre, accomplished by a T. LAND equation.

To illustrate the system of equations describing the use of the total grazing area throughout the year, consider a simplified system consisting of six periods and 12 LAND USE activities. A set of LAND constraints and the T. LAND constraint are shown in Figure A 3.2.

The LAND constraints describe land use at any time. For example, in period 1 feed is made available from X_7 and X_9 acres 1/, that is $(X_7 + X_9)$ acres of land are grazed in period 1. Also, X_1 acres of land

1/ X_j refers to the level of activity P_j.

are spelled from period 1 and grazed in period 3, and X_2 acres of land are spelled from period 1 and grazed in period 4. It is clear that the total area spelled from period 1 must equal the area grazed in period 1, hence:

$$X_1 + X_2 = X_7 + X_9$$

$$\text{or,} \qquad X_1 + X_2 - X_7 - X_9 = 0$$

as in equation (1), Figure A 3.3. Equations (2) through (6) in Figure A 3.3 are derived in a similar way for each period.

It is also clear that in any period the total land area must either be grazed or spelled. For example, in period 1 $(X_7 + X_9)$ acres are grazed while $(X_{10} + X_{11} + X_{12})$ acres are being spelled. X_{10} acres are spelled from period 5 and grazed in period 2 and hence are 'being spelled' in period 1. Because the nominal total area under consideration in the model is 1 acre, we have an additional constraint for period 1:

$$X_7 + X_9 + X_{10} + X_{11} + X_{12} = 1$$

as shown in equation (7), Figure A 3.3. Equations (8) through (12) in Figure A 3.3 are derived in a similar way for each period.

The equations presented in Figure A 3.3 therefore ensure that land grazed in any period is spelled from that period, and all land is either being grazed or spelled in every period.

Inspection of the equations in Figure A 3.3 reveals that equations (1) through (6) plus any other equation implies the remaining equations. For example: equation (1) + equation (7) = equation (8). If equations (1) and (7) hold, then equation (8) must hold. There is no need therefore to explicitly include equation (8). Similarly:

$$(9) = (1) + (2) + (7)$$
$$(10) = (1) + (2) + (3) + (7)$$
$$(11) = (1) + (2) + (3) + (4) + (7)$$
$$(12) = (1) + (2) + (3) + (4) + (5) + (7)$$

Therefore, in the model only one TOTAL LAND equation, derived from land use in one period, is required in addition to the LAND equations.

FIGURE A 3.1 THE PASTURE PRODUCTION MODEL

	C_j		0	0	0	0		0	0	0
	B		P_1	P_2	P_3	P_4	. . .	[illegible]	$_{n}$ [illegible]	P_n
F_1	0	≥						$-a_{1,n-2}$		
F_2	0	≥							$-a_{2,n-1}$	
F_3	0	≥	$-a_{31}$							$-a_{3,n}$
F_4	0	≥		$-a_{42}$		$-a_{44}$				
F_5	0	≥			$-a_{53}$					
.										
.										
.										
F_m	0	≥								
L_1	0 0	=	1	1	1			−1		
L_2	0	=				1			−1	
L_3	0	=	−1							−1
L_4	0	=		−1		−1				
L_5	0	=			−1					
.										
.										
.										
L_m	0	=						1	1	1
F.PROD		Fr	$-a_{31}$	$-a_{42}$	$-a_{53}$	$-a_{44}$		$-a_{1,n-2}$	$-a_{2,n-1}$	$-a_{3,n}$

FIGURE A 3.2 LAND RESTRAINTS FOR A SIMPLIFIED SYSTEM

	B		P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}
L_1	0	=	1	1					-1		-1			
L_2	0	=			1	1						-1	-1	
L_3	0	=	-1				1	1	1					-1
L_4	0	=		-1	-1					1				
L_5	0	=				-1	-1				1	1		
L_6	0	=						-1		-1			1	1
T.LAND	1	=	1	1								1	1	1

FIGURE A 3.3 EQUATIONS DESCRIBING LAND USE IN EACH PERIOD

$$X_1 + X_2 - X_7 - X_9 = 0 \quad (1)$$

$$X_3 + X_4 - X_{10} - X_{11} = 0 \quad (2)$$

$$-X_1 + X_5 + X_6 + X_7 - X_{12} = 0 \quad (3)$$

$$-X_2 - X_3 + X_8 = 0 \quad (4)$$

$$-X_4 - X_5 + X_9 + X_{10} = 0 \quad (5)$$

$$-X_6 - X_8 + X_{11} + X_{12} = 0 \quad (6)$$

$$X_7 + X_9 + X_{10} + X_{11} + X_{12} = 1 \quad (7)$$

$$X_1 + X_2 + X_{10} + X_{11} + X_{12} = 1 \quad (8)$$

$$X_1 + X_2 + X_3 + X_4 + X_{12} = 1 \quad (9)$$

$$X_2 + X_3 + X_4 + X_5 + X_6 + X_7 = 1 \quad (10)$$

$$X_4 + X_5 + X_6 + X_7 + X_8 = 1 \quad (11)$$

$$X_6 + X_7 + X_8 + X_9 + X_{10} = 1 \quad (12)$$

A 3.5 NITROGEN ACTIVITIES

In Figure A 3.4, LAND USE activity P_j refers to the spelling of one acre of land between periods s and t, making a lbs DM available in period t for grazing. Nitrogen activities (P_{jn} and P'_{jn}) are alternative LAND USE activities except that they represent the application of 50 or 100 lbs N/acre respectively, following grazing in period s and make available a' and a'' lbs DM/acre respectively in period t.

FIGURE A 3.4 NITROGEN ACTIVITIES

					0	$-C_n$	$-C'_n$	
		B		. . .	P_j	P_{jn}	P'_{jn}	. . .
Feed Reconciliation rows	F_1	0	$\geq$					
	.							
	.							
	F_t	0	$\geq$		$-a$	$-a'$	$-a''$	
	.							
	.							
	.							
	F_m	0	$\geq$					
LAND Restraints	L_1	0	=					
	.							
	.							
	L_s	0	=		1	1	1	
	.							
	.							
	L_t	0	=		-1	-1	-1	
	.							
	.							
	.							
	L_m	0	=					

APPENDIX 4

THE DERIVATION OF ANIMAL DRY MATTER REQUIREMENTS

A 4.1 DRY COW REQUIREMENTS

Dry cow requirements for an 'average' cow in the herd in each period can be derived from Figure 5.1 and Table 5.2. The dry cow requirements in the first period in July (JUL 1) are calculated below:

(a) Maintenance Requirement

1 cow x 15 days x 11.0 Mcals ME/day = 165 Mcals ME

(b) Pregnancy Requirement

.33 cows x 15 days x 8.5 Mcals ME/day = 42.1 Mcals ME

.42 cows x 15 days x 7.0 Mcals ME/day = 44.1 Mcals ME

.25 cows x 15 days x 2.5 Mcals ME/day = 9.4 Mcals ME

Total Pregnancy Requirement = 95.6 Mcals ME

(c) Total average dry cow requirement = 260.7 Mcals ME

Dry matter requirements in this period can be calculated by dividing energy requirements by 1.28 1/.

Dry matter requirements in JUL 1 therefore are:

Maintenance	129
Pregnancy	75
Total	204 lbs DM

Dry matter requirements for the dry cows in all periods are presented in Table A4.1. As only 90 percent of the feed supplied is utilised in the dry period 2/, the total feed requirement shown in Table A4.1 must be adjusted by this factor in the model if it is to represent feed required per cow in each period.

1/ Pasture quality in JUL 1 is assumed to be 1.28 Mcals ME/lb DM. (See Table 5.1).

2/ See Table 4.5.

TABLE A4.1 DRY COW REQUIREMENTS

	(lbs dry matter)		
Period	Maintenance	Pregnancy	Total
May 1	28	2	30
2	29	7	36
June 1	138	27	165
2	138	45	183
July 1	129	75	204
2	92	52	144
Aug. 1	32	21	53
2	34	26	60

A 4.2 THE DERIVATION OF BUTTERFAT PRODUCTION FUNCTIONS

It is assumed in the study that calving date does not influence maximum intake and corresponding milk production patterns throughout lactation. Consequently, Figure A 4.1 and A 4.2 depicting these relationships for each calving date assumed in the model [1] have been derived from Figure 5.2 and 5.3 respectively. From Figure A 4.1 and A 4.2, average maximum intake and milk production in each period can be derived for the calving distribution assumed in the study. For example, in period OCT 1:

(a) Maximum dry matter intake

At the beginning of OCT 1, from Figure A 4.1

.33 cows x 28.31 lbs DM/day = 9.3 lbs DM
.42 cows x 27.0 lbs DM/day = 11.3 lbs DM
.25 cows x 24.5 lbs DM/day = 6.1 lbs DM
Total 26.7 lbs DM/day

At the end of OCT 1

.33 cows x 29.0 lbs DM/day = 9.6 lbs DM
.42 cows x 28.3 lbs DM/day = 11.9 lbs DM
.25 cows x 26.2 lbs DM/day = 6.6 lbs DM
Total 28.1 lbs DM/day

Average Maximum Intake = 27.5 lbs DM/cow/day

1/ The calving dates assumed in the study for different proportions of the herd are presented in Figure 5.1, Chapter 5.

(b) Maximum milk production

At the beginning of OCT 1, from Figure A 4.2

.33 cows x 34.5 lbs Milk/day	=	11.4	
.42 cows x 34.9 lbs Milk/day	=	14.7	
.25 cows x 3 [illegible] 2 lbs Milk/day	=	8.6	
[illegible]otal	=	34.7	lbs Milk/day

At the end of O[illegible] 1

.33 cows x 34.2 lbs Milk/day	=	11.3	
.42 cows x 34.5 lbs Milk/day	=	14.4	
.25 cows x 35.0 lbs Milk/day	=	8.8	
	=	34.5	lbs Milk/day
Average Maximum Milk Production in OCT 1	=	34.6	lbs Milk/day

Average maximum intake and milk production is similarly derived for all periods and is presented in Figure A 4.3 and A 4.4. Using this information, together with average maintenance requirements presented in Table 5.4, a butterfat production function can be constructed for each period.

For example, in OCT 1, the maintenance requirement is assumed to be 11.3 Mcals ME/day 1/. As pasture quality in this period is assumed to be 1.28 Mcals ME/lbs DM 2/, a daily maintenance requirement of 8.8 lbs DM is required. There are 15 days in OCT 1, so that total maintenance requirement in this period is 132 lbs DM, (point B in Figure 5.6).

The co-ordinates of point A in Figure 5.6 for OCT 1 are derived as follows:

Maximum intake in OCT 1 = 27.5 x 15 = 413 lbs DM

Maximum BF Production 3/ = 34.6 x 5/100 x 15 = 26.0 lbs BF

The butterfat production/dry matter intake relationship for OCT 1 is shown in Figure A 4.5. A minimum intake restriction of 308 lbs DM is imposed in this period. At this intake level, 21.0 lbs of butterfat will be produced, (point C in Figure 5.6).

These relationships are similarly derived for other periods and are presented in Table A4.2.

1/ Table 5.4.

2/ Table 5.1.

3/ Butterfat content of milk assumed to be 5 percent in all periods.

In the model, October and November are divided into four periods so the co-ordinates of points A, B and C have been halved in Table A4.2.

TABLE A4.2 THE BUTTERFAT PRODUCTION FUNCTIONS

Point*	B	C		D		A	
Period	Mainten. Rqmt. (lbs DM)	Y_1 lbs BF	X_1 lbs DM	Y_2 BF	X_2 DM	Y_3 BF	X_3 DM
July 2	46	7.0	95			8.5	115
Aug. 1	97	15.5	205			18.3	253
2	104	17.5	235			20.6	293
Sep. 1	132	20.5	280			25.5	375
2	132	21.0	298			26.0	400
Oct. 1 (1)	66	10.5	154			13.0	207
1 (2)	66	10.5	154			13.0	207
2 (1)	71	11.0	165			13.7	229
2 (2)	71	11.0	165			13.7	229
Nov. 1 (1)	73	9.5	150	11.4	185	12.6	218
1 (2)	73	9.5	150	11.4	185	12.6	218
2 (1)	73	9.3	152	11.1	188	12.3	[illegible]
2 (2)	73	9.3	152	11.1	188	12.3	222
Dec. 1	146	18.0	307	21.5	378	23.7	449
2	155	18.0	325	22.0	403	24.2	480
Jan. 1	161	13.0	273	18.8	362	21.7	447
2	171	13.0	289	19.0	383	22.0	474
Feb. 1	150	11.0	256	15.8	335	18.2	412
2	150	10.5	256	14.8	332	17.0	405
Mar. 1	156	8.5	237	14.4	335	16.9	424
2	166	8.0	248	13.8	348	16.3	439
Apr. 1	156	5.5	213	11.2	313	13.7	401
2	156	4.5	205	10.1	303	12.2	386
May 1	120	0.0	140	6.4	217	8.4	294
2	128	0.0	150	5.5	226	7.4	302

* This table provides the co-ordinates of points A, B, C, and D in Figure 5.6 for each period.

FIGURE A4.1 MAXIMUM INTAKE PATTERN FOR EACH CALVING DATE.

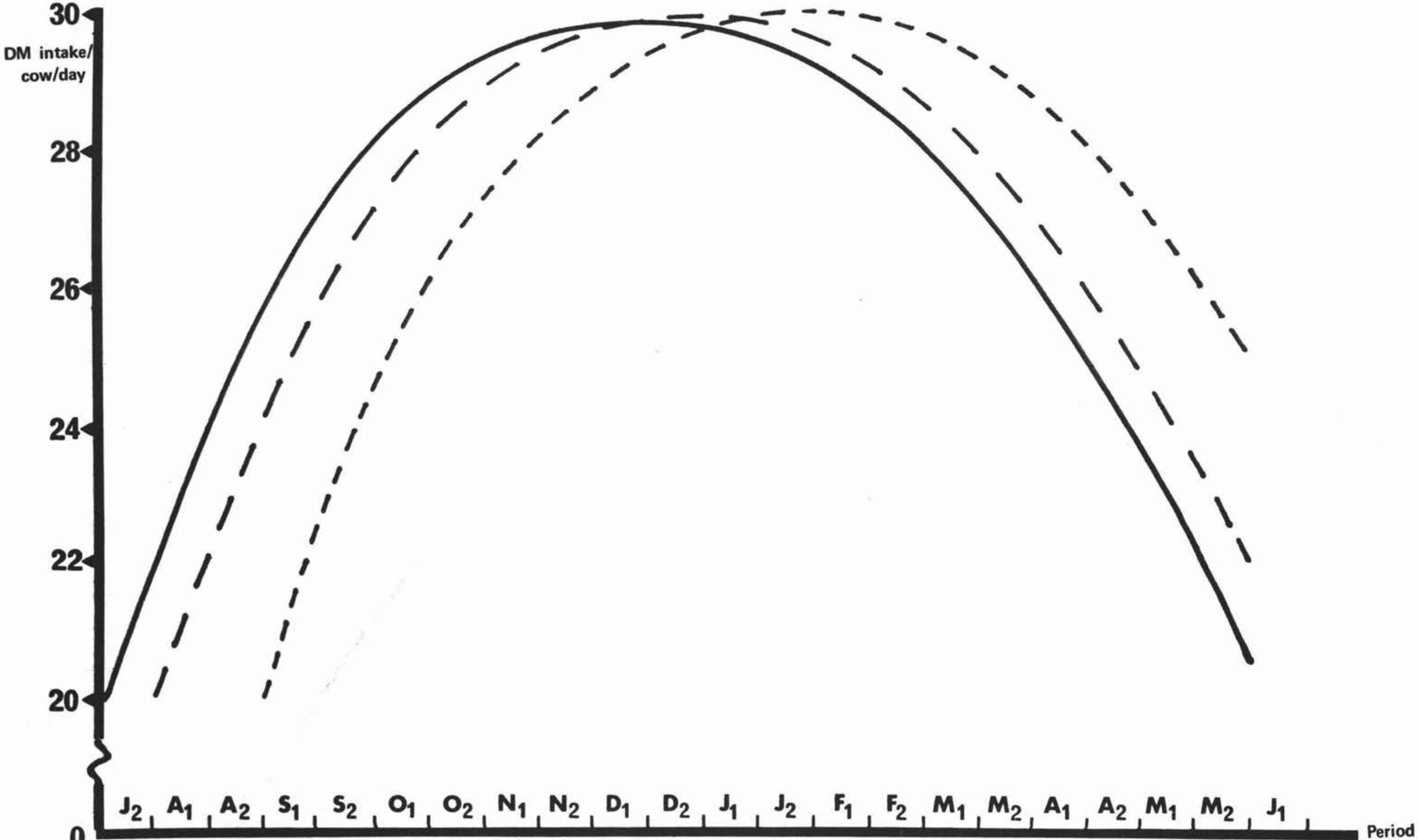
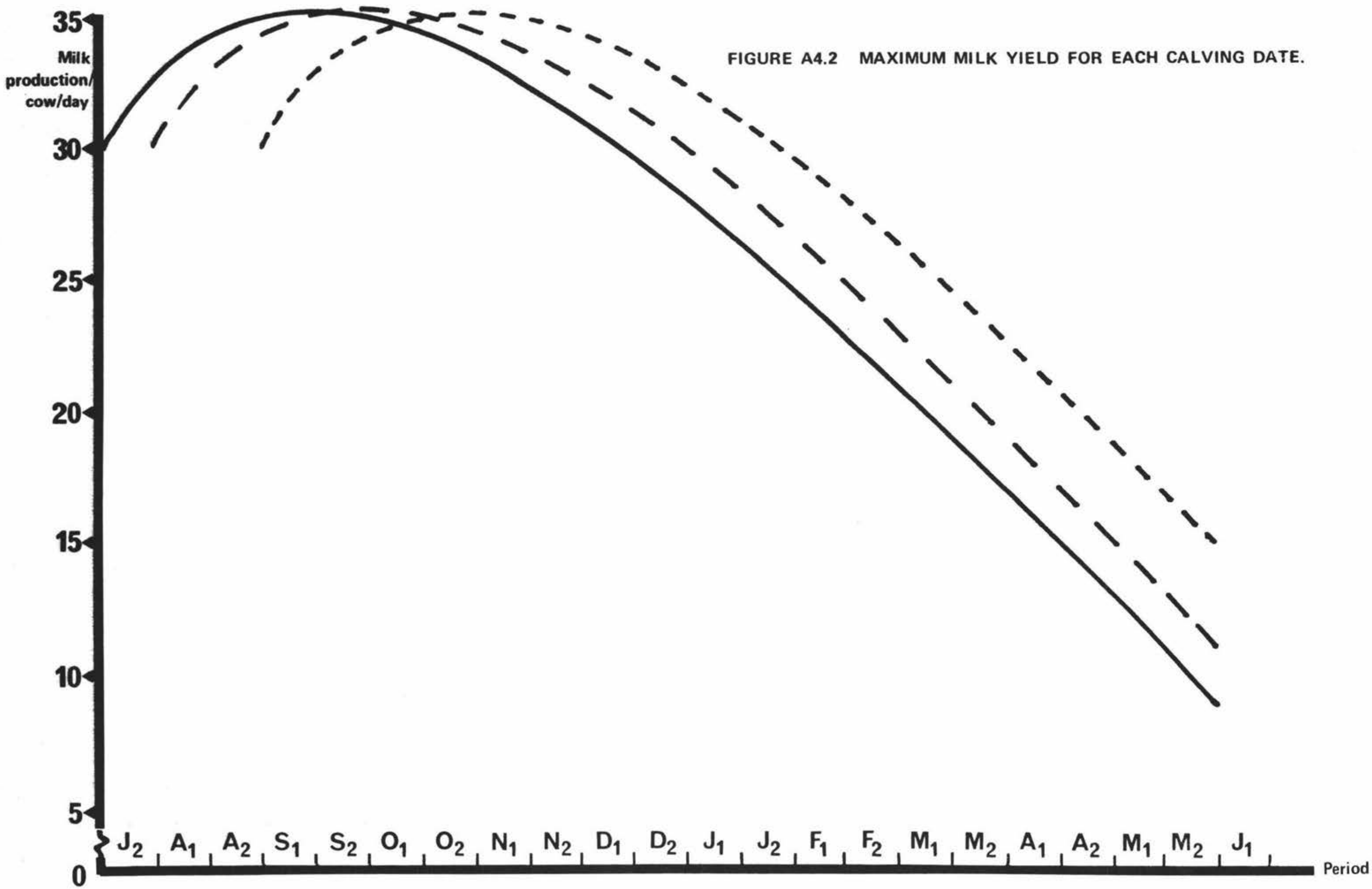


FIGURE A4.2 MAXIMUM MILK YIELD FOR EACH CALVING DATE.



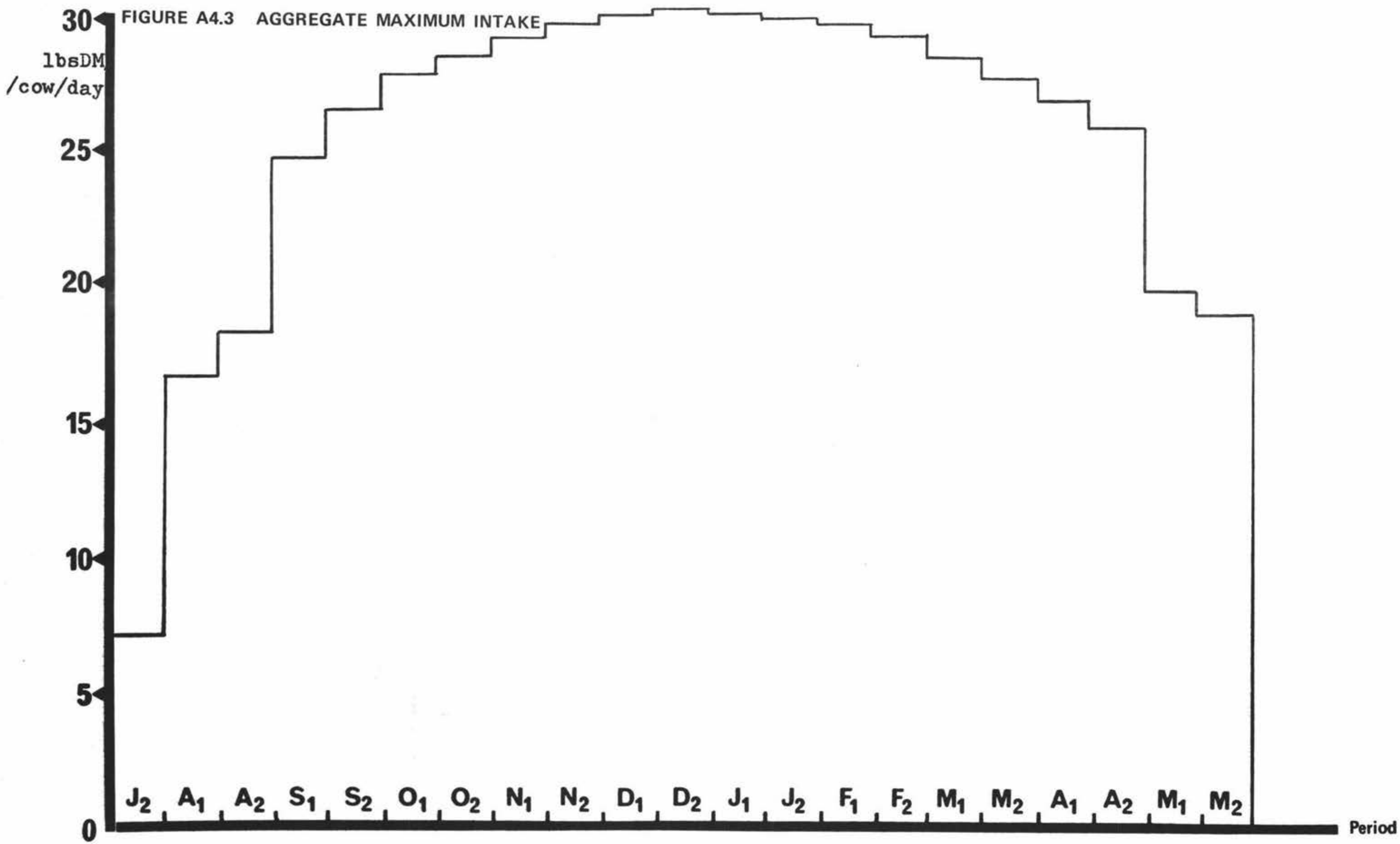


FIGURE A4.3 AGGREGATE MAXIMUM INTAKE
lbsDM /cow/day
30
25
20
15
10
5
0
J2 A1 A2 S1 S2 O1 O2 N1 N2 D1 D2 J1 J2 F1 F2 M1 M2 A1 A2 M1 M2
Period

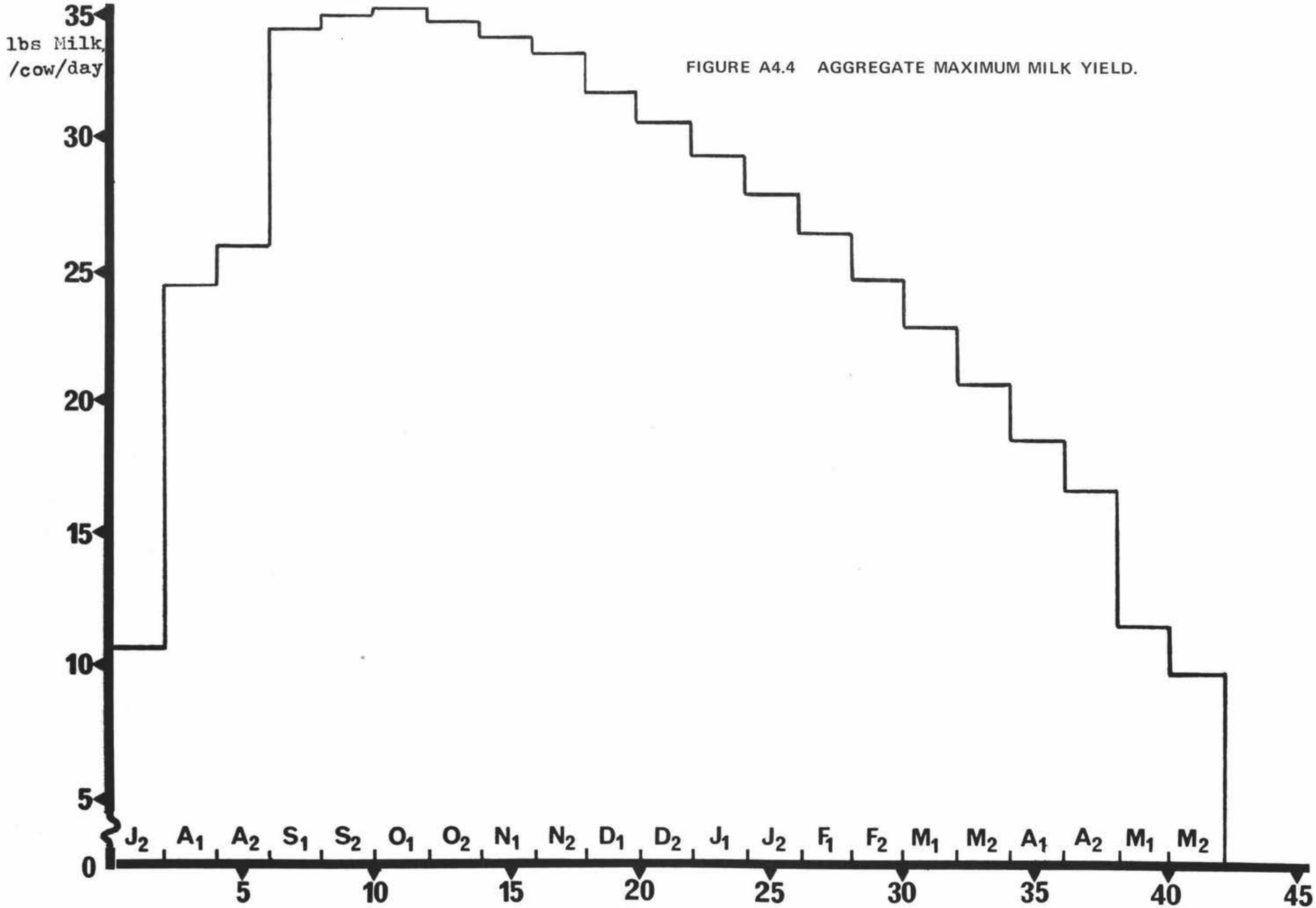
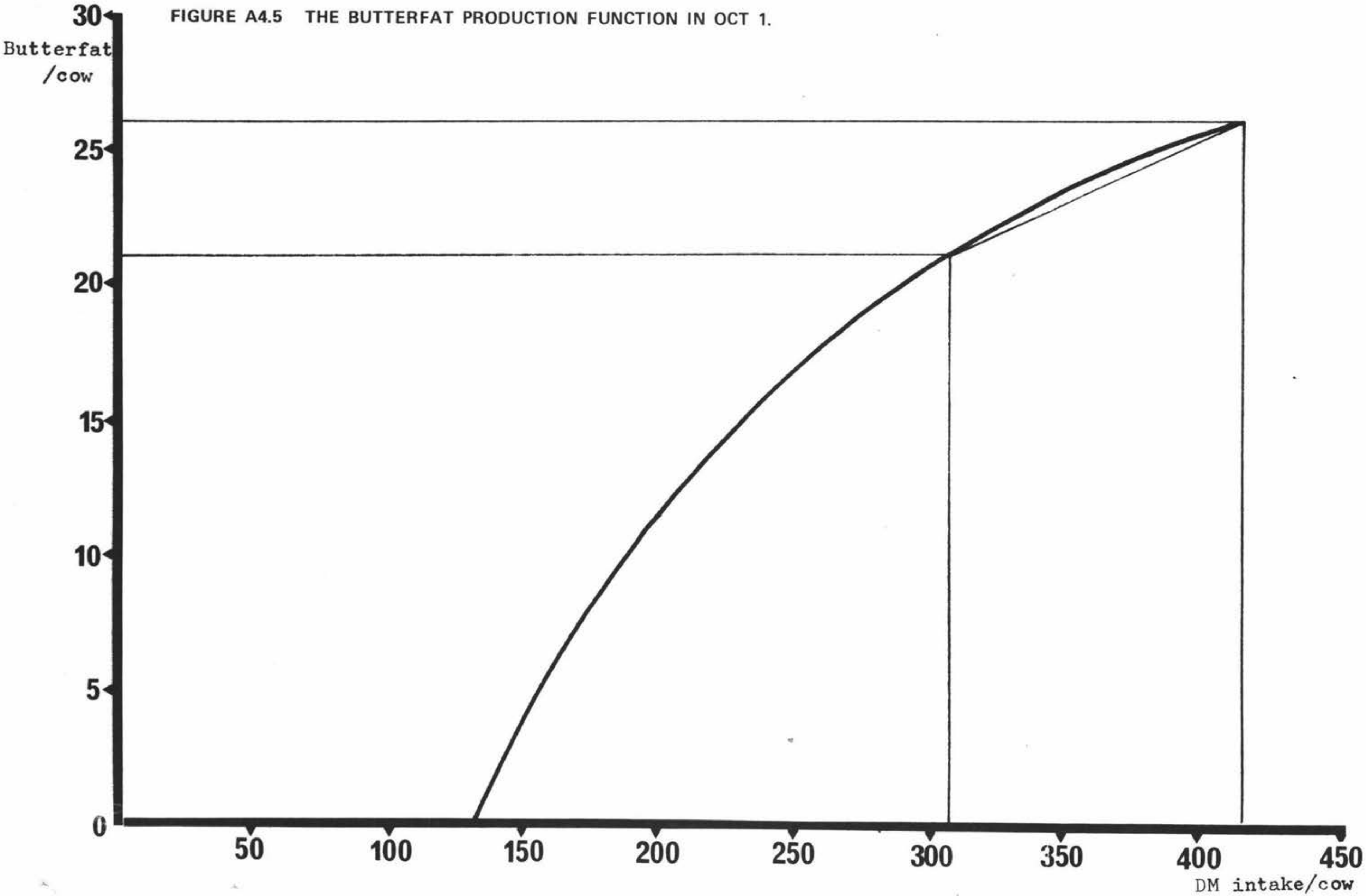


FIGURE A4.4 AGGREGATE MAXIMUM MILK YIELD.

FIGURE A4.5 THE BUTTERFAT PRODUCTION FUNCTION IN OCT 1.



APPENDIX 5

THE ANIMAL MODEL

A 5.1 THE BUTTERFAT PRODUCTION MATRIX

A representation of the LP matrix is contained in Figure A5.1.

(a) Restraints

Rows F_1 to F_m (m=28) are the feed reconciliation rows described in Section A3.2. Butterfat production in each period will be determined by the amount of dry matter supplied to the feed reconciliation rows.

The butterfat production restraints, R_1 to R_x (x=55) allow butterfat production to vary between predetermined limits in each period according to dry matter supply. In period t, Row R_t ensures that a minimum level of intake occurs. Row R_{t+1} allows actual butterfat production to vary between this minimum level and the level corresponding to maximum intake. In periods when dry cow requirements only must be met (June and JUL 1) only Row R_t is necessary. The BF row calculates total butterfat production which is supplied to the BF selling activity.

(b) Activities

Three dry cow activities ensure that feed requirements are met in June and JUL 1.

Sixty six butterfat production activities are also included in the matrix. The derivation of each activity is discussed in Section A4.2, Appendix 4.

A butterfat selling activity was used instead of valuing each butterfat production activity, as this enabled the number of data cards required for experimentation with the model at different stocking rates and butterfat prices to be considerably reduced.

(c) Input/output coefficients

In period t, a minimum intake of X_1 lbs DM, (adjusted for utilisation losses) must be available to produce the minimum level of BF/cow, (Y_1 lbs BF). Butterfat production is allowed to vary between Y_1 and Y_3 lbs BF/cow in period t. X_2 is the DM intake that is required for an output of Y_2 lbs BF/cow, hence $(X_2 - X_1)$ is the additional DM intake required for an extra $(Y_2 - Y_1)$ lbs BF/cow over the minimum output level. Similarly, $(X_3 - X_2)$ is the additional DM intake required for an extra $(Y_3 - Y_2)$ lbs BF/cow over the Y_2 output level. The appropriate butterfat production and dry matter intake coefficients for each period are obtained from Table A4.2 after adjusting the latter figures for utilisation losses. In this way then the three activities: P_{1t}, P_{2t} and P_{3t} represent a range of possible intake levels and corresponding BF production levels, expressed as a per cow basis, for period t.

In periods where both dry and lactating cow requirements occur, for example in August, the dry cow requirements are added to the minimum BF production requirement, (i.e., to X_1). The appropriate dry cow requirement coefficients are obtained from Table A4.1 after adjusting the figures for dry cow utilisation losses.

Figure A5.1 THE BUTTERFAT PRODUCTION MATRIX

	C_j			0	0	0		C
	B		. . .	P_{1t}	P_{2t}	P_{3t}	. . .	Sell BF
F_1	0	$\geq$						
.								
.								
F_t	0	$\geq$		X_1	(X_2-X_1)	(X_3-X_1)		
.								
.								
.								
F_m	0	$\geq$						
R_1								
.								
.								
.								
R_t	1	=		1				
R_{t+1}	0	$\geq$		-1	1	1		
.								
.								
.								
R_x								
BF		=		$-Y_1$	$-(Y_2-Y_1)$	$-(Y_3-Y_1)$		1

A 5.2 SUPPLEMENTARY FEEDING MATRIX

A representation of the LP matrix required to take into account the quality of hay and silage fed, as well as effects on intake, is shown in Figure A5.2.

(a) Restraints

Twenty-five maximum consumption rows impose a dry matter restriction on intake in any period. X_3 in period t is the appetite level of dry matter in that period.

Hay and silage reconciliation rows ensure that consumption of conserved grass products does not exceed production by the pasture model.

(b) Activities

Twenty-five silage feeding activities allow silage to be fed to lactating cows in each period. Thirty-one hay feeding activities allow hay to be fed to both dry and lactating cows throughout the year.

(c) Input/output coefficients

In period t, maximum butterfat production occurs when $P_{1t} = 1$ and $P_{3t} = 1$, (from Table A5.1). This corresponds to a dry matter intake level of $X_1 + (X_3 - X_1) = X_3$, which is the appetite level of intake.

The feeding of z lbs DM as har or silage will depress the appetite intake level by z lbs DM, and will supply dry matter equivalent in feeding value to only z' lbs of grass dry matter where:

$$z' = \frac{\text{ME content/lb hay or silage dry matter}}{\text{ME content/lb grass dry matter}}$$

FIGURE A5.2 THE SUPPLEMENTARY FEEDING MATRIX

	C_j			0	0	0		$-C_h$
	B		. . .	P_{1t}	P_{2t}	P_{3t}	. . .	Feed H or S period t. z lbs DM
F_1	0	≥						
.								
.								
.								
F_t	0	≥		X_1	(X_2-X_1)	(X_3-X_1)		$-z'$
.								
.								
.								
F_m	0	≥						
C_1								
.								
.								
.								
C_t	X_3	≥		X_1	(X_2-X_1)	(X_3-X_1)		z
.								
.								
.								
H or S REC	0	≥						z

APPENDIX 6

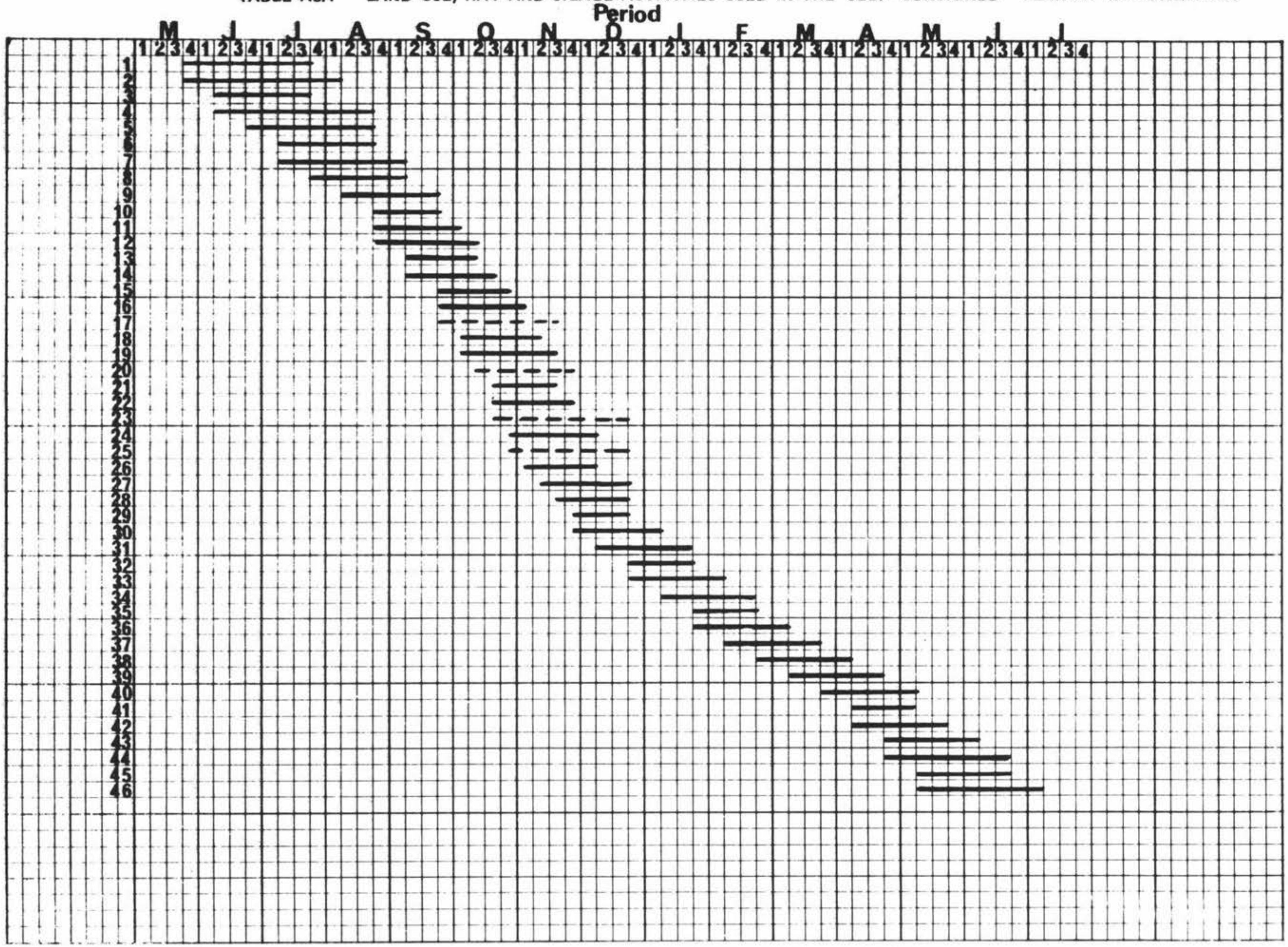
GRAZING MANAGEMENT, CONSERVATION PRACTICES AND RESULTING DRY MATTER PRODUCTION OF OPTIMAL PLANS AT STOCKING RATES OF 1.5 AND 2.0 COWS/ACRE

Tables A6.1 to A6.8 include every LAND USE, hay, silage and N activity included in each optimal plan at 1.5 and 2.0 cows/acre.

For each activity, moving from left to right along the line, the start of the line indicates the period in which the pasture was last grazed, while the end of the line indicates the period in which it is to be grazed next. The length of the line, therefore, represents the length of spell of an area of pasture corresponding to the activity level. Broken lines indicate hay or silage activities.

Where N activities are included in the optimum plan, all application rates are 50 lbs N/acre.

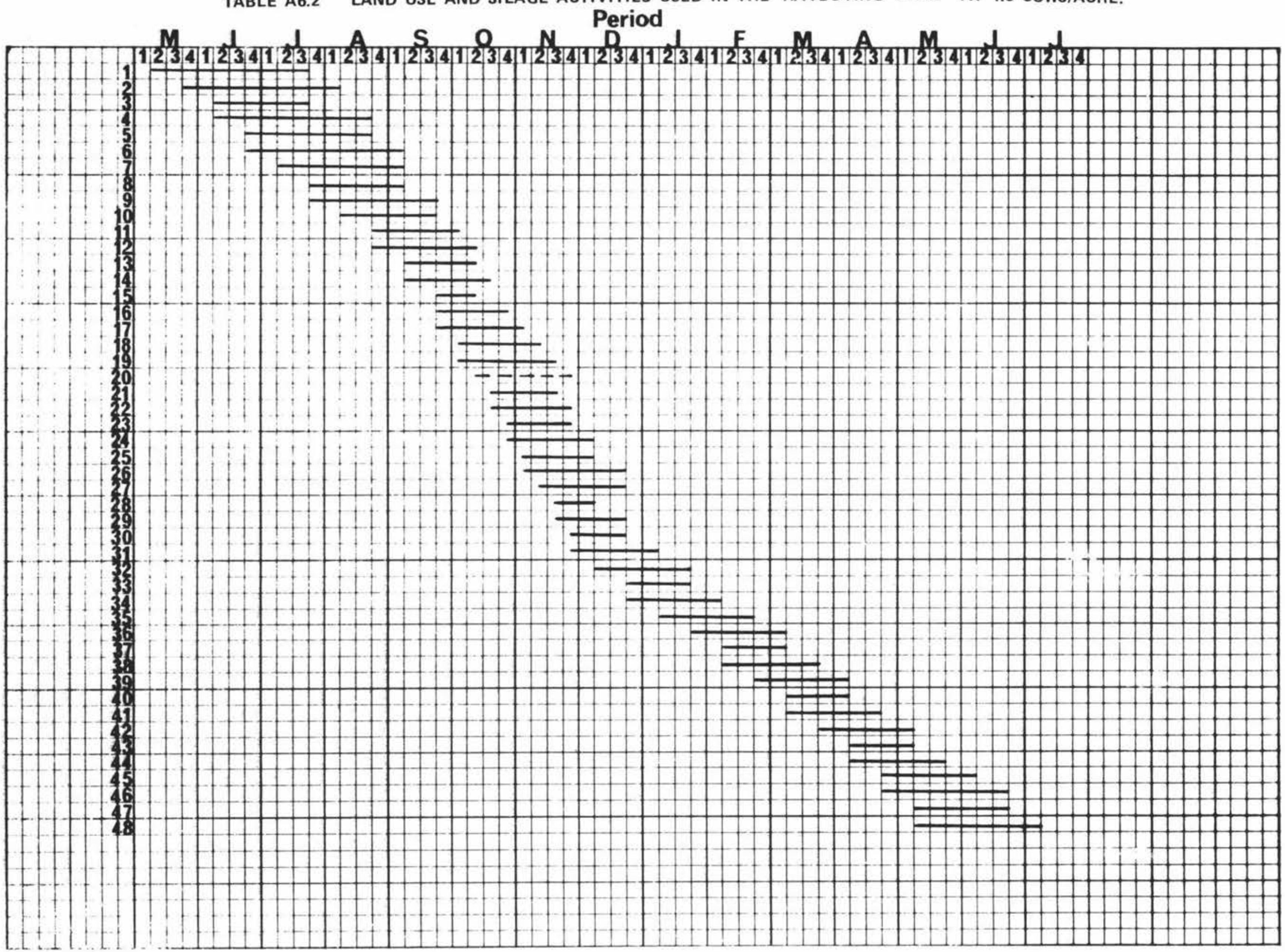
TABLE A6.1 LAND USE, HAY AND SILAGE ACTIVITIES USED IN THE 'SELF-CONTAINED' PLAN AT 1.5 COWS/ACRE.



LAND USE, HAY AND SILAGE ACTIVITIES

	Activity Level (acres)	Length of Spell (weeks)	Pasture Supply (lbs DM)	Hay Production (lbs DM)	Silage Production (lbs DM)
1	.030	8.7	24		
2	.264	11.0	317		
3	.220	6.5	143		
4	.019	11.0	27		
5	.278	8.8	334		
6	.093	6.7	84		
7	.096	8.8	134		
8	.251	6.6	276		
9	.264	6.5	396		
10	.128	4.3	128		
11	.210	6.0	357		
12	.052	7.1	114		
13	.157	4.9	243		
14	.188	6.0	395		
15	.207	5.0	393		
16	.126	6.0	315		
17	.058	8.2			194
18	.123	5.5	314		
19	.088	6.6	290		623
20	.209	6.5			
21	.014	4.3	28		
22	.121	5.4	321		
23	.053	9.3		217	
24	.120	6.0	366		
25	.087	8.2		329	
26	.126	4.9	277		
27	.123	6.0	338		
28	.160	4.9	312		
29	.025	3.9	36		
30	.305	6.1	717		
31	.246	6.7	467		
32	.147	4.4	176		
33	.301	6.5	512		
34	.305	6.3	488		
35	.017	4.1	17		
36	.377	6.2	566		
37	.301	6.3	437		
38	.322	6.5	419		
39	.377	6.5	490		
40	.301	6.5	391		
41	.028	4.3	28		
42	.294	6.5	412		
43	.239	6.6	275		
44	.138	8.7	179		
45	.14	6.5	126		
46	.189	8.7	208		

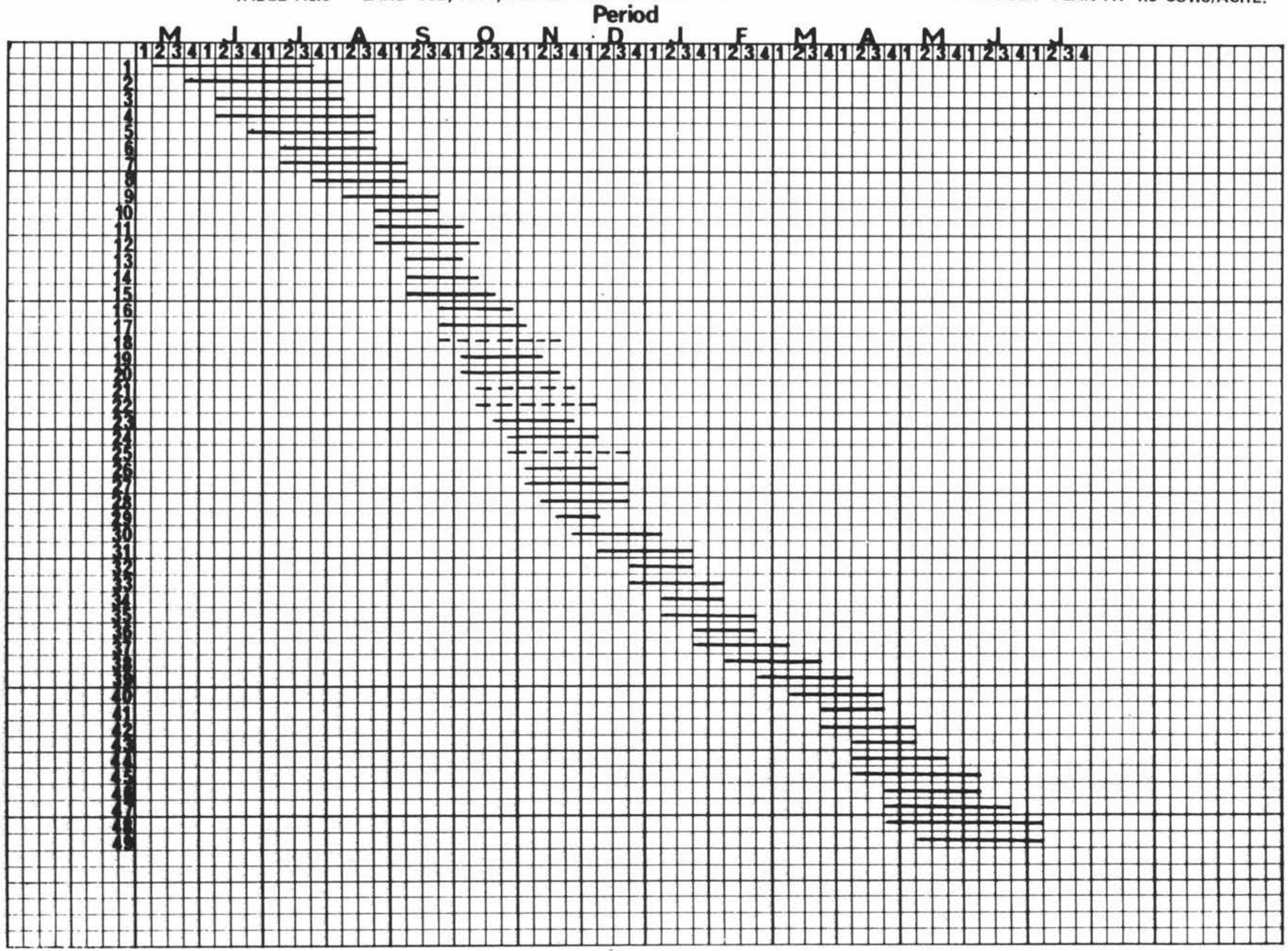
TABLE A6.2 LAND USE AND SILAGE ACTIVITIES USED IN THE 'HAYBUYING' PLAN AT 1.5 COWS/ACRE.



LAND USE AND SILAGE ACTIVITIES

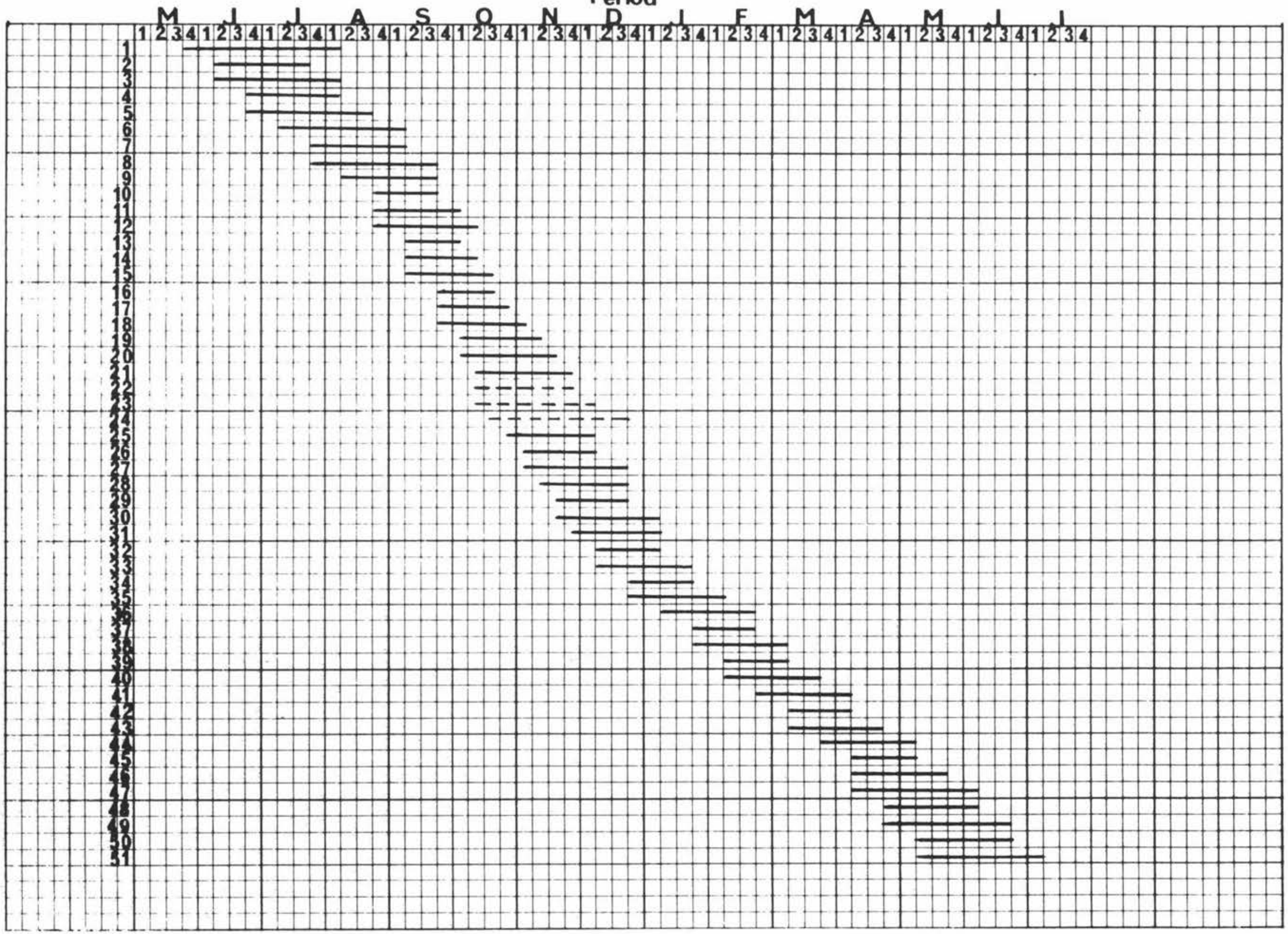
	Activity Level (acres)	Length of Spell (weeks)	Pasture Supply (lbs DM)	Silage Production (lbs DM)
1	.043	10.9	46	
2	.318	11.0	382	
3	.185	6.5	120	
4	.054	11.0	76	
5	.222	8.8	266	
6	.067	11.0	114	
7	.111	8.8	155	
8	.112	6.6	123	
9	.117	8.8	211	
10	.318	6.5	477	
11	.210	6.0	357	
12	.065	7.1	143	
13	.100	4.9	155	
14	.188	6.0	395	
15	.079	2.7	59	
16	.207	5.0	393	
17	.149	6.0	373	
18	.146	5.5	372	
19	.066	6.6	218	
20	.245	6.5		728
21	.081	4.3	162	
22	.107	5.4	284	
23	.048	4.3	96	
24	.159	6.0	485	
25	.047	4.9	213	
26	.052	7.1	161	
27	.146	6.0	402	
28	.073	2.7	66	
29	.074	4.9	144	
30	.077	3.9	112	
31	.322	6.1	757	
32	.329	6.7	625	
33	.016	4.4	19	
34	.332	6.5	564	
35	.322	6.3	575	
36	.346	6.2	519	
37	.031	4.1	30	
38	.301	6.3	437	
39	.322	6.5	419	
40	.024	4.4	19	
41	.353	6.5	459	
42	.301	6.5	391	
43	.028	4.3	28	
44	.318	6.5	445	
45	.239	6.6	275	
46	.113	8.7	147	
47	.175	6.5	158	
48	.111	8.7	122	

TABLE A6.3 LAND USE, HAY, SILAGE AND NITROGEN ACTIVITIES USED IN THE 'NITROGEN' PLAN AT 1.5 COWS/ACRE.



	LAND USE, HAY AND SILAGE ACTIVITIES					NITROGEN ACTIVITIES		
	Activity Level (acres)	Length of Spell (weeks)	Pasture Supply (lbs DM)	Hay Production (lbs DM)	Silage Production (lbs DM)	Activity Level (acres)	Pasture Supply (lbs DM)	Silage Production (lbs DM)
1	.113	10.9	122			.113	45	
2	.228	11.0	274					
3	.073	8.8	73					
4	.150	11.0	210					
5	.161	8.8	193					
6	.044	6.7	40					
7	.231	8.8	323			.231	134	
8	.113	6.6	124			.113	63	
9	.300	6.5	450			.196	127	
10	.110	4.3	110					
11	.140	6.0	238					
12	.106	7.1	233					
13	.121	3.8	121					
14	.081	4.9	126					
15	.143	6.0	300			.102	94	
16	.207	5.0	393					
17	.149	6.0	373					
18	.053	8.2			177	.053		48
19	.146	5.5	372					
20	.115	6.6	380					
21	.179	6.5			532			
22	.008	8.2		31				
23	.143	5.4	379					
24	.191	6.0	583					
25	.016	8.2		61				
26	.014	4.9	31					
27	.134	7.1	415					
28	.146	6.0	402					
29	.168	2.7	151					
30	.322	6.1	757					
31	.381	6.7	724					
32	.064	4.4	77					
33	.233	6.5	396					
34	.069	4.3	76					
35	.254	6.3	406					
36	.069	4.1	69					
37	.377	6.2	566					
38	.301	6.3	437					
39	.322	6.5	419					
40	.377	6.5	490					
41	.038	4.3	27					
42	.264	6.5	343					
43	.077	4.3	77					
44	.228	6.5	319			.188	126	
45	.017	8.7	26			.017	13	
46	.206	6.6	237					
47	.161	8.7	209			.161	95	
48	.047	10.9	60			.047	28	
49	.228	8.7	251					

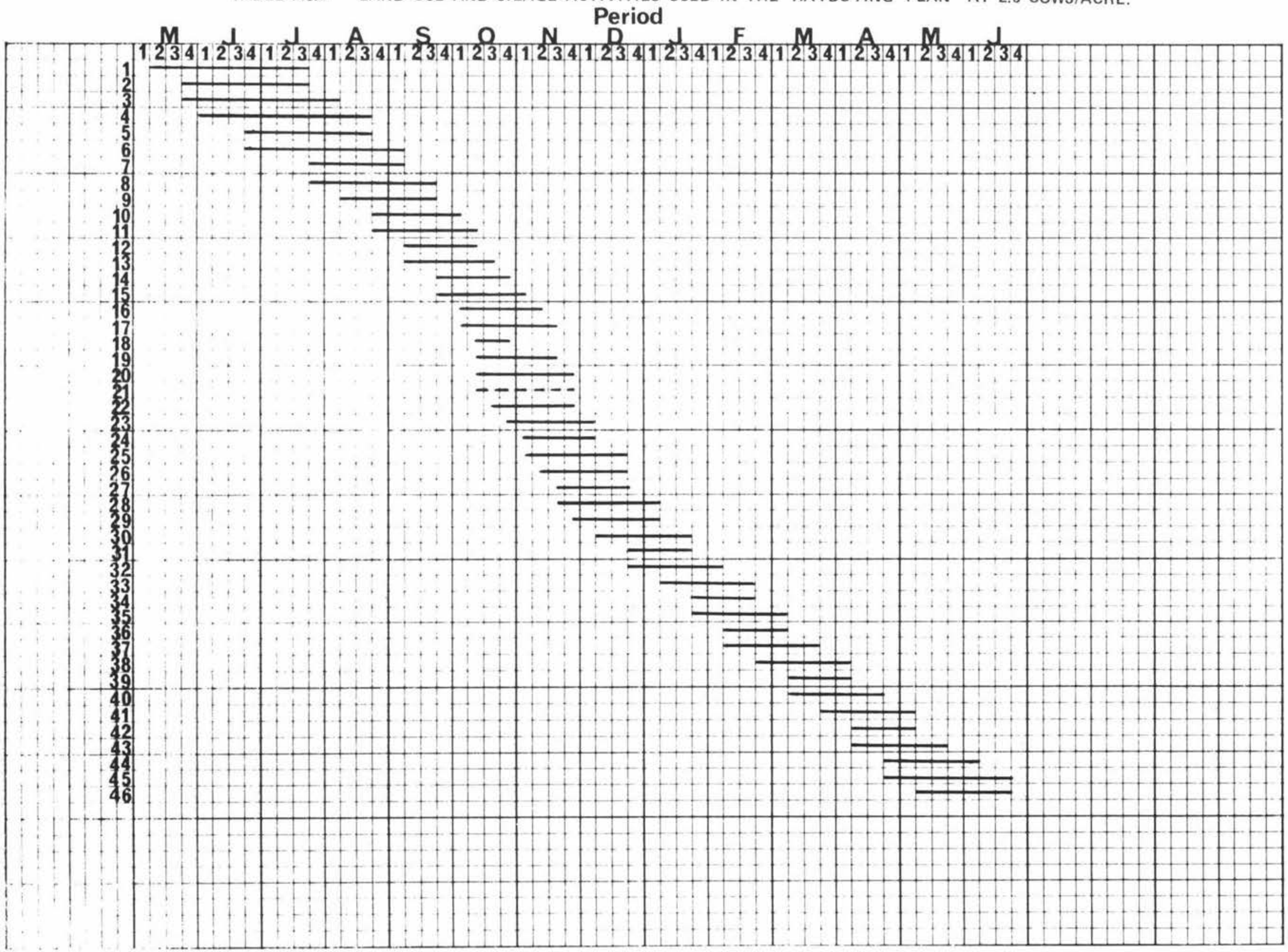
TABLE A6.4 LAND USE, HAY AND SILAGE ACTIVITIES USED IN THE 'SELF-CONTAINED' PLAN AT 2.0 COWS/ACRE.



LAND USE, HAY AND SILAGE ACTIVITIES

	Activity Level (acres)	Length of Spell (weeks)	Pasture Supply (lbs DM)	Hay Production (lbs DM)	Silage Production (lbs DM)
1	.245	11.0	291		
2	.274	6.5	178		
3	.023	8.8	23		
4	.014	6.6	11		
5	.370	8.8	444		
6	.074	8.8	104		
7	.240	6.6	264		
8	.034	8.8	61		
9	.282	6.5	423		
10	.176	4.3	175		
11	.154	6.0	262		
12	.041	7.1	90		
13	.080	3.8	80		
14	.161	4.9	250		
15	.072	6.0	151		
16	.165	3.8	215		
17	.193	5.0	367		
18	.133	6.0	333		
19	.131	5.5	334		
20	.103	6.6	340		
21	.106	6.5	339		
22	.055	6.5			163
23	.042	8.2		161	
24	.238	9.3		975	
25	.193	6.0	589		
26	.043	4.9	95		
27	.091	7.1	282		
28	.131	6.0	360		
29	.041	4.9	80		
30	.061	7.1	159		
31	.160	6.1	376		
32	.052	4.4	73		
33	.226	6.7	429		
34	.179	4.4	215		
35	.321	6.5	546		
36	.274	6.3	438		
37	.099	4.1	99		
38	.306	6.2	459		
39	.090	4.1	86		
40	.232	6.3	336		
41	.373	6.5	485		
42	.019	4.4	15		
43	.376	6.5	489		
44	.232	6.5	302		
45	.076	4.3	76		
46	.245	6.5	343		
47	.071	8.7	107		
48	.226	6.6	260		
49	.150	8.7	195		
50	.234	6.5	211		
51	.074	8.7	81		

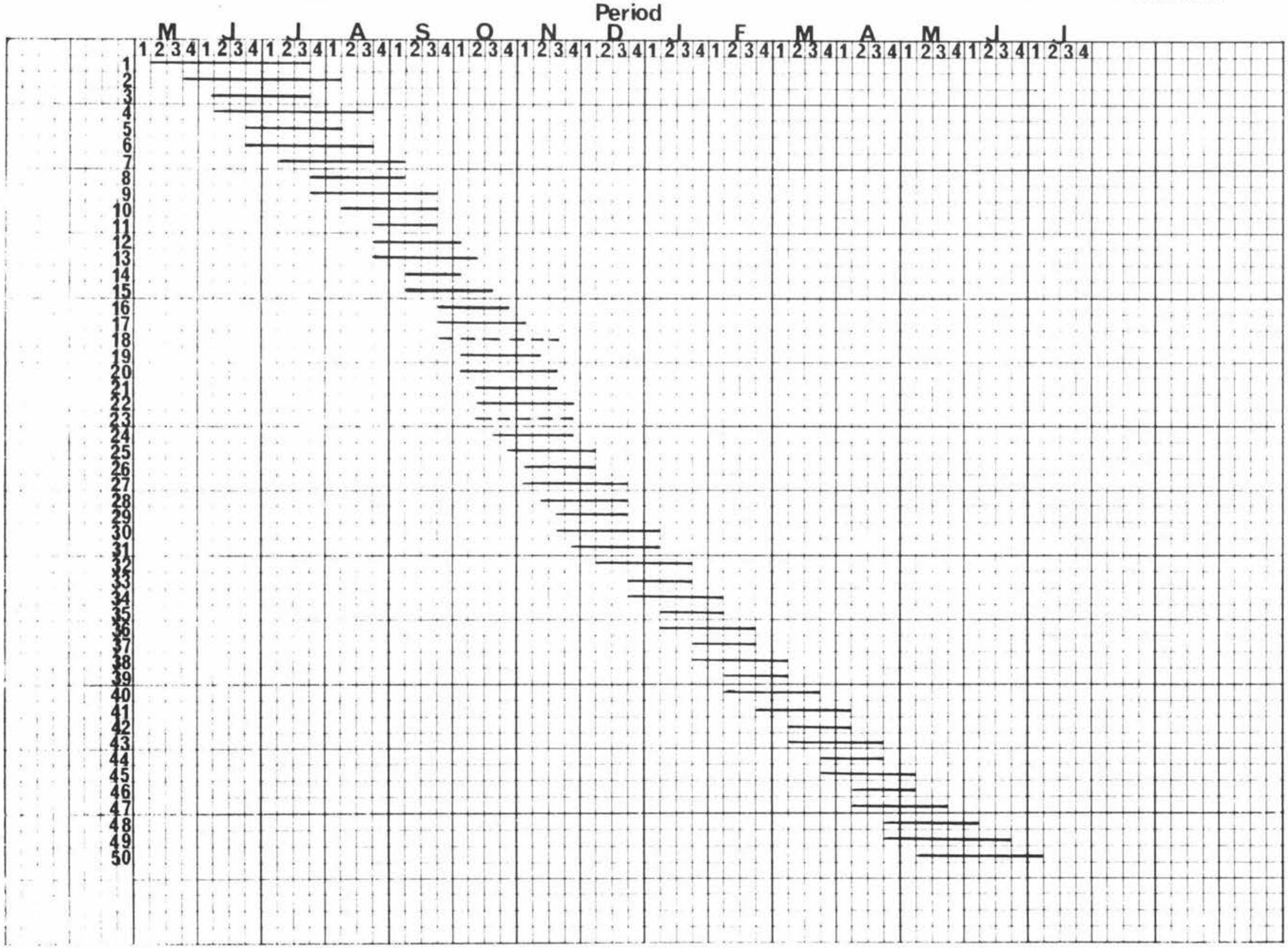
TABLE A6.5 LAND USE AND SILAGE ACTIVITIES USED IN THE 'HAYBUYING' PLAN AT 2.0 COWS/ACRE.



LAND USE AND SILAGE ACTIVITIES

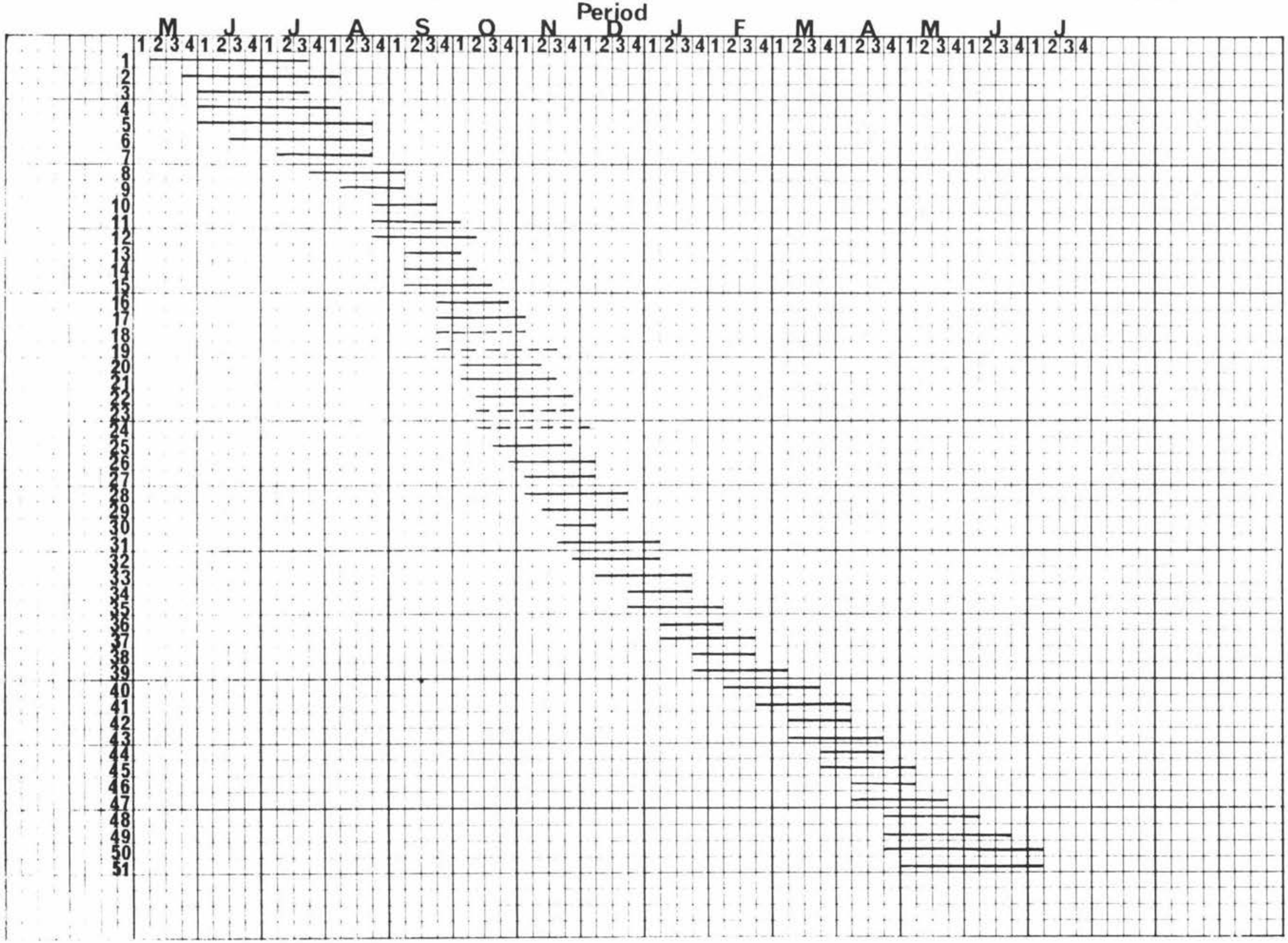
	Activity Level (acres)	Length of Spell (weeks)	Pasture Supply (lbs DM)	Silage Production (lbs DM)
1	.203	10.9	219	
2	.003	8.7	2	
3	.312	11.0	374	
4	.318	11.0	445	
5	.006	8.8	7	
6	.157	11.0	267	
7	.159	6.6	175	
8	.047	8.8	85	
9	.312	6.5	468	
10	.269	6.0	457	
11	.055	7.1	121	
12	.142	4.9	220	
13	.175	6.0	368	
14	.195	5.0	371	
15	.164	6.0	410	
16	.190	5.5	485	
17	.079	6.6	261	
18	.014	2.2	9	
19	.061	5.5	156	
20	.010	6.5	32	
21	.112	6.5		333
22	.175	5.4	464	
23	.209	6.0	638	
24	.106	4.9	233	
25	.058	7.1	180	
26	.190	6.0	523	
27	.099	4.9	193	
28	.041	7.1	107	
29	.297	6.1	698	
30	.315	6.7	599	
31	.055	4.4	66	
32	.292	6.5	496	
33	.338	6.3	541	
34	.032	4.1	32	
35	.338	6.2	507	
36	.066	4.1	63	
37	.226	6.3	328	
38	.370	6.5	481	
39	.057	4.4	46	
40	.347	6.5	451	
41	.226	6.5	294	
42	.112	4.3	112	
43	.315	6.5	444	
44	.318	6.6	366	
45	.029	8.7	38	
46	.134	6.5	121	

TABLE A6.6 LAND USE, SILAGE AND NITROGEN ACTIVITIES USED IN THE 'NITROGEN' PLAN AT 2.0 COWS/ACRE.



	LAND USE AND SILAGE ACTIVITIES				NITROGEN ACTIVITIES		
	Activity Levels (acres)	Length of Spell (weeks)	Pasture Supply (lbs DM)	Silage Production (lbs DM)	Activity Level (acres)	Nitrogen Pasture (lbs DM)	Nitrogen Silage (lbs DM)
1	.128	10.9	138		.128	51	
2	.281	11.0	337				
3	.038	6.5	25				
4	.179	11.0	251				
5	.046	6.6	37				
6	.169	8.8	203				
7	.159	8.8	223		.159	92	
8	.131	6.6	144		.131	73	
9	.035	8.8	63		.035	27	
10	.327	6.5	491		.327	213	
11	.059	4.3	59		.059	35	
12	.138	6.0	235		.138	106	
13	.151	7.1	332		.151	130	
14	.122	3.8	122				
15	.168	6.0	353		.168	155	
16	.190	5.0	361		.190	148	
17	.144	6.0	360		.144	125	
18	.087	8.2		290	.087		78
19	.148	5.5	377		.148	110	
20	.112	6.6	370		.112	90	
21	.010	5.5	26		.010	7	
22	.012	6.5	38		.012	10	
23	.129	6.5		383	.129		118
24	.168	5.4	445				
25	.190	6.0	580		.190	118	
26	.099	4.9	218				
27	.045	7.1	140				
28	.148	6.0	407				
29	.180	4.9	351				
30	.030	7.1	78				
31	.309	6.1	726				
32	.289	6.7	549				
33	.092	4.4	110				
34	.281	6.5	478				
35	.084	4.3	92				
36	.255	6.3	408				
37	.097	4.1	97				
38	.283	6.2	425				
39	.153	4.1	145				
40	.212	6.3	307				
41	.352	6.5	458				
42	.086	4.4	69				
43	.350	6.5	455				
44	.081	4.3	57				
45	.131	6.5	170				
46	.157	4.3	157		.157	85	
47	.281	6.5	393		.281	188	
48	.217	6.6	250		.217	117	
49	.215	8.7	280		.215	127	
50	.159	8.7	175				

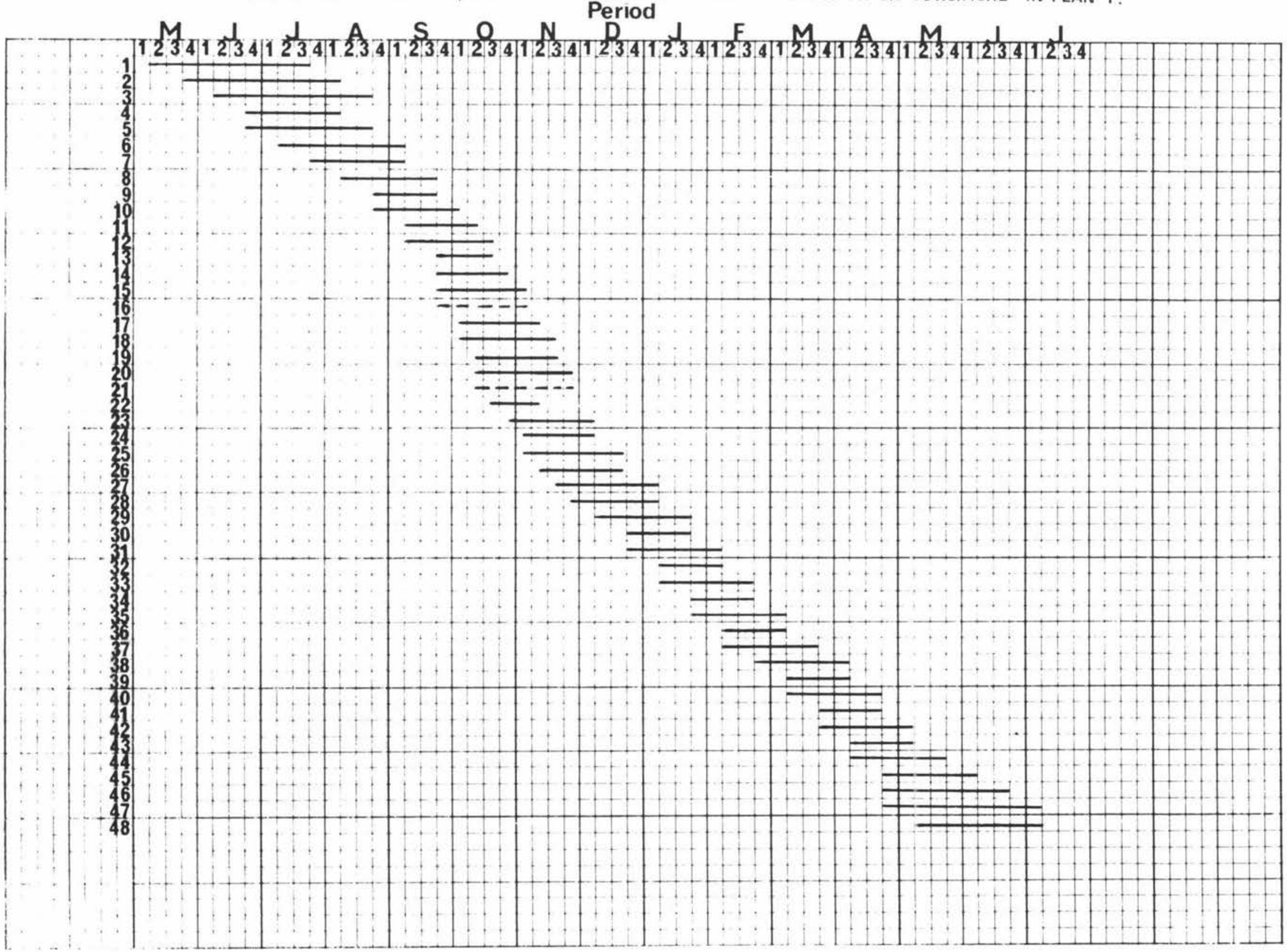
TABLE A6.7 LAND USE, HAY, SILAGE AND NITROGEN ACTIVITIES SELECTED AT 1.5 COWS/ACRE IN PLAN 'D'.



	LAND USE, HAY AND SILAGE ACTIVITIES					NITROGEN ACTIVITIES		
	Activity Level (acres)	Length of Spell (weeks)	Pasture Supply (lbs DM)	Silage Production (lbs DM)	Hay Production (lbs DM)	Activity Level (acres)	Pasture Production (lbs DM)	Silage Production (lbs DM)
1	.172	10.9	186			.172	69	
2	.278	11.0	334			.278	94*	
3	.021	6.5	14					
4	.007	8.8	7					
5	.135	11.0	189					
6	.161	8.8	193					
7	.226	6.7	203			.226	88	
8	.193	6.6	212			.193	108	
9	.285	4.4	200			.285	125	
10	.433	4.3	433			.433	255	
11	.076	6.0	129			.076	59	
12	.013	7.1	29			.013	11	
13	.170	3.8	170					
14	.177	4.9	274			.056	43	
15	.130	6.0	273			.130	120	
16	.207	5.0	393					
17	.110	6.0	275			.110	96	
18	.042	6.0		95		.042		33
19	.073	8.2		243		.073		66
20	.146	5.5	372					
21	.100	6.6	330			.059	47	
22	.010	6.5	32					
23	.103	6.5		306				
24	.077	8.2			295			
25	.130	5.4	345					
26	.207	6.0	631					
27	.018	4.9	40					
28	.134	7.1	415					
29	.146	6.0	402					
30	.103	2.7	93					
31	.070	7.1	182					
32	.244	6.1	573					
33	.405	6.7	770					
34	.026	4.4	31					
35	.254	6.5	432					
36	.047	4.3	52					
37	.268	6.3	429					
38	.151	4.1	151					
39	.280	6.2	420					
40	.301	6.3	436					
41	.418	6.5	543					
42	.032	4.4	26					
43	.248	6.5	322					
44	.082	4.3	57					
45	.219	6.5	285					
46	.173	4.3	173			.173	93	
47	.278	6.5	389			.278	186	
48	.163	6.6	187			.163	88	
49	.161	8.7	209			.161	95	
50	.006	10.9	8			.006	4	
51	.220	8.7	242			.220	86	

* Of the .278 acres to which N is applied, .047 acres receive a dressing of 100 lbs N/acre which produced a pasture response of 25 lbs DM.

TABLE A6.8 LAND USE, SILAGE & NITROGEN ACTIVITIES SELECTED AT 2.0 COWS/ACRE IN PLAN 'I'.



	LAND USE AND SILAGE ACTIVITIES				NITROGEN ACTIVITIES		
	Activity Level (acres)	Length of Spell (weeks)	Pasture Supply (lbs DM)	Silage Production (lbs DM)	Activity Level (acres)	Pasture Supply (lbs DM)	Silage Production (lbs DM)
1	.150	10.9	162		.150	60	
2	.213	11.0	256		.213	64	
3	.217	11.0	304				
4	.085	6.6	68				
5	.125	8.8	150				
6	.210	8.8	294		.210	122	
7	.150	6.6	165		.150	84	
8	.298	6.5	447		.298	194	
9	.154	4.3	154		.154	91	
10	.187	6.0	318		.187	144	
11	.199	4.9	308		.199	153	
12	.161	6.0	338		.161	148	
13	.011	3.8	14		.011	7	
14	.189	5.0	359		.189	147	
15	.144	6.0	360		.144	125	
16	.109	6.0		245	.109		85
17	.082	5.5	209		.082	61	
18	.105	6.6	347		.105	84	
19	.019	5.5	48		.019	14	
20	.123	6.5	394		.123	98	
21	.054	6.5		160	.054		39
22	.172	3.3	215				
23	.192	6.0	586		.192	119	
24	.134	4.9	295				
25	.119	7.1	369				
26	.254	6.0	699				
27	.124	7.1	322				
28	.177	6.1	416				
29	.326	6.7	619				
30	.038	4.4	46				
31	.335	6.5	570				
32	.015	4.3	17				
33	.286	6.3	458				
34	.009	4.1	9				
35	.355	6.2	533				
36	.040	4.1	38				
37	.310	6.3	450				
38	.295	6.5	384				
39	.178	4.4	142				
40	.217	6.5	282				
41	.306	4.3	214				
42	.004	6.5	5				
43	.260	4.3	260		.260	140	
44	.213	6.5	298		.213	143	
45	.217	6.6	250		.217	117	
46	.210	8.7	273		.210	124	
47	.096	10.9	123		.096	58	
48	.114	8.7	125				

APPENDIX 7

DERIVATION OF PHOSPHATE MAINTENANCE REQUIREMENTS

An average annual pasture utilisation figure is derived from Table 4.5 for each stocking rate. Consequently, utilisation is assumed to be 82 percent at one cow per acre and 88 percent at 1.5 cows per acre. The phosphorus maintenance requirement for plan Y(1) 1/ may be derived as follows:

1. Losses of Phosphorus by fixation

A P output of 38 lbs P per acre per year is required at a pasture production level of 12,027 lbs dry matter per acre per year. This requires an annual P input of 54 lbs per acre per year 2/. Consequently, the amount of P lost by fixation is 16 lbs per acre per year.

2. Losses of P in Animal products

(i) Animal sales

P contained in animals sold off the farm is assumed to be 11.2 lbs P per 1,400 lbs live weight, (i.e., 0.8 percent P content). It is assumed that 20 percent of the herd is culled each year, and 66 percent of calves are sold, (90 percent calving, 33 percent calves retained). The average weight of a Jersey cow and calf is assumed to be 800 and 50 lbs live weight respectively.

Therefore, P contained in animals sold off the farm plan Y(1)

$$= \left(\frac{1}{5} \times 800 + \frac{6}{10} \times 50\right) \times .008 = 1.5 \text{ lbs P per acre}$$

(ii) Butterfat sales

The sale of 450 lbs butterfat is assumed to represent a P loss to the farm equivalent to one cwt. of superphosphate.

The sale of 1 lb butterfat, therefore, represents a loss of .025 lbs P 3/.

Losses of P in milk sales in plan Y(1) therefore are

394.3 x .025 = 9.9 lbs P per acre

Therefore Total P contained in animal products sold off farm

= 9.9 + 1.5

= 11.4 lbs per acre

1/ Summarised in Table 7.1.

2/ Summarised in Figure 7.2.

3/ The Phosphorus content of superphosphate is 10 percent P.

3. Losses of P contained in Dung

Total phosphorus output = 38 lbs P per acre per year.

Pasture utilisation in plan Y(1) is assumed to be 82 percent. Consequently, .82 x 38 = 31.2 lbs P per acre is ingested by grazing animals and 6.8 lbs per acre returns directly to the soil via decomposed herbage.

As 11.4 lbs P per acre is removed in animal products, the annual P content of dung is 19.8 lbs P per acre. It is assumed that 10 percent of this, 2 lbs P/acre, is lost outside the grazing area so that 17.8 lbs P per acre returns to the soil in dung.

4. Losses of P in hay sales

It is assumed that the P content of hay is .33 percent. Therefore, losses of P in hay sales in plan Y(1) are:

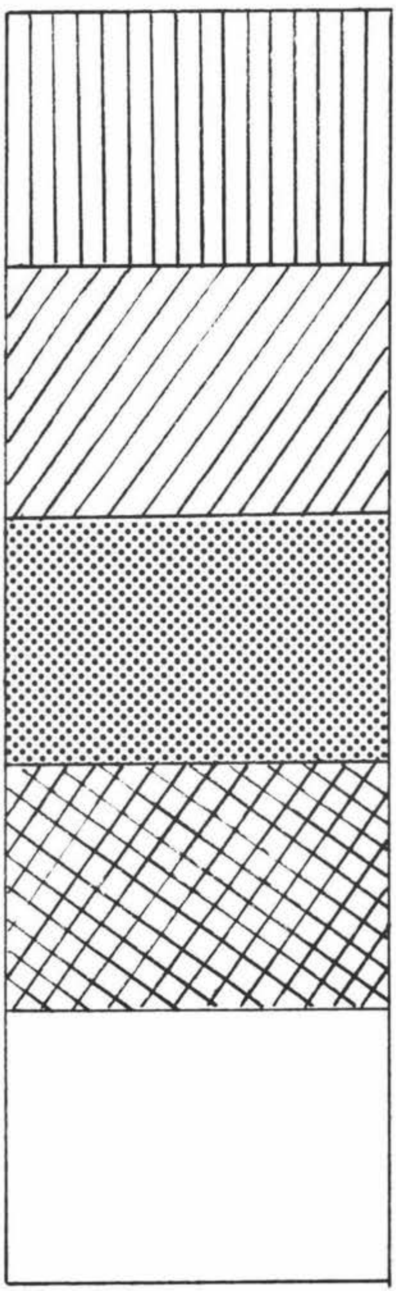
.0033 x 1064 = 3.5 lbs P per acre.

5. Summary of P losses: Plan Y(1)

		(lbs)
Fixation		16.0
Animal products		
Animal sales	1.5	
Butterfat	9.9	11.4
Dung voided off pasture		2.0
Hay sales		3.5
TOTAL		32.9

Total annual P loss from the grazing area for plan Y(1) is estimated at 32.9 lbs P per acre; this is equivalent to 2.9 cwt of superphosphate.

APPENDIX EIGHT KEY TO DRY MATTER PRODUCTION AND CONSUMPTION PROFILES



MEAL

HAY

SILAGE

N PRODUCED GRASS

PASTURE

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