EVALUATION OF ALTERNATIVE DAIRY FARM MANAGEMENT PRACTICES USING A SIMULATION MODEL

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

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1994

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ABSTRACT

New Zealand dairy farming is known worldwide for its on-farm efficiency, particularly for being one of the world's most cost-effective milk producers. New Zealand farmers' attempts to minimize costs by aiming to match the pattern of pasture growth with animal requirements. However, a more even production through the year may lower factory operating costs, would reverse the tendency to increase peak milk production during spring, and allow fresh products and products with a higher added value to be supplied all year round. For this reason a differential payment for the peak production periods will be introduced locally by Tui Milk Products Ltd.

On-farm efficiency is likely to be affected by changes to the payment system. In this study practices under the new payment system were evaluated. From among the large number of practices affecting dairy farm productivity, calving and drying off dates, stocking rate, supplementary feeding and nitrogen fertiliser, were identified as important variables in the design of alternative management systems. The variables were manipulated within a whole farm system, giving production and financial responses.

A computer simulation model, (UDDER), was used in a case-study approach to evaluate management alternatives for farms which supply the local dairy company. The effects of changes in those variables on the system's physical and financial parameters were monitored. Improvements in gross margins were achieved in the model by changing calving and drying off dates, improving the match of animal requirements with pasture production. As stocking rate was increased, so did gross margin improve, giving better feed utilization and hence lower herbage losses. The above changes have also been combined with changes in supplementary feeding and nitrogen fertiliser.

The manipulation of calving and drying off dates, stocking rate, supplements fed, and nitrogen fertiliser applied, increase total milk production within the range 4% to 12%, and gross margins were increased within the range 6% to 22%, while peak production was affected by only 1% to 3% for the "improved" strategies for all farms. Hence, the potential to shift a proportion of total milk production into shoulder months, profitably, is small.

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CHAPTER 1

INTRODUCTION

New Zealand dairy farming is known worldwide for its on-farm efficiency, particularly for being one of the world's most cost-effective milk producers. Almost all the milk is manufactured into dairy products for export (Holmes, 1987). About 92% of farms throughout New Zealand supply milk to dairy factories on a seasonal basis (seasonal-supply dairy farms). New Zealand farmers attempt to minimize costs by aiming to match the pattern of pasture growth with animal requirements.

A typical feed flow throughout the year on a seasonal-supply dairy farm with a peak of milk production during spring is summarised as follows: herds calve in a concentrated period in late winter-early spring. During spring, the highest pasture growth rates match or exceed the peak milk production requirements of the herd (October-November). From late spring until autumn, as pasture growth decreases, cows are fed less. During the winter months the cows are dry with lower feed requirements.

The industry's cooperative structure allows its produce to be marketed globally. In fact, New Zealand, as a supplier of dairy products to the international market, plays a significant role, supplying nearly 25 per cent of all trade (Paul, 1982; NZDB, 1993). However, on-farm efficiency can be offset by lower factory efficiency. Greater levels of efficiency may be achieved by an improved utilization of factory capacity.

Implementing a differential payment system, reflecting the marginal value of milk, provides market signals to suppliers. A differential payment encourages producers to choose management alternatives that will maximise on-farm and factory processing efficiency. Accordingly, the local dairy cooperative, Tui Milk Products, (TMP) has established the following objectives for a future payment structure:

- to maximise the total payout to suppliers;
- to provide market signals to suppliers of the real value of milk supplied to the company;
- to be concise and easily understood by the suppliers; and
- to ensure a reasonable flow of cash to suppliers through the season.

The main purpose of the company payment system is to give market signals to company suppliers of the real value of the milk supplied. The company expects that, through differential seasonal payments, farmers will shift their supply patterns in order to improve processing efficiency resulting in higher net returns to the farmer.

1.1. Problem statement

As a result of the peak milk production in spring, dairy companies have developed a high processing capacity. On average, only 55% of its total capacity is being utilized throughout other times of the year, that is, during summer, autumn and winter when utilization of factory capacity is low due to the lower levels of milk production. This low factory utilization increases the average cost of processing the milk. Hence, on-farm efficiency is offset by lower factory efficiency (Parker, 1994). For example, TMP processed 720 million litres of milk in the 1992/93 season, an increase of 2% in the total milk-flow over the previous season. The increased milk-flow came from conversion of dry-stock farms into dairying and from increased production from existing farms. In order to accommodate future increases in milk-flow, TMP will relocate its plant and expand its processing capacity by 800,000 litres, giving a total processing capacity of 5.5 million litres per day in 1995. Improved efficiency could have been achieved by a better supply pattern of milk to the processing plants, rather than by increased capacity using extra capital investment.

A price differential is a financial incentive to off-peak milk production, and may necessitate a change in management practices. From the changes in payout the company expects to increase company payout, and hence all supplier returns by an extra 5.08 cents per kilogram of milksolids on the payout to all suppliers. This is an added advantage because by attracting milk during the off-peak period, the company will utilise its assets more efficiently, where much of the milk can be manufactured into products offering better returns.

Improved efficiency of processing seems a likely result from a better spread of milk supply. However, the new payment system needs to be evaluated at both biological and financial levels. Hence, the implementation of the new payment should be undertaken with caution, as the shift in supply patterns may result in an increase in the initial on-farm costs of production.

An important problem that a farmer faces, is identifying optimum management practices under the new payment system. Changing production practices such as feeding, pasture conservation, fertiliser applications, reproductive management, etc., may result in increased costs as moves towards off-peak milk production are implemented. Hence, at the farmer level, the evaluation of alternative management practices can guide the farmer to modify the management of the farm.

1.2. Hypothesis

Based on the above information the following hypothesis was formulated: "that TMP suppliers can adapt to the new payment system to improve gross margin".

Whether the study supports the hypothesis or not, the results of this study are expected to be useful for producers, consultants and dairy companies. Key management issues and opportunities identified will serve both the farmers and the dairy industry as a guide to improving the productivity of the system.

1.3. Systems and farming systems

Spedding (1988) defines a *system* as a group of interrelated components that interact for a common purpose and react as a whole to external and internal stimuli. Similarly, Ackoff (1973) defined a *system* as a set of interrelated elements of any kind, e.g. concepts, object, or people. Dent and Anderson (1971), also stated that the systems view is a holistic one, which implies that an isolated study of parts of the system will not be adequate to understand the complete system.

A systems approach is a synthetic mode of thinking applied to system problems. It is the observation of the performance of each part of a system and its effect on the performance of the system as a whole. According to Checkland (1981), systems thinking is a response to the impotence of reductionism in the face of the great complexity of the problems. Similarly, Malik (1990) and Malcolm (1990), noted the limitations of reductionist models as a problem solving approach.

In Dent *et al.* (1979), systems are generally defined as a complex set of related components within an autonomous framework. They identified four specific properties of a system:

- is defined both by a set of identified components, and interconnections between them;
- is a hierarchical structure comprising various subsystems;
- requires explicit consideration of times and rates of change; and

- systems are sensitive to the environment in which they exist, an environment usually unpredictable and certainly variable.

Farming systems are characterised by the fact that people are attempting to control biological systems in an uncertain environment to achieve goals which are predominantly economic in nature (Wright, 1971). In farm production systems, Anderson and White (1991) support the idea that interactions between seasonal climate, farming intensity and farm improvement are critical in assessing and comparing production systems, and should not be excluded from research.

Mathematical models have been used to explain the operation and organization of farming processes and to make predictions about their behaviour. These types of models are important in the development of agricultural practice, but can be misleading because of their simplification (Dent and Anderson, 1971).

Agricultural research involves a wide range of areas such as socio-economic and biological activities, which are largely affected by uncertain conditions. The use of quantitative methods in these areas is an important attempt to overcome some of the limitations founded in agriculture. Thus, the use of mathematical models gives alternatives to tackle several of the conditions involved in agricultural research and production systems. Hence, it is important to understand the relationship of mathematics to both the practice of agriculture and agricultural research, which is concerned with the improvement of agricultural practice.

Models can contribute, in different ways, to both research and production. The approach adopted will depend largely on personal objectives and the purposes which the model serves.

Farming Systems Research (FSR) is a broad term which involves on-farm research, the socio-economic environment and transmission of information. The above activities must be interdisciplinary, farmer and system orientated in order to achieve a good identification and adoption of the technology. FSR is an important approach developing improved technologies which are relevant to socio-economic circumstances and production goals in farming. Sands (1986) and Dent *et al.* (1986) mention that many technologies and research findings have not been adopted by farmers.

Anderson *et al.* (1991) describes a structure for FSR in which there should be a clear definition of the objectives, the boundaries, the components, and the interrelation between system components. It is essential to realise, in advance, the boundaries of the system because it is impractical to take all factors into account in analysing a system. The definition of the components of the system and their interactions will be within the boundaries, as identified.

1.4. Modelling in agricultural research

Modelling is the action of formulating and/or constructing a model which will represent a real situation (system). Wilson (1992) defines modelling more precisely as the act of formulating a model; a mental construction process used to make sense out of phenomena that are made explicit to others through the use of one or more symbolic languages, narrative, pictures, mathematical equations, charts, diagrams, replicas, games.

Spedding (1988) considers a model as "an equation or set of equations which represents the behaviour of a system" can be either too specific or too general. Too specific because it refers to only mathematical expressions, and too general in relating the definition to a system. However, models are not necessarily restricted to mathematical versions and can relate to parts of systems. Thus, Spedding (1988) suggests a more general definition where a model is a simplified abstraction of the real world. This is to capture the principal interactions and behaviours of the systems under study, and to be capable of experimental manipulation to project sequences of changes in the determinants of system behaviour. Similarly, Wilson (1992) and Brockington (1979) define models as a simplification, reduction, representation, or a copy of reality carried out according to a standard, conceptual abstractions that represent a simple or complex reality.

Models of a determined system might be used to attempt to identify an improved basic organization, or to determine points in the organization that are sensitive to managerial interference. These possibilities imply that the model is an adequate representation of the real system (Dent and Anderson, 1971). However, Hunt (1972) mentions that even complex models have not been able to cope well with the complex and dynamic nature of the biological system together with attitudes and objectives of the manager.

1.5. Model application

Modelling has a wide scope in agriculture, where uncertainty is present, and experimentation on real farm systems is particularly difficult for reasons of economy, efficiency, information availability, and/or flexibility. Modelling has a limitless range of areas for its application. Given that a real system can be simplified into a model, Dent and Anderson (1971) mention that a major advantage of the simulation approach is its ability to incorporate, realistically, important stochastic elements of a model.

McCall (1984), mentioned three different purposes which could be served by a model of the production system in the conduct and management of agricultural research:

- A focus for communicating and coordinating basic research needs in relation to our ability to describe the entire system.
- As an aid to synthesise results into improved systems and quantitative prediction of systems behaviour under changed circumstances.
- Communicating priorities for research resources.

A major objective of programming approaches to farm planning is to take risk into account to provide decision makers with a set of management strategies which will help to maximise farmer's utility functions (Patten *et al.*, 1988). Additionally, modelling in farming systems has an important role in assisting with understanding the way risk affects the development of targeted project activities. It is also useful to find the best way to develop more efficient solutions under stochastic systems (Hardaker, Pundey and Patten, 1991).

Beck and Dent (1987) mention that bioeconomic simulation models have an important contribution to improvement in animal production and management standards in pastoral systems, because models facilitate the evaluation of alternative management strategies under various environmental and economic conditions. Similarly, formulation and experimentation with models of a particular farm system can make a major contribution to the process of improving management chances of goal achievement (Hunt, 1972).

Models are used in systems research in various ways, but two basic distinctions should be made between *descriptive* and *normative* applications. In descriptive applications the model acts as a framework for the identification of the system components and relationships. All known information is included and a complex model is developed. This will help to identify the unknown aspects of the system. The main objective in this type of model is to obtain a more complete understanding of the system; normative applications attempt to solve problems. The solution of these problems will assist a decision maker to arrive at an improved decision. Thus, a normative model needs an objective function to evaluate different decision rules (Dent and Anderson, 1971).

Poor ability in experimental testing and control in real herd studies makes computer models a helpful tool in whole farm research (Sorensen *et al.*, 1992). Thus, monitoring of information is limited by the availability of researchers to absorb the detail. It is obvious that modelling cannot exist without some information based on experimentation and observation of real-life situations. Models will give an improved efficiency to subsequent real-life experimentation. By the use of modelling, changes in factors can be tested individually, looking at cause-effect relationships within the change and the systems performance (Dent and Anderson, 1971).

On the other hand, in some situations, a restrained application of simulation is probably due to both the lack of experience of agriculturalists in computer use, and by the difficulties associated with obtaining adequate data for the development of complex models (Dent and Anderson, 1971).

Models have been widely used to analyze and design farming systems (McCall, 1984; Ridler *et al.*, 1987; Larcombe, 1990). Dent and Anderson (1971) and Dent and Blackie (1979), distinguish three basic classes of models: iconic, analogue, and symbolic. Iconic models are similar to real systems but developed on a smaller scale, eg. the farmlet in agronomic research; analogue models refer to situations or properties that can represent another, for instance, the mechanical mowing of pasture as a substitution for animal grazing; and symbolic models, models where properties are represented by symbols, and systems research which is primarily concerned with the models where the symbols represent quantities, ie. quantitative mathematical models, spreadsheet models or linear programming models.

Quantitative models are classified according to their behaviour within time as static or dynamic models (Wilson, 1992; France *et al.*, 1984; Dent and Anderson, 1971). Another method is the classification of quantitative models according to their certainty and predictability giving deterministic and stochastic models (France *et al.*, 1984). Wilson (1992) also classifies system models, according to their behaviour in relation to factor variation, into stable and unstable models, or according to how the elements of a system are influenced by changes in external factors, giving steady-state or transient models. Models are also either optimising or non-optimising where optimising models give the optimal possible answer or strategy, while non-optimising models give an answer which is subject to user judgement in relation to other options available.

1.6. Objectives

Given the problems outlined, the hypothesis to be tested and the potential of models, this study can be seen to have several objectives.

A. To describe the old and new payment systems installed by the New Zealand dairy processing industry. That is, examine changes in the seasonality and financial security of both the factory and the dairy farmer.

B. To evaluate alternative management strategies by using a simulation model as a framework:

- to identify and describe geographical and biological factors which are likely to influence milk production on the case study farms;
- to determine the limiting factors which restrict higher economic returns in their respective regions; and
- to apply the factors identified above to the development of strategies and management practices identifying ways of improving production and profitability under TMP's new payment system.

CHAPTER 2

NEW ZEALAND DAIRY INDUSTRY

The dairy industry is important to New Zealand's economy, with the value of exports for at 1992/93 season of NZ$3.3 billion representing about 15% of total exports. Dairy industry exports consist mainly of dairy products, but also include beef, veal, hides and other products derived from the dairy industry (NZDB, 1991).

The dairy industry is a uniquely integrated industry comprising around 14,000 dairy farmers who supply milk for manufacture. It includes 15 dairy co-operative companies with 28 manufacturing sites, mainly located in the North Island (NZDB, 1993). The New Zealand Dairy Board plays an important role in planning and marketing of products.

2.1. Farms and factories in New Zealand

New Zealand has approximately 2.7 million dairy cows producing more than 7,000 million litres of milk, annually, with average annual cow yields of 3,300 litres. Over the last decade the production per cow and production per hectare has increased, with a further increase in the average herd size (Table 2.1), mainly achieved through improved farm management practices and genetic techniques, as well as an increase in the average herd size. The most common breed of dairy cow is the Holstein-Friesian (over 50%), with Jersey and Holstein-Friesian-Jersey cross as the other main breeds.

Table 2.1. Changes in milk production and average herd size over the last decade (Livestock Improvement 1991/92)

Year	1980	1990
Total milk production (million litres)	5,800	7,000
Average herd size	130	170

While New Zealand produces less than 1.5% of the world's total milk supply, it is, however a significant exporter of dairy products, with an estimated 25% share of total world trade. Consequently, dairy farming in New Zealand is strongly focused on producing milk for the manufacture of dairy products rather than for liquid consumption. About 96% of New Zealand herds supply milk for manufacture into dairy products, and are known as factory-supply herds. The remainder supply milk for the local liquid milk industry. From the total milk production, about 85-90% is sold overseas reflecting the industry's export orientation.

New Zealand on-farm efficiency is recognised worldwide as being one of the world's most cost effective producers, with a cost advantage of 30% over its nearest rival, Australia (Table 2.2).

Table 2.2. Gross Income and On-farm Cost in Four Countries (NZ$/ Kg milkfat) (Holmes, 1990)

	United Kingdom	U.S.A	Australia (Victoria)	New Zealand
Gross Income (including stock)	14.3	13.0	7.0	6.6
Total Costs (excluding interest)	11.2	9.6	4.0	3.0
Feed	4.1	5.8	0.4	0.5
Labour	1.6	0.9	---	0.3

During the 1980s the New Zealand dairy industry was restructured, resulting in the total elimination of subsidies. New Zealand is currently acknowledge as the world's largest unsubsidized exporter of dairy products.

2.2. The New Zealand Dairy Board (NZDB)

The industry is structured so that farmers are members of co-operative dairy companies that are autonomous commercial entities, with independent powers to decide on investment, milk utilisation and manufacturing operations. Supplying farmers must hold shares in the co-operatives. Thus dairy farmers are members and owners of the industry.

The NZDB is the marketing arm of the New Zealand dairy industry, which is recognised for its competence, research and development (R&D), marketing efficiency, and the major contribution it makes to the nation's export earnings. The Board, established by an Act of Parliament in 1961, is based in Wellington and has about 60 subsidiaries throughout the world (NZDB, 1991).

The co-operatives are required to offer all export products to the NZDB which is the statutory single seller of all New Zealand dairy export products. However, through the purchase price mechanisms and its own assessment of market demand, the Board encourages companies to produce the mix of products which best matches market requirements. Thus, companies decide their own "preferred product mix" which would enable them to maximise their payout to suppliers by processing their available milk into the products which offer the best yields, factory efficiencies and profitability. The NZDB also operates a system of premiums and penalties to encourage companies to manufacture the products most in demand.

Historically the NZDB's main products were butter and cheese, exported to England. Since 1973, when England joined the European Community (EC), restrictions have been in place, and the NZDB's focus has moved towards value added products reducing trade in commodity products. In 1982, standard commodities represented about 55% of total sales while branded products were only 5%. Today, commodity products represent 25% of total sales, and branded products have grown to 26% of total sales.

2.3. Assessment of the dairy industry

2.3.1. Strengths

The following summarize the strengths of the industry.

- The vertically integrated structure of the industry gives it strength to face disadvantages in the external environment, including distance from markets, lack of a large local market to develop its products, relative smallness compared to its costumers and competitors (Mtonga, 1993).

- A large offshore network of companies secure positions in a range of markets throughout USA, South-East Asia, Latin America and Japan. Similarly, the NZDB has also invested significantly in marketing, processing and R&D activities. These activities included for the 1992/3 year R&D operations in Germany and Singapore, and the establishment of companies in Russia, Venezuela, Bangladesh, and South Africa.

- The New Zealand dairy industry is well-equipped to exploit the interrelationships between various product mixes. Many companies operate large multi-product manufacturing plants with sophisticated processing technology. This allows flexibility to switch between products according to the most profitable product mix.

- Adaptation of livestock and management practices to the generally mild and moist climate, give New Zealand a major international comparative advantage, while favourable growing conditions and an efficient farming sector, have constantly upgraded production efficiency. New Zealand farms are characterised by cows grazing on high-growth pastures with minimal use of supplementary feeding.

- New Zealand farmers are among the most educated in the world, and are noted for their willingness to adopt new technologies. It is estimated that at least 40% of New Zealand farmers have had some form of higher education related to farming, compared with 20% of Australian farmers (Crocombe, Enright and Porter, 1991).

- A network of agricultural research institutes have enhanced cow productivity, farm management techniques, soil-fertiliser programmes, product manufacturing and product packaging. Good examples of this network are institutions such as the Dairy Research Institute (DRI), Dairy Research Corporation (DRC), the Crown Research Institutes (CRI) (former the Ministry of Agriculture and Fisheries (MAF) and Department of Scientific and Industrial Research (DSIR), and the universities, especially Massey and Lincoln Universities.

- A consolidation of the industry. In 1935 there were more than 500 dairy co-operatives. By 1983 there were 36 dairy co-operatives and currently they are 15 dairy co-operatives (Crocombe *et al.*, 1991; NZDB, 1993).

- Average herd size gives economies of scale in comparison to other countries. Giving higher levels of production, better utilization of labour units and fixed capital on the farm (Table 2.3).

Table 2.3. International Comparisons of Average Herd Size (NZDB, 1991)

Country	Average Herd Size	Country	Average Herd Size
New Zealand	165	Canada	42
Australia	106	Japan	33
United Kingdom	66	EEC	19
United States	46	Germany	17

2.3.2. Weaknesses

The following summarize the weaknesses of the industry.

- The payment system is based on processing costs. Dairy factories focus their efforts towards decreasing processing costs rather than on research and development.

- The payment system can also have distorting effects on farmers' returns from their milk. These distortions can be explained by business deals made by the NZDB overseas, such as merchandising dairy products from other countries.

- As shown in Figure 2.1, NZDB sales have not grown at the same rate as multinational companies such as Nestle, Borden or Kraft (Crocombe *et al.,* 1991). Crocombe *el al.* (1991) suggest that this could be explained by having marketing strategies which are not as aggressive as Nestle or Kraft, or not exploiting the possibilities of developing added value products.

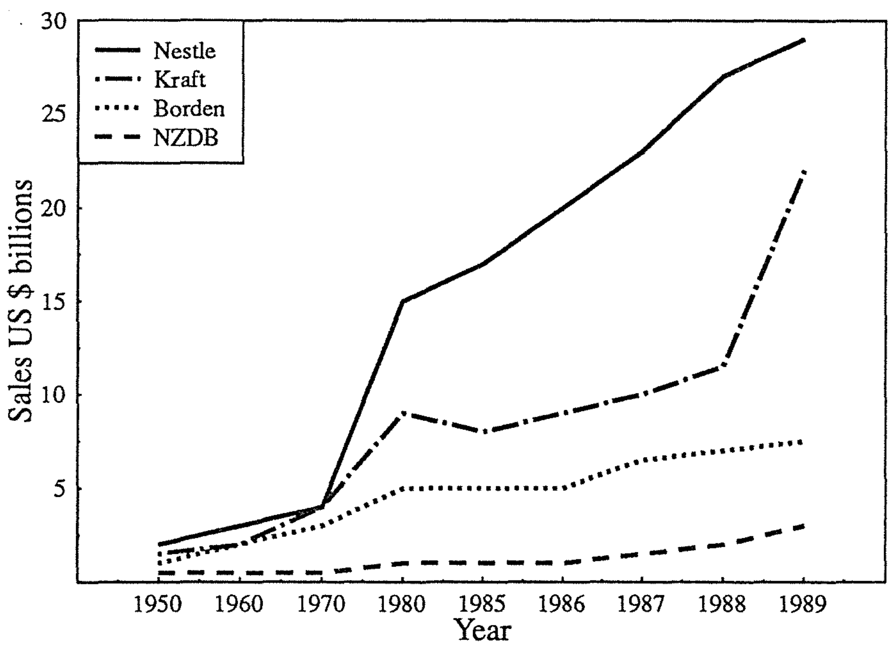

Figure 2.1. Multinational Food Companies Growth Trends (Crocombe et al., 1991)

2.2.3. Opportunities

Four opportunities appear to exist for the NZDB.

- The Uruguay Round of the General Agreement on Tariffs and Trade (GATT) was expected to reduce export subsidies and increase market access into the EC market. From this, the New Zealand dairy industry can increase its returns as a result of higher world prices for dairy products, in particular commodity products such as butter.

- Asia, and specially South-East Asia offers large opportunities to the New Zealand dairy industry. It is recognised that this region is one of the world fastest growing economies. Income *per capita* is also increasing rapidly; consequently their consumption rate will also increase.

- Latin America offers a large potential market.

- Integration with overseas food and marketing companies, through joint ventures and the establishment of foreign subsidiary companies will give opportunities to the industry to reinforce its role in the international dairy market.

2.4. Tui Milk Products (TMP)

2.4.1. Description of Tui Milk Products

TMP is New Zealand's fourth largest dairy company with a milk collection area covering the lower third of the North Island. It was formed in 1989 through the merger of two medium-sized companies, Manawatu Co-operative Dairy Company and Tui Co-operatives Dairy Company. TMP comprises about 1300 suppliers, of whom about 1160 are seasonal suppliers and only 140 are winter suppliers. The majority of the company's dairy processing operations are developed and based in three main sites, Longburn near

Palmerston North, and Pahiatua, in the Northern Wairarapa, with a cheese factory at Mangatainoka. A summary of the products manufactured by TMP in the 1992/92 season is shown in Table 2.4.

Table 2.4. Products Manufactured by TMP (1991/92 & 1992/93) (TMP, 1993)

Product Specification	Factory	1991/92 (tonnes)	1992/93 (tonnes)
Creamery Butter	Pahiatua	24,112	36,771
Anhydrous Milkfat	Pahiatua	0	0
Whey Butter	Pahiatua	218	367
Cheese	Mangatainoka	9,334	13,892
Casein	Longburn	9,148	9,100
Alacen	Longburn	1,653	1,469
Alamin	Longburn	166	410
Lactose	Longburn	5,670	7,973
Wholemilk Powder	Pahiatua	29,151	27,486
Skim-milk Powder	Pahiatua & Longburn	2,292	3,963
Buttermilk Powder	Pahiatua & Longburn	1,717	2,572
Total Production		83,461	94,003

In the 1992/93 season TMP manufactured approximately 84,000 tonnes of dairy products for export through the NZDB. TMP has a good customer mix, without being too dependent on one country. Some main export markets are:

- Japan: 50% of TMP's casein production and a high proportion of its whey products are exported to Japan.
- Middle East: The company's butter unit has been producing most of its output to meet the requirements of the NZDB for the Middle East.

- South-East Asia: Both the milk powder and butter units have a strong demand from this region. Longburn's whey processing plant produces Anelene which is a high calcium low-fat milk powder. Anelene being exported successfully to Malaysia, with demand increasing annually.
- Caribbean, Central and South America: The major demands from these regions are for cheese, butter and whole-milk powder. Whole-milk powder is predominantly sent to Venezuela, Mexico and Peru.
- North America: TMP's cheese operations and whey processing activities are focused on the North American market.

The company chooses which products to manufacture according to the value they represent. Whole-milk powder and cheese are the most valuable products, followed by casein and whey. The lowest value products are skim-milk powder and butter.

Longburn and Pahiatua plants have a processing capacity of 4.1 million litres of milk per day, which, together with the processing capacity of Mangatainoka, give a total capacity of 4.7 million litres per day.

In the 1991/92 dairy season, suppliers sent 720 million litres of milk (approximately 35 million Kg of milkfat) to TMP. This amount equates to approximately 9% of the New Zealand milk supply. To accommodate increased supply TMP is assessing options to increase its processing capacity.

The payout for the 1991/92 season of $5.93 per Kg of milkfat, reflects a premium of 73 cents per Kg of milkfat over the NZDB base price. For the 1992/93 season, the payout was $6.42 per Kg of milkfat ($3.68 per kg milksolids), 77 cents per Kg of milkfat over the NZDB base price, showing record payouts.

2.4.2. Milk Supply

Total milk processed by TMP in the 1992/93 season was 735.5 million litres, an increase of 2% over the previous season (Figure 2.2). The increase in milk flow in the region is explained by dairy farming currently being one of the most profitable farming types in the North Island (Holloway, 1993). Increases in milk flow comes from conversion of dry-stock farms into dairying, and from increased production of existing farms.

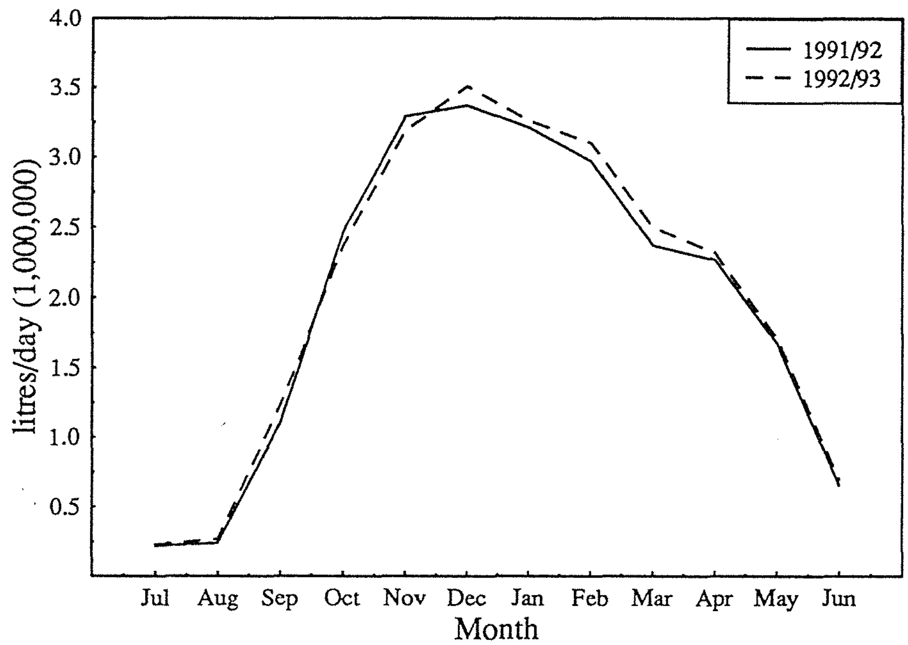

Figure 2.2. Seasonal supply pattern (TMP, 1993)

In order to accommodate an increase in the future milk flow, TMP will relocate the cheese plant from Mangatainoka to Longburn and expand the facility, increasing its daily capacity from 600,000 to 1.4 million litres. The Longburn milk powder plant will also be recommissioned. This will give a total processing capacity of 5.5 million litres per day in 1995, or enough to cope with the expected growth in milk supply.

In the 1992/93 season peak milk supply was 3.59 million litres per day (3.5% over the 1991/92 season), despite the very wet winter and spring that forced some farmers to use supplements and to establish once-a-day milking during spring. The increase in milk production is, however, as a result of a 5% increase in cow numbers from farms converted to dairying, and from an increase in cows being milked by existing suppliers. Table 2.5 shows production for the last two seasons.

Table 2.5. Milkfat Production in 1991/92 and 1992/93 by TMP Suppliers (Watters, 1992)

Parameter	1991/92 (Kg milkfat)	1992/93 (Kg milkfat)
Cows Calved	200,000	215,500
Kg milksolids produced		
per cow	298	289
per Ha.	679	666

TMP aims to control the excess of milk production during the peak months (October and November) by maintaining total milk production, while increasing milk production during the shoulder months (July to September, and December to May). The seasonal payment system will be introduced for the 1994/95 season, farmers receiving a base payment in the peak months of October and November, and a premium above that base payment for the months outside the peak. Further, milk payments will be based on milksolids rather than milkfat.

2.4.3. Milk Payments

2.4.3.1. Current Payment System

The payment system relies on the principle that the income which farmers receive for the components of milk should reflect the overseas market value of the resulting products. Consequently, the payout is exposed to fluctuations. As the dairy industry mainly depends on the international market, these fluctuations are highly correlated with international prices. Returns from the NZDB are then distributed to the manufacturing dairy companies in the form of payment for products purchased. At the moment, all the companies are under this payment system. The companies, in turn, make payments to their farmers for the milk supplied.

The price at which the NZDB purchases products from the companies is based on several elements: the price of the milk, average milk collection costs, and standard processing costs. The price for milk comprises the estimated value for solids, mainly milkfat and protein. The payout during the season is an "advance price" which is set at the start of each season and is reviewed periodically, adjusted according to the international prices at which dairy products are sold. At the end of the season the final purchase price is set and readjusted by price differentials applied by the NZDB. Thus, payments from dairy companies to their suppliers are made on the basis of prevailing NZDB advance price. Like the dairy companies themselves, suppliers receive a retrospective adjustment at the end of the season.

Payouts to farmers vary according to the type of product the company manufactures, the efficiency of the plant, and what proportion of its earnings, the company may decide to retain. For example, companies involved in substantial investment or upgrading existing plant may retain a proportion of their earnings for these purposes.

The averaging system has been one of the greatest strengths of the industry, providing a ratchet mechanism by which the industry has competed with itself, when companies are constantly trying to improve their own efficiency. Thus, every company must work hard to improve its own efficiency. Additionally, a continuous cash flow is maintained to suppliers even during winter months when milk is not being produced.

A major weakness of the current payment system is the way in which extra costs, which are involved in the processing of the milk, are not recognised. Bay (1983) noted that, collectively, the dairy industry is spending tens of millions of dollars simply to accommodate the seasonal peak. No extra income is created; rather the increasingly high cost structure reduces New Zealand's competitive advantage on world markets. Further, the present payment system for milk does not adequately recognise the value of the milk supplied and the true costs associated with it, as the payout is independent of the costs involved through the year.

2.4.3.2. Seasonal Payment System

In a perfect world market returns determine the volume and spread of milk produced (Dawson, 1988). Increasing output of low value products will lower the average price received. Hence, a flatter milk supply curve would be desirable. Further, a significant factor in high payout is related to the utilization of the processing facilities. In New Zealand, factories are built to accommodate peak milk supply. Consequently, on-farm efficiencies are partially offset by poor plant utilization (Table 2.6). That is, the processing capacity is more evenly distributed in other countries, so factory utilization is higher. However, the costs and benefits of increasing processing capacity up to 70-85% has not been yet quantified.

Table 2.6. Capacity utilisation index for dairy factories in several countries (Dawson, 1988)

Country	Percentage
New Zealand	55
United Kingdom	63
Netherlands	77
West Germany	83

2.4.3.3. TMP's Seasonal Payment Objectives

TMP has established the following objectives for the implementation of a future payment structure (TMP, 1992):

- to maximise the total payout to suppliers;

- to provide market signals to the suppliers of the real value of milk to the company;
- to be concise and easily understood by suppliers; and
- to ensure a reasonable flow of cash to suppliers through the season.

It is foreseen that the market signals provided by the seasonal payment system will result in a shift in supply patterns which will improve processing efficiency and net returns for the farmer.

Seasonal farmers are currently paid a flat rate for milk throughout the year irrespective of the costs involved in processing the milk or the value of the final product. Milk processed during the peak months (October and November) has higher processing costs due to an under utilization of plant and labour, and a lower final value compared to other times of the year because, at the peak flow, milk must be diverted from being processed into a high value specialised product, like cheese, into lower value bulk commodities like butter, because the capacity of the plant is insufficient to process more high value products.

If milk production continues increasing at current rates, it will be necessary to construct a new dairy factory every two to three years in order to process the additional milk output (Paul, 1982). TMP's increase in production at a rate of 1-2% per annum coincides with national trends. The move towards Friesian cows, whose milkfat content is lower than Jersey cows, and larger volumes of milk produced, are affecting the increase in the milk flow.

Dairy companies could change the system of payment for milk, reflecting the extra costs involved with peak milk processing, or by setting milk quotas. This could be the case as in other regions, like Victoria (Australia), where the revenue generated from the liquid milk market in Melbourne is an incentive to shoulder production.

In the case of New Zealand, where the population is small, the local market only represents 10% of total production. Another option is to increase production of short shelf life products, like Irish Cream in Ireland. However, these ideas are not feasible under New Zealand conditions. In the short term, the problem is the capital cost of providing the "next" factory to increase the efficiency of the industry by reducing processing costs. Other incentives also include manufacturing products at a higher marginal value (Paul, 1982).

2.4.3.4. Implementation of a Seasonal Payment System

During the 1993/94 and 1994/95 season TMP proposed to introduce various changes to the payment system for manufacturing milk. For the 1994/95 season TMP will pay a premium of 43¢ per kg of milksolids (equivalent to 75¢ per kilogram of milkfat) in all shoulder months (June to September, and December to May). During the peak months (October and November) they will receive the base payment only.

Within the industry, TMP is the only company implementing a seasonal payment system. In 1992 the New Zealand Dairy Group (another cooperative) tried to initiate a seasonal payment, but it was not approved by its suppliers. In 1993 the Northland Dairy Cooperative studied the possibility of implementing a seasonal payment to its suppliers. Thus, TMP is a pioneer and leader in the issue of seasonal payments to dairy farmers.

2.4.3.5. Marginal Value of Milk at Peak and Shoulder Seasons

The 43¢ per kg of milksolids differential payment was estimated using the company's labour requirements, quality implications, improvement in capacity utilisation and product mix options in an optimization model to determine the marginal value of milk on a monthly basis. The results show a difference in the marginal value of milk of 51.38 ¢ per kilogram of milksolids in favour of the months outside the peak (October-November) (Watters, 1992).

2.4.3.6. Price Structure

To determine the price structure it is necessary that the magnitude of the seasonal price will influence a shift in milk supply from the peak months, when is approximately 30% of the company's milk is produced. An effective differential of 43¢ per kilogram of milksolids will be paid. That is at the peak of the season, 30.4% of the differential is paid as premium (43¢ x 30.4% = 13.07¢/Kg milksolids). As the remainder of the production 69.6% is produced during the shoulder months, to balance the differential, the effective levy to the peak months is 29.93¢/Kg milksolids (43¢ x 69.6% = 29.93¢/Kg milksolids). This means that milk produced during the shoulder months will have a premium of 13.07¢ above the average company payout, while the peak months will be paid 29.93¢ less than the average payout. Thus, the net difference between shoulder and peak month payments will be 43¢ per kg milksolids. The pricing structure of the seasonal payment is shown in Figure 2.3.

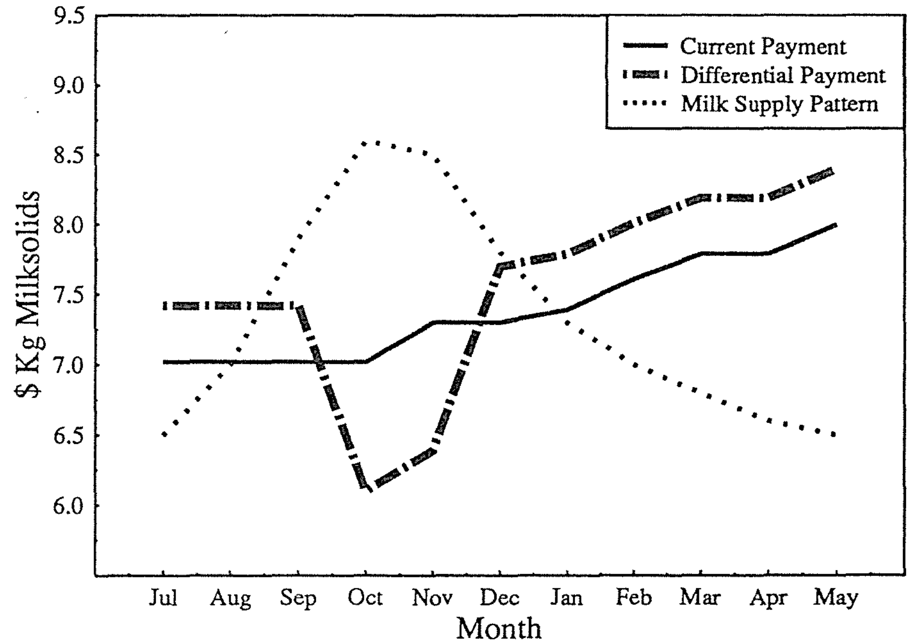

Figure 2.3. Seasonal Pricing Structure (Watters, 1992)

The premium payment also reinforces good management practices, ensuring for example, that the herd is well fed through early spring. If the best management option is to maintain the current management practices, the new payment system will not affect the returns by more than 0.5 and 1% (TMP, 1992).

The program of the implementation and assessment of a seasonal payment system started in 1990, and was launched to the suppliers at the end of 1992. Watters (1992) from a survey in 1991 reports supplier attitudes towards alternative payment systems. The results of the survey show that 75% of the suppliers were neutral or in favour, 52% strongly agreed and 17% were against a change. This shows that a new payment system is generally accepted by the suppliers. It is also forecast that, in order to achieve a complete change in management, two to three years would be necessary. The company expects to improve net returns for suppliers through achieving a more efficient conversion of pasture to milksolids, and improving the efficiency of the processing facilities.

2.4.3.7. Advantages

The advantages of a seasonal payment are a follows.

- A seasonal payment system will provide a market signal to farmers about the real value of the milk according to the month of supply.

- The company will reduce further expansion in processing capacity. Therefore, the additional capital costs and associated interest payments will not apply.

- The redistribution of milk volume will allow increased plant and human resources utilisation, resulting in reduction of the intense pressure under which staff and plant currently operate during peak periods.

- There is an added advantage in attracting more milk during the off-peak period. This is because assets with spare capacity can be utilised particularly to manufacture best returning products.

2.4.3.8. Disadvantages

The disadvantages of a seasonal payment are a follows.

- Additional on-farm costs will be incurred as a result of changing management practices, such as calving patterns and feeding regimes.

- Socio-economic costs incurred will include the willingness to milk for a longer period and under more difficult conditions.

- Because of difficult climatic and physical conditions, a major problem could be the inability of a large number of farms to adjust to a different system.

- It may be difficult to select the best type and quantity of feed to be conserved, and determine its most effective use during pasture shortage.

CHAPTER 3

FACTORS AFFECTING MILK PRODUCTION FROM PASTURE

3.1. Introduction

When analysing the economics of a grazing system, the land is one of the most valuable resources. For this reason, milk produced per hectare is a most important economic indicator of the profitability of a dairy farm, under grazing conditions (Holmes, 1993).

The productivity of pastoral dairy farms depends on the supply and utilization of the pasture (Bryant and Holmes, 1985). Additionally, McMeekan (1961) and O'Sullivan (1983) identified three main factors on which production efficiency depends:

- the quantity and quality of the pasture grown;
- the proportion of the pasture harvested (consumed) by the stock; and
- the feed-conversion efficiency.

Milk production from pastures involves a large number and combination of skills and knowledge from agronomy, physiology, animal health and husbandry. Together with good management skills and economic knowledge, these will achieve an appropriate farm productivity and profitability.

A milk production grazing system is affected by many factors. Figure 3.1 shows a simplified model and the relationships of the main elements and factors of a pastoral dairy farm (Holmes, 1990).

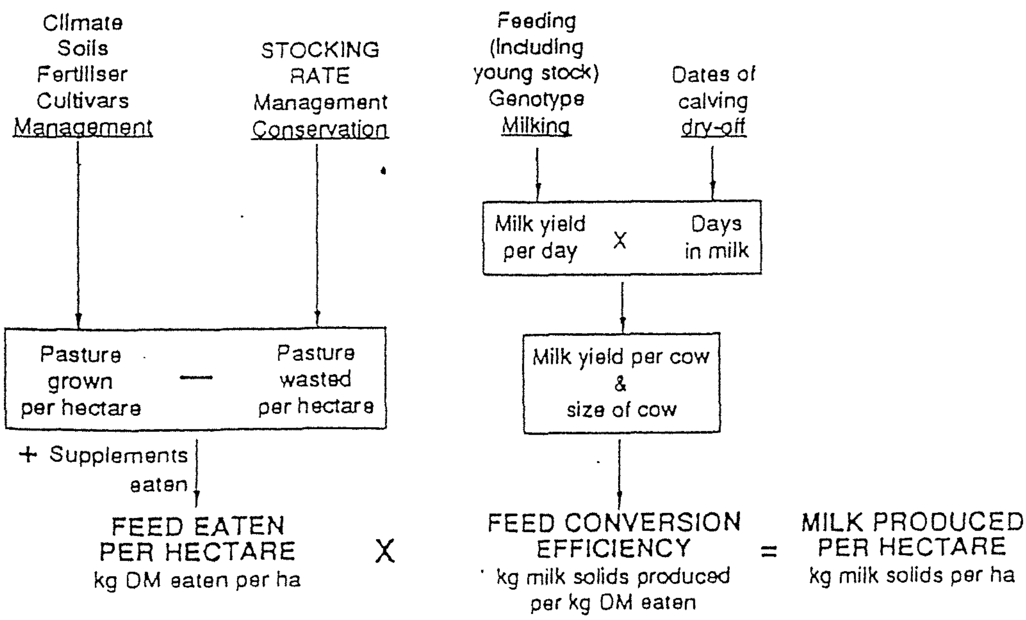

Figure 3.1. A simple illustration of the key elements of milk production per hectare, and of the factors which affect the key elements (Holmes, 1990)

Of these factors, stocking rate is dominant, linking the pasture and animal components of a grazing system. Stocking rate has generally been increased in order to obtain a more efficient system, maximising output and reducing wastage of pasture per hectare.

3.2. Productivity of grassland dairy farms

3.2.1. Pasture production

Generally, temperate grassland provides a low cost, highly nutritional value feed for ruminants. Pasture production depends on the climate, soil, grazing management, and fertilizer (Holmes, 1987). Correct management and interaction of these factors will help to move closer to the estimated potential of total pasture production for each different region.

Cooper (1970) estimates annual potential herbage production based on the conversion rate of light to pasture growth. Under British conditions this is 27-30 tonnes DM/ha and for New Zealand conditions, 37 tonnes DM/ha. For pasture containing ryegrass (*Lolium* *perenne*) and clover (*Trifolium repens*) and provided with nutrients and water, herbage yields, determined by cutting, have been estimated at 24 tonnes DM/ha under New Zealand conditions (Brougham, 1959) and 16.1 tonnes DM/ha under British conditions (Reid, 1972).

Under grazing conditions, dairy pastures receiving no nitrogenous fertilizer produce between 12 and 16 tonnes DM/ha in New Zealand (Holmes, 1982; Bryant *et al.*, 1982; Radcliffe and Baars, 1987), 5.7 tonnes DM/ha in Britain (Williams, 1980), and 7 tonnes DM/ha in Ireland (Gordon, 1979).

3.2.2. Pasture utilization

Pasture utilization is usually defined as the amount of herbage eaten by the animal, expressed as a percentage of either total annual pasture yield or the amount offered to the animal at each grazing (O'Sullivan, 1983). Holmes (1987) found that the most important effect of increased stocking rate is to increase the annual harvesting efficiency (pasture utilization), expressing this as the relationship between the pasture consumed per hectare, annually, in relation to the pasture grown per hectare, annually, which is then transferred by the animal into milk (Figure 3.2).

	PASTURE GROWN ↓	
Efficiency of grazing	Grazed and conserved	→ Losses due to decay and conservation
	PASTURE CONSUMED ↓	
Gross efficiency of feed conversion	Utilised by the animal.	→ Losses as heat, faeces, urine and gas.
	↓	→ Used for maintenance, pregnancy, live weight gain and growth.
	MILK PRODUCED	

Figure 3.2. Diagram of pasture utilization (Bryant and Holmes, 1985)

Intensively stocked farms may achieve utilization of 95%. However this value should be interpreted cautiously. Holmes (1987) reports feed utilization percentages of 80-90% and of 40-70% for New Zealand and British farms, respectively.

3.2.3. Sward dynamics

Pasture growth and development is a dynamic component of grazing systems where pastures are in a continuous state of growth, senescence and defoliation. Consequently, control of the severity and frequency of defoliation influences the balance of growth and senescence, which also affects pasture utilization (Leaver, 1987; Hodgson, 1990).

Korte (1987) defined the effects of defoliation as a result of intensity, frequency and timing of defoliation. Intensity of defoliation refers to the proportion of the herbage removed (measured by residual mass, or leaf area index), while frequency refers to the timing between grazing or between successive defoliations, with timing alluding to the developmental stage of the sward at the time of defoliation.

Looking at the frequency and intensity of defoliation, Korte (1987) mentions that herbage dry matter production is usually reduced by more frequent and intense defoliation (by cutting or grazing), where the effect of one can be reduced by decreasing the impact of the other. Negative effects of a more intensive defoliation are often reduced by a less frequent defoliation, or *vice-versa.* Reductions in herbage production can be explained by a reduction in the photosynthesis and growth of the swards (Hodgson, 1990; Korte, 1987).

On the other hand, Korte (1987) also reports that in some cases more frequent or intensive defoliation has increased DM production, because dead and decayed herbage are also reduced. Adverse effects of more frequent and intense defoliation have been attributed to reduced light interception by photosynthetic tissue; depletion of metabolic reserves; reduced uptake of nutrients and water, and damage to meristem or depletion of root reserves.

Korte (1987) cites several studies supporting the contention that the most important aspect of timing of defoliation is in relation to the stage of reproductive development of the sward. He noted that greater annual yields of herbage are usually obtained when reproductive development is allowed to occur uninterrupted. In another study, it is suggested that control of spring growth, inhibiting ryegrass tiller flowering, leads to a further growth of stems, later, during summer (Korte, 1984; Baker and Leaver (1986). Contrarily, Mathew, Chu, Hodgson and Mackay (1991) found that if flowering tillers are removed before seed formation, the carbohydrate reserves go to enhance the formation of young and new tillers. Thus, a late control of the pasture during spring will increase pasture production (Da Silva, 1993).

Frequency and intensity of defoliation influences pasture growth rate and persistence of a sward. Frequency, intensity and timing of defoliation together with stocking rate should be manipulated to match the needs of high pasture harvesting efficiency and the pasture dynamics. This is the case where reductions in growth, with more frequent and intense defoliations, are generally offset by an increase in the harvesting efficiency. The quality of the pasture is also improved by more frequent defoliation.

3.2.4. Pasture species

Pasture plant species composition change in response to climate, soil fertility, and grazing management including the use of fertilizers or irrigation. For example, as fertility increases, browntop (*Agrostis taiwanese sibth.*) and other low fertility tolerant species, decrease in proportion, while the proportion of clovers, ryegrass (*Lolium perenne L.*) and other high fertility responsive species, increase (Grant, 1981).

In another experiment the species composition of unfertilised hill pasture in winter, at the start of a experiment, was 4% ryegrass, 31% browntop (*Agrostis taiwanese sibth.*), 4% sweet vernal (*Athoxathum odoratum L.*), 10% crested dogstail (*Cynosurus cristatus L.*), 4% Yorkshire fog (*Holcus lanatus L.*), 6% other grasses including chewings fescue (*Festuca rubra L. spp. commutata Gaud.*), danthonia (*Nothodanthonia spp.*), poa pratensis (*Poa pratensis L.*), and cocksfoot (*Dactylis glomerata L.*), 8% clovers, predominantly white clover (*Trifolium repens L.*) and 23% weeds. Ryegrass responded to both N and P, and became dominant (78%) by the winter of the second year. In addition, measurements indicated that these changes in botanical composition were in response to fertiliser treatments and intensive management (Luscombe, 1981).

There is also a seasonal change of production with high fertility. Production increases, with high fertility, were relatively higher in autumn and spring than at other times of the year. This change could be explained by changed grass:clover balance or by an increased incidence of low fertility tolerant species (Mathew, 1988). Browntop can remain an important species component on high fertility lowland soils which are closely and continuously grazed (Harris & Brougham, 1968 cited by Korte and Harris, 1987).

Fertility, with climate, often becomes the main criterion for selecting pasture species. Greater production by the introduction of new pasture species will deplete soil resources more rapidly, or they may not increase yields. Additionally, there are more costs involved in sowing new species, increasing fertilizer application, or irrigation, in order to obtain high levels of production and/or a longer persistence, if possible. Fertilising the resident pastures will cause a change in botanical composition and an increase in pasture production. Also, there will be a balance of plant species that best fits the environmental conditions of each farm system. Thus, to chose the appropriate alternative, will depend on the specific conditions and on the economics involved.

3.3. Stocking rate on grazing systems

3.3.1. Effects of stocking rate on pasture

3.3.1.1. Pasture production and Quality

McMeekan and Walshe (1963), O'Sullivan (1983), and Stockdale and King (1980) found that high stocking rates reduce total annual dry matter production. This effect is explained by White (1987) and O'Sullivan (1983) as the result of an increase in defoliation caused by more intense grazing pressure, reduced interception of solar radiation, and hence lower photosynthetic activity in the sward. Another cause could be that the pasture community becomes unstable and the system fails (White, 1987).

On the other hand, White (1987) reports that pasture growth rates can also be reduced at low stocking rates, because of an increased senescence and a greater abundance of old leaves that are photosynthetically less efficient.

Figure 3.3 shows the influence of stocking rate on rates of herbage growth, senescence and net production. Hodgson (1990) points out that the rate of herbage growth increases as stocking rate is reduced. This effect is eventually offset by increasing losses to senescence so that herbage production plateaus and eventually declines again at low stocking rate.

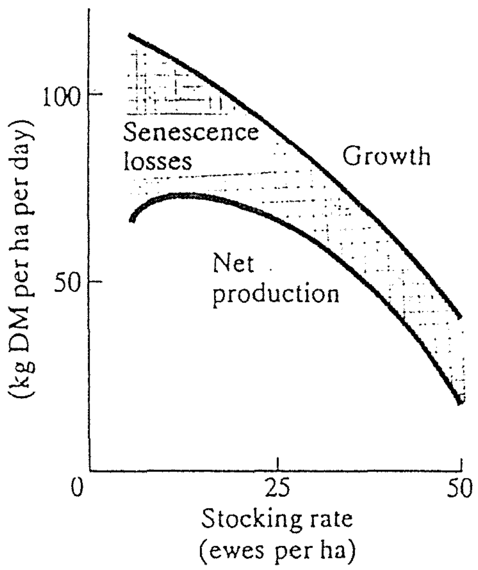

Figure 3.3. The influence of stocking rate on rates of herbage growth, senescence and net production (Hodgson, 1990)

At low stocking rate there is an accumulation of substantial amounts of stem and dead tissue and a marked reduction in the proportion of leaf in the sward. Digestibility of the herbage increased as stocking rate increased because increased defoliation of pasture lowers the fibre content, raising the digestibility (Baker and Leaver, 1986; Stockdale and King, 1980).

Although a high stocking rate ensures the maintenance of a high proportion of leaf in the total herbage, it may result in a depression in the digestibility of the herbage eaten because the opportunity for selective grazing is reduced (Hodgson, 1975,1990; Holmes and MacMillan, 1982). Additionally, other authors (Langlands and Bennett, 1973b; Jones and Sandland, 1974) found that digestibility of the herbage eaten declines with increasing stocking rate.

3.3.1.2. Botanical Composition

White (1987) indicates that high stocking rates often reduced the proportion of palatable species in the pasture. However, Holmes and MacMillan (1982) point out that by increasing higher stocking rates there is an increase in the content of clover and a decrease in cocksfoot.

Stockdale and King (1980) maintain that the weed content of pasture remained negligible and unaffected by stocking rate. The clover content of the pasture increased as stocking rate increased. This can be explained because the cows eat the growing points of the erect grasses. Similarly, Langlands and Bennett (1973a) maintain that at low stocking rates clover was almost non-existent, because of the shading effect from the grasses, reducing the clover growth.

3.3.2. Effects of stocking rate on the animal

Since grazing systems are dynamic and interdependent, stocking rate cannot be considered in isolation from other factors. Thus, other management variables can change; the stocking rate of one livestock enterprise can affect other enterprises, and other inputs may interact with stocking rate. It is important to distinguish between grazing management and the effects of stocking rate and better animal husbandry techniques, as well as taking into account the economic costs involved in rotational grazing, such as extra fencing. Figure 3.4 shows how stocking rate is a framework under which management can work to balance pasture and animal production.

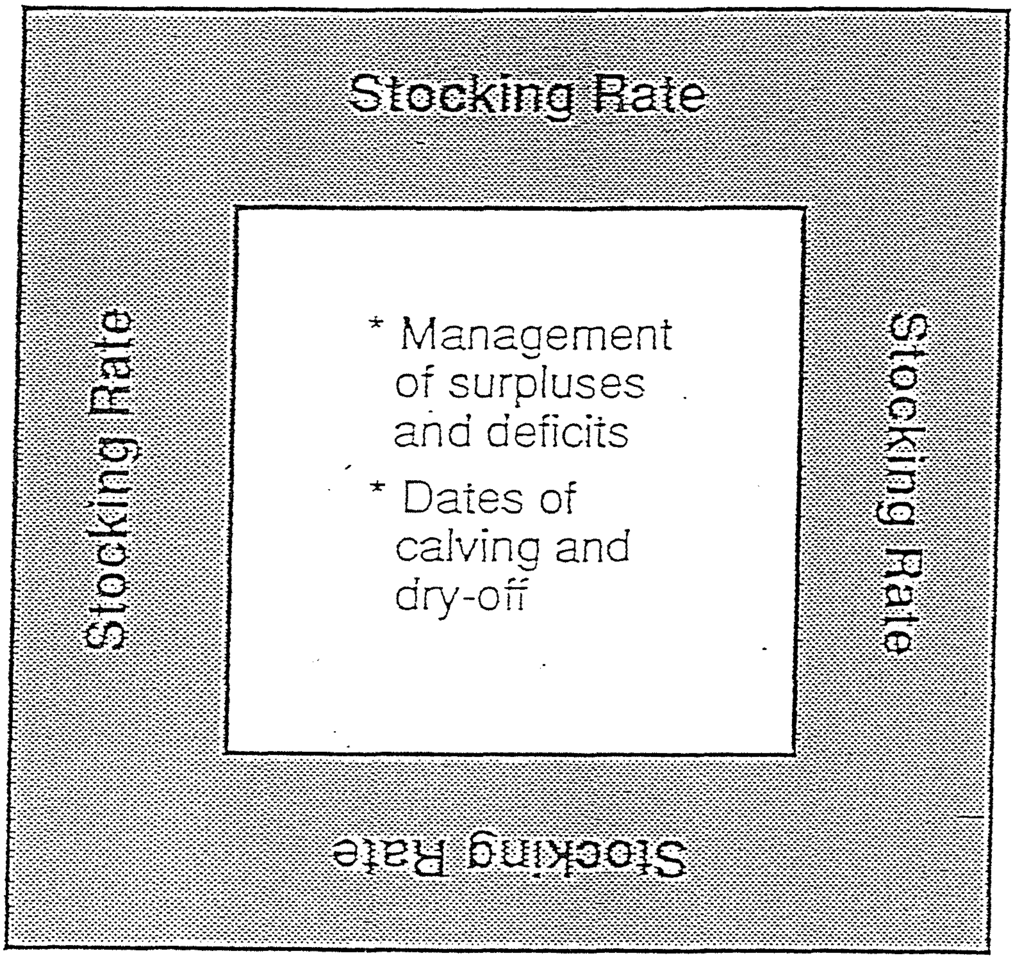

Figure 3.4. Stocking rate the framework for the pasture balance (Holmes, 1993)

3.3.2.1. Feed conversion efficiency

Feed conversion efficiency (FCE) refers to the efficiency with which ingested nutrients are transformed into animal products (milk, meat, wool, etc), eg. kg milksolids per tonne DM eaten, and is influenced by animal and managerial characteristics.

A general approach to define FCE for a dairy farming system is given by Bryant and Holmes (1985) in the equation:

$$\frac{\text{Milk produced per hectare (or per cow) annually}}{\text{Pasture eaten per hectare (or per cow) annually}}$$

King and Stockdale (1980), in Australia, estimated a feed conversion efficiency of 27-33 kg milkfat/tonne of DM eaten, while McMeekan and Walsh (1963) estimated this value in New Zealand as 33-39 kg milkfat/tonne DM eaten. Using an intermediate value of 35 kg milkfat/tonne DM, it indicates that where cows consume 13 tonnes DM/ha annually milkfat yield should be about 455 kg milkfat/ha.

More updated values give productions of 50 kg milkfat/tonne DM eaten (Holmes and Parker, 1992). Higher values of conversion efficiency are a result of a higher genetic merit of the animals, greater levels of nutrition and improved farm management. In general the level of feed conversion will depend on milk yield and on the animal size.

Holmes and Wilson (1987) indicate that pasture eaten by cows is utilized for many purposes other than milk production such as maintenance, live weight gain and pregnancy. Therefore, feed conversion efficiency as described above would be reduced by anything which increased the proportion of total feed partitioned for other purposes.

3.3.2.2. Pasture intake per cow and per hectare

Animal production depends partly on stocking rate, the genetic potential and health of the stock, and the way they are managed (Campbell, 1966a). Hutton (1963) discusses the importance of obtaining high animal efficiency in early lactation, which requires a high level of feeding giving a high yield per day. Additionally, harvesting efficiency can be maximised in this period, in which case a high stocking rate is usually required, and can be achieved by setting the stocking rate to eat the pasture available. Stocking rate may also have some social impacts as a result of a smaller area to graze, lowering the feed availability. Thus, intake for heifers will probably be more affected, when grazed together, by increasing stocking rate, than it would be for older cows.

The direct effect of stocking rate on animal production is on herbage intake by the grazing animal. By increasing stocking rate herbage allowance is reduced and hence animal intake will also be reduced (McMeekan, 1956; Stockdale and King, 1980; Holmes and Parker (1992). However, this does not happen at very low stocking rates (Campbell, 1966b).

Stockdale and King (1980) also studied the effect of stocking rate on herbage intake through the relationships between stocking rate and residual pasture after grazing (tonnes DM/ha), pasture allowance (kg DM/cow/day) and pasture utilization (pasture intake x 100/pasture allowance). As stocking rate increased, residual pasture and pasture allowance decreased, but pasture utilization increased. Similar trends were reported by Langlands and Bennett (1973b).

Looking at the pasture intake per hectare McMeekan and Walshe (1963) and Holmes and Parker (1992) report that pasture eaten per hectare increased with higher stocking rates. Thus, annual pasture utilization also increased. The main mechanism by which stocking rate influences production per hectare is that greater amounts of the dry matter available are actually eaten by the animals.

3.3.2.3. Milkfat production per animal and per hectare

Several authors report that production per cow is decreased when a high stocking rate is reached (McMeekan, 1961; McMeekan and Walshe, 1963; Gordon, 1973; Holmes, 1987). Holmes and MacMillan (1982) found that by increasing one cow per hectare there would be an increase of 70kg milkfat/ha and a reduction of 18kg milkfat/cow. This decrease is associated with a decrease in the ratio of milk produced to feed consumed (Holmes and Parker, 1992), and tends to be cumulative from year to year (Bryant and Parker, 1971).

However, Baker and Leaver (1986), working with stocking rates between 4.7 and 6.4 cows per hectare, found that at higher stocking rates milk production per cow was higher that at the lower stocking rates. This can be explained by the energy content of the pasture at the high stocking rate, being higher than at other stocking rates. However, these were short term experiments, without evaluating the long term effect of the higher SR.

Production per unit area is positively related to the percentage of utilization of available dry matter, but negatively related to the average mass of available dry matter. However, production per cow was highly related to pregrazing pasture mass (Campbell, 1966c).

3.3.2.4. Animal health

While animal health has not been directly related to stocking rate, results from several experiments give an idea of some possible effects, mainly relate to nutritional problems. However, some parasite incidence can be presented. White (1987) and Hodgson (1975) report some relationship between stocking rate and the incidence of parasitism.

McMeekan (1961) reports a high incidence of hypomagnesaemia under continuous grazing and low stocking rate, explained as an association between milk fever and a high level of precalving feeding, to which those animals were exposed. However, McMeekan and Walshe (1963) and King and Stockdale (1980) did not find a significant correlation between the effect of stocking rate and the incidence of disease.

3.3.2.5. Live weight and condition score (CS)

It has been mentioned that higher stocking rates cause larger decreases in live weight. King and Stockdale (1980) report that the time taken after calving for cows to reach their lowest live weight was 6.8 weeks at 4.4 cows/ha, and 12.1 weeks at 8.6 cows/ha. This means that cows at the high stocking rate continue losing live weight beyond 6.8 weeks. For each additional cow/ha, live weight at drying off decreased from 20 to 24 kg/cow (approximately 1 unit of condition score). A similar trend is indicated by Holmes and Parker (1992), and McDougall (1992). Diminishing body condition at drying off is caused by increasing the stocking rate.

When there is limited pasture production, the effect of a higher stocking rate has a higher effect on condition score. McMeekan and Walshe (1963) found that under controlled grazing, stocking rate had little effect on mean live weight over the season. Under uncontrolled grazing, however, the effect of the stocking rate was much greater, because of the low capacity of dairy cattle to recover from periods of under-nutrition. Similarly, in King and Stockdale's (1980) trial, cows at higher stocking rates were more susceptible to death under adverse weather conditions. The authors explain that by the animals not having sufficient reserves to endure these conditions.

As an indicator of the relation between live weight and condition score, Grainger *et al.* (1982) estimate that one unit of condition score was equivalent to 26 kg of live weight in Jerseys, and 42 in Friesians. Similarly, Holmes (1987) reports values of 20-30 kg per unit of condition score, while Hodgson (1975) mentions that the length of time over which the measurement is made, and the stage of maturity of the animals, affects the level of response of live weight changes to variations of stocking rate. This explains the variations of some experiments, and also that the age of the animal can affect the results of some experiments relating to stocking rate.

3.3.2.6. Animal reproduction

Live weight and condition score have an important effect on reproductive efficiency, particularly at mating, since ovulation is closely related to maternal live weight (White, 1987; McDougall, 1992).

McDougall (1992) studied the effects of breed and stocking rate on the reproductive performance of grazing dairy cattle in the New Zealand system. The results show that high stocking rates increase the interval to first ovulation, and low condition score at calving can increase the interval from calving to first heat.

On the other hand, McMeekan and Walshe (1963) found that the effects of stocking rate on mating were negligible and did not follow a consistent pattern from year to year. Accordingly, they suggest that stocking rate does not affect herd fertility.

The difference between McMeekan and Walshe (1963) and McDougall's (1992) experiment can be explained because the trials were developed at different stocking rates; McMeekan's being the lower, can not be compared directly, depending on the absolute values for stocking rate, because feed intake for the cows on McMeekan's trial was not as restricted as in McDougall's experiment.

3.3.2.7. Animal genotype

Measurements of relative intakes, live weight, efficiency of feed utilization and overall production in the field are essential to identify the more desirable breeds for a particular environment (White, 1987). Farms with low stocking rates can support bigger animals or animals with a higher genetic merit, achieving higher individual levels of production. Figure 3.5 shows how a breed of smaller size (Jersey) has a better productive performance than larger animals (Friesians), although in New Zealand, there is a trend to change to Friesian in order to achieve higher production. The difference between breeds can be because of different genetic merit of the animals (Bryant, 1992), as well as different feed requirements per cow.

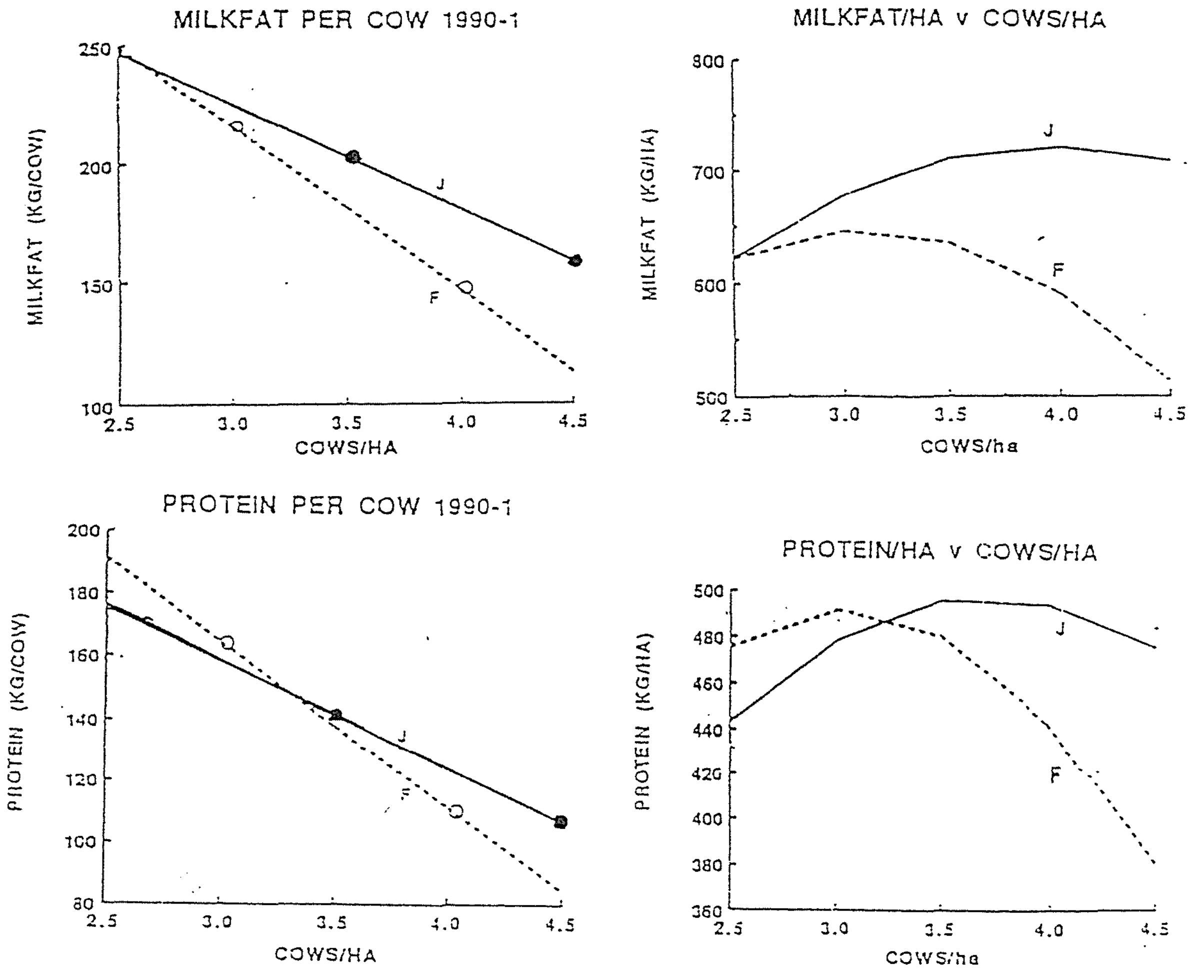

Figure 3.5. *Productive performance of Jersey cows (J) and Friesian (F) cows (Bryant, 1992)*

McMeekan (1961) mentions that since a high proportion of the total feed consumption by a dairy cow goes into maintenance, the smaller the cow, the less the feed that goes into maintenance and the more into milk. This depends on the relative differences in live weight and milk production.

Holmes and MacMillan (1982) report that cows of high genetic merit produce more milk, and eat more feed during part of the lactation than the low genetic merit cows. Nevertheless, the high genetic merit cows converted their feed into milk more efficiently, losing condition during lactation, whereas the low genetic merit cows gained condition. If the extra feed which would be required to gain this loss of condition is taken into account, then the difference in feed conversion efficiency between the two groups of cows would be smaller. Thus, to exploit all the genetic potential of high genetic merit cows, it is necessary to maintain them at lower stocking rates, so that feed allowance will not be restricted. However, higher or lower productivity in relation to other methods needs to be assessed.

3.3.2.8. Mathematical models quantifying animal output in relation to stocking rate

White (1987) indicates that the quantitative relationship between animal output and stocking rate is not yet defined. As a result, it is difficult to define clear biological and economic optima for stocking rate, since this estimation requires rational assumptions concerning the probable relationship between per animal production and stocking rate.

Different research workers have proposed mathematical models to explain the relationship between stocking rate and animal production. The models most cited in the literature are those suggested by Mott (1960), Peterson *et al.* (1965), Owen and Ridgman (1968), Conniffe *et al.* (1970, 1972), and Jones and Sandland (1974), and Hildreth and Riewe, Smith, Jones and Holt (1963).

3.3.2.9. Effects of stocking rate on soil

Increases in stocking rate will increase the severity and the frequency of defoliation of individual tillers in the sward. These effects are likely to be reinforced by a greater degree of treading damage and soil compactation at high stocking rate, but maybe offset by the more effective recycling of plant nutrients in dung and urine (White, 1987; Hodgson, 1990). Similarly, Langlands and Bennett (1973a) found that as stocking rate increased pore space decreased, resulting in a reduction of water infiltration. The authors attribute this compacting to the direct effect of trampling, a decline of root mass in the surface soil, and a reduced protection of the soil from the rainfall.

These effects then lead to a compactation of the soil, which will then affect the filtration of the water during winter, and the pastures or animals can be affected by constant muddy conditions. Pugging affects pasture growth and quality, while the animals will not eat dirty grass. The effect of pugging is higher in clay soil types which are badly drained (McMeekan, 1963; Brown and Evans, 1973).

3.4. Grazing management

Effective grazing management on a dairy farm will ensure that large quantities of good quality herbage are grown, and consumed by the animals in order to fulfil their requirements and reduce pasture wastage. The way pasture is offered and the interrelations between animals and pasture are important management issues. Bryant and Sheath (1987) defined grazing management as the control of grazing required to accumulate, transfer and allocate pasture from periods of surplus to those of deficit, or to those where a higher animal response can be achieved.

Different methods of grazing management can influence both the quantity of pasture eaten and the way in which the pasture is grazed. These can influence animal and pasture production. According to Holmes and MacMillan (1982) the aims of good grazing management are to ensure that:

- the stock are fed "adequately" at each period of the year;
- most of the available pasture is eaten to prevent the accumulation of dead material in the pasture, and the wastage of pasture;
- there is stimulation for the development and survival of vigorous new tillers; and
- after each grazing, there is sufficient quantity of photosynthetic tissue left ungrazed to allow rapid regrowth of pasture.

If the above objectives are met, efficient pasture utilization can be reached, where pasture production and persistence are maximised, and wastage is minimised. These objectives lead to appropriate animal feeding throughout the year.

3.4.1. Grazing methods

Because grazing management systems vary widely in the degree of control which they provide, there is no universal method. Requirements for capital, labour and system influence on animal performance and pasture utilization, as well as on the farm resources vary enormously. However, a general principle behind any grazing method is to match pasture supply to the feed requirements of the animals (Holmes, 1980).

Several authors describe and discuss the pros and cons of several grazing methods, grazing methods which can be grouped in two general types: continuous stocking and rotational grazing (Holmes, 1980; Holmes, 1987; Hodgson, 1990; Frame, 1992; Bryant, 1981).

Other grazing methods include deferred grazing and clean grazing (Frame, 1992; Cawthorne, 1985), mixed grazing (Frame, 1992), zero grazing (Holmes, 1987; Hodgson, 1990; Frame, 1992).

In the implementation of a grazing system herbage allowance (rotational grazing) (Dougherty *et al.,* 1992) and pasture mass (continuous grazing) (Hodgson, 1990) need to be monitored and estimated. The grazing method for a specific region or environment depends on the season, pasture cover and other factors such as farm resources (Bryant and Holmes, 1985; and Leaver, 1987). Holmes (1987) notes that there is no optimal rotation length for all seasons and all conditions.

The major difference between continuous and rotational methods is in pasture physiology. Continuous stocking encourages the development of a dense sward with little bare ground, which may encourage the maintenance of clover in the sward

(Holmes, 1980). In contrast, rotational methods, specially with long grazing cycles, tend to develop a more open sward which may be as, or more, productive, but may also be more sensitive to damage from poaching, and be less suitable for the maintenance of white clover (Holmes, 1980; Bryant and Holmes, 1985). However, Hodgson (1990) points out that variations in grazing management are likely to have little impact on the amount of herbage produced. Similar results were reported by Campbell (1966a).

Systems of grazing management for beef cattle are reviewed by several authors (Marsh, 1976; Butterworth, 1985) and for dairy cattle (McMeekan, 1956; Castle and Watson, 1975; Holmes, 1968; Campling, 1976; Leaver, 1985; Holmes, 1987; Hodgson, 1990).

In dairy cattle experiments MacMeekan (1956), MacMeekan and Walshe (1963) and Castle and Watson (1975) report that rotational grazing gave advantages of 8-15% over set stocking in production levels, in terms of live weight gain, milk production per hectare and milk production per year.

On the other hand, Journet and Demarquilly (1979) report an advantage of only 1.5% in milk production per hectare to rotational systems. Similar results are also reported by Hood (1974), Campling (1976), Freer (1959), Archibald *et al.* (1975), Mayne (1990), Journet and Demarquilly (1979), White (1987), and Mayne *et al.* (1990).

An advantage of intensive rotational grazing is that animals spread evenly in the paddock will minimise phosphorus losses through transfer of phosphorus to different areas of the paddock (Cornforth and Sinclair, 1982; Thomson, McCallum and Judd, 1993).

The evidence does not show significant production differences between rotational and continuous grazing methods. When differences are reported, these are mainly a result of improving harvesting efficiency by manipulating stocking rate (Hughes, 1992). Other management strategies can also give advantages to each of the methods, but the most powerful is stocking rate. Thus, independent of any other activity when implementing a grazing method, attention should be paid to simplicity and convenience of operation and to their effect in maintaining the harvesting efficiency and productivity of the pastures.

Rotational grazing also resulted in a better control and utilization of the dry matter available on the paddock, when high stocking rates were used. Thus, there is an important interaction between high stocking rates and grazing management. O'Sullivan (1983) notes that variations in stocking rates have a higher influence on animal production than grazing method.

3.5. Fertilizers in pasture grazing systems

Fertilizers have a direct effect on soil fertility and pasture production. In a grazing system, the end users of this extra production are the animals. Snaydon (1987) notes that nitrogen and phosphate are the most important nutrients determining herbage production, though other macroelements, such as magnesium, potassium, and sulphur can be limiting in many soils. Additionally, trace elements such as boron, copper, and molybdenum, can also limit growth especially in marginal agricultural areas and land recently transformed into agricultural production. The application of lime may also have a significant effect in modifying soil pH, and therefore affect the availability of many mineral nutrients and toxins (Thompson, 1982). As a result of the interactions between climate, soil characteristics, grazing management and pasture types it is difficult to predict the effects of fertiliser on herbage yield and quality (Morrison, 1987).

A great number of factors affect the response of pastures to fertilizers including, climate (Field and Ball, 1982; Roberts and Thomson, 1989; Thomson and Roberts, 1982; and O'Connor, Edmeades and Feyter, 1989), soil nutrient levels (Richards, 1975; Field and Ball, 1982; Morrison, 1987), species composition (Haggar, 1976; Cowling and Lookyer, 1965; Morrison 1987), frequency of defoliation (Korte and Harris, 1987; Roberts and Thomson, Roberts McCallum, Judd and Johnson, 1989), grazing (Morrison, 1987), presence of legumes (Reid, 1972), and leaching (Frame, 1992).

3.5.1. Nitrogen fertilizer

Nitrogen (N) is the fertilizer used in greatest quantity in agriculture; phosphorus and then potassium are used in the next largest quantities (Stangel, 1976 cited by Snaydon, 1987b). Much of the N fertilizer is used on arable crops. Its use on grassland, even when intensively managed, varies from 30 to 265 kg/ha (Morrison, 1987). However, in grassland production it is essential to take advantage of the symbiotic effect between rhizobium and legumes, where N from the air is fixed by the legumes.

In temperate regions, like New Zealand and some areas of Australia, intensive grassland farming is based on N fixation by clover, rather than N fertilization (Holmes, 1987; Hodgson, 1990). Thus, N fertiliser is used in lower amounts than in other countries.

N losses from grassland ecosystems are significant. Steele (1987) and Cooke (1975) report that N is lost in the following forms: ammonia emission from soil, plant, animal excreta and fertilizers; biological and chemical denitrification; erosion by wind and water; fire; leaching; retention in animals; transfer to unproductive areas in the excreta of animals; and removal in animal products. Efficiency of use can be improved by controlling these "leakages" from the system, and, therefore maintaining a balance of nutrients.

3.5.1.1. Herbage yield

The role of N in the management of pasture for cattle is reviewed by several authors including Holmes (1968), Bryant (1983), Morrison (1987), Snaydon (1987d), Leaver (1990) and Roberts, Ledgard, O'Connor and Thomson (1992).

The response of grassland to fertilizer N follows the shape of a sigmoid curve where, at low N application, the response is linear up to a peak, then declining at very high levels of N fertilizer (Morrison, 1987).

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In Morrison's UK trial the response of dry matter yield to N was almost linear between 0 and 386 kg N/ha, with an average yield of 21 kg DM/Kg N, and obtaining a maximum response at 624 kg N/ha. In another experiment Reid (1972) found similar results, obtaining a maximum response at 560 kg N/ha, and an average response of 27.8 kg DM/kg N. On a grass and clover sward the responses had a similar pattern. However, the response to N rates of between 0 and 336 kg N/ha increased from 13.1 kg DM/kg N in the first year to 20.2 kg DM/kg N in the sixth year. In the sixth year it was as a result of a decrease in the clover content in the sward. From these results it can be seen that the response to N in the presence of clover is lower than in a sward with only grass. However, there is still a response to N application in a clover sward, because the amount of N that is fixed by the clover cannot meet the total requirements of the grass.

The above responses are similar to the ones reported by Holmes and MacMillan (1982) who mention that the application of N to grazed pastures usually results in an extra growth of between 10 and 25 kg DM/kg of N. Even so, there are wide variations in the results obtained by other authors. For example, Bryant (1983) obtained responses of 3-9 and 10-15 kg DM/kg N, Poole *et al.* (1983) cited by Leaver (1985a) obtained response of 8 kg DM/kg N, Holmes (1968) reports responses of 10-15 kg DM/kg N, Holmes (1982) responses of 7.4-10.5 kg DM/kg N, and Cameron, (1993) responses of 6-18 kg DM/kg N. This large variability in responses to N fertilizer can be explained by those factors previously mentioned.

Wilman (1970) found that, in general, the response to N fertilizer can be expected between 6 to 10 weeks after the N application. However, this value is highly influenced by pasture growth rates and the weather conditions at the time. Strategic applications are needed in order to meet the extra pasture production when it is most necessary.

(O'Connor, 1982). In New Zealand a balanced sward can be manipulated under applications of N up to 100 kg N/ha/year (O'Connor, 1982).

3.5.1.2. Milk production and nitrogen fertilizer

Benefits from an increase in pasture production as a result of N fertilizer may come from an increase in either the production per cow or the carrying capacity; but, the extent of the benefit will be influenced by the stocking rate (King and Stockdale, 1980).

In an experiment developed by Hawkins and Rose (1979) the milk production responses to combinations of N and stocking rate were identified. The overall response to 1 kg of N was 9.9 litres, of this 4.9 litre were directly related to the increase in N fertilizer, and 4.5 were associated with an increase in stocking rate. This example shows the need to increase stocking rate in order to maximise the extra response to N fertilizer. An appropriate stocking rate increases the harvesting efficiency on the farm, playing an important role in exploiting the extra pasture production.

Many biological and economic factors are involved in the response of N fertilizer, thus the economic benefits of the use of N fertilizers in dairy farming are not easy to estimate. Pasture should be valued according to the market price for products generated by grazing animals, and, hence applying appropriate nutritional data (Middleton, 1973).

With continuous applications of N, the animal response to N, with time, may decrease. This results from the build-up of soil fertility by the cycling of plant nutrients, hence reducing the relative response in production (Gordon, 1973; Stockdale and King, 1980).

The economics of using N fertilizer in New Zealand were analyzed by Buxton (1982) who reported that fertilizer applications of N higher than 80 kg N/ha are unlikely to be profitable. Bryant (1983) then suggested that N applications should be about 25 kg N/ha, and also recommended that further management options should aim to maintain clover content in the pastures to be economically feasible. Results from another study in

Taranaki show that the most profitable rate of phosphorus (P) fertilizer was 50 kg P/ha/year (Thomson *et al.,* 1993).

It is important to take into account that the prices of N and milk apply to each respective year in which the experiments have been realized. In general, the use of N or any other fertilizer can be an economical strategy, being totally related to the costs of the inputs and the payout for the farm products eg. milk.

3.5.2. Phosphorus fertilizer

Plants depend entirely on phosphorus (P) drawn from the soil solution, which is derived from the either inorganic or organic components of the soil or from added fertilizes (Donald, 1964). According to Gillingham (1987) uptake of P, a relatively immobile nutrient, generally occurs from the surface soil and is largely dependent on the root distribution pattern of the plant concerned.

Most of the soil of the world is, by definition, P deficient (Donald, 1964). In order to overcome this problem, in New Zealand large amounts of phosphatic fertilizer have been applied over the whole country. Karlovsky (1964) points out that in 1963 the country ranked as the world's eleventh largest consumer of phosphatic fertilizer. Cornforth and Sinclair (1982) reported New Zealand soils as deficient in P, with the need of P fertilizer to achieve desirable rates of production. Once these levels are meet it is still necessary to apply P fertilizer regularly in order to keep a balance of the P available in the soil.

Phosphate fertilizer accounts for up to 25% of the operating costs of a dairy farm (Thomson *et al.,* 1993). This amount shows the relevance of P in the New Zealand farming systems and fertilizer programmes.

3.5.2.1. Herbage yield

Responses to P fertilizer are influenced by the availability of soluble P in the soil, which is then available to plants.

When Olsen P levels are above 20 only maintenance amounts of P will be required (O'Connor *et al.*, 1989). If an Olsen P test is higher than 20, fertilizer can be reduced or even stopped for a period of time (Roberts and Thomson, 1991). However, on highly stocked farms stopping fertilizers application can result in a reduction of 7-13% in pasture production (Feyter, 1981). Thus, once soil tests reach Olsen P levels of 20, a long term maintenance of soil phosphate levels should be implemented. More recent research suggest that Olsen P levels greater than 30 result in profitable increases in dairy production (Thomson *et al.,* 1993).

Application of P fertilizer to deficient soils was shown to increase herbage growth (Ryan and Finn, 1976); it increases the abundance of legumes, at least in the short term, increasing N fixation and hence grass production (Rossiter, 1964), and increasing the P contents of the herbage. However, Roberts and Thomson (1988) found no significant differences in herbage production by not applying superphosphate fertilizer. This can be explained by the long-term effect of phosphate fertilizer on soil fertility and plant growth (Thomson *et al.,* 1993). However, this small difference would not last for many years.

3.5.2.2. Milk production

The effects of P fertilizer (500 and 1000 kg of superphosphate/ha) and stocking rates (3.2 and 5.0 cows/ha) on milk production were measured by Smith (1968). P fertilizer increased production per hectare at the highest stocking rate, clearly showing the importance of stocking rate in increasing pasture utilization and therefore farm productivity.

3.5.3. Potassium fertilizer

Potassium (K) is present in significant amounts in the soil. However, as with P it is not all available to plants. Most soils contain large amounts of K (up to several tonnes) in the top 15 cm, but only a small proportion (less than 2%) is available to plants. Plants take up about 140 kg K/ha/year giving a shortage in the exchangeable K available, requiring about 40 kg K/ha/year (Hodgson, 1990). Of the K consumed by grazing animals 90% is redistributed into the soil, most of it in urine, while small amounts are retained in animal tissues or removed as milk. The excreted K is readily available for the plants. However, an important proportion of it is lost in sheds, races, or is leached.

An important relationship exists between K and magnesium (Mg). High levels of K in herbage affect the availability of Mg to the plants, resulting in problems of hypomagnesaemia (grass staggers) in the animals. K application to grassland should be closely related to current needs and given according to soil mineral contents (Williams, 1980). O'Connor, Pearce, Gravett and Towers (1987) found that applications of 220 kg MgO/ha will prevent the incidence of hypomagnesaemia in dairy cows for two years with a probable longer protection up to five years. However, most farmers give Mg by drench, or by dusting it onto the feed.

3.5.4. Lime

Frame (1992) reports from field surveys in the UK, that a quarter of grassland soils have a pH below optimum (5.5 to 6). This pH is similar to the optimum pH (5.9) levels suggested by O'Connor (1984). Acidity can cause deficiencies in the availability of several major elements (N, P, K, Ca and S) and trace elements (Fe, Cu, Bo, and Mo). The use of lime may reduce the acidity of the soils giving better conditions for plant growth.

Some other practical benefits of lime application on dairy farms were analyzed by Thomson (1982) who reports the following: deeper rooting pasture resulting in better drought tolerance and reduced pasture "pull" during grazing; improved soil structure and earthworm activity, and improved stock health. However, some metabolic diseases should be considered.

An appropriate fertilizer programme can be developed according to the soil tests of each specific farm or even each paddock, taking weather and environmental conditions into account. Most of the herbage produced must be consumed if an economic benefit is to be gained from the fertilizer. The economic returns depend on the cost of the inputs, the price received for the animal outputs and the response of the pasture to the fertilizer. Additionally, the stocking rate should be appropriate to guarantee a good utilization of the increase in pasture production.

3.6. Irrigation

In New Zealand soil, water supplies are usually replenished over winter, so early seasonal growth is little affected by moisture deficiency. As a result, spring growth rates show relatively little variation between years (Radcliffe, 1975). On the other hand, large areas have insufficient soil water in summer for maximum grass growth; spring and summer rainfall accounts for 60% of the variation in annual herbage yield (Radcliffe and Baars, 1987).

Radcliffe (1975) reports that herbage production in New Zealand, increased by about 13.5 kg DM for every millimetre increase in rainfall for sites receiving up to 550 mm of rain in spring and summer, but only by about 4 kg DM/ha for every millimetre increase in rainfall in areas where mean summer rainfall was between 130 and 400 mm. Holmes and MacMillan (1982) report that the application of an extra 600 mm of water in summer resulted in an extra 3200 kg DM/ha being grown, annually. Similar results were also reported by Hutton (1978).

Further, responses to N application are higher without soil moisture deficits (Holmes, 1968; and Williams, 1980) (Table 3.1).

Table 3.1. Annual yield of perennial ryegrass-white clover as influenced by irrigation and fertilizer N (Williams, 1980).

	Tonnes DM/ha (mean for 4 years)	
Kg N/ha/year	Not irrigated	Irrigated
0	5.7	9.7
130	6.3	10.9
260	8.7	12.2
520	11.4	15.8

In general, irrigation allows an increase in pasture production as well as pasture quality in the periods of moisture stress. However, to achieve all the benefits of the increase in pasture production the stocking rates of each individual farm should be sufficiently high to maximise harvesting efficiency. In regions where annual rainfall is limiting herbage production, irrigation could play an important role in increasing farm returns. However, due to the high costs incurred in implementing an irrigation system on a farm, it is likely that in many situations irrigation will not be economically viable. Besides, in some regions, dry summers are very rare.

3.7. Dairy cattle husbandry

3.7.1. Calving date

Reproductive performance on a dairy farm is of vital importance. Without cows calving there would not be consequent milk production, unless lactation is induced by hormone therapy (Phillips, 1989). The date of calving should be highly correlated with the amount of feed available for the animals and feed supply pattern.

A seasonally concentrated calving pattern is recognised as a feature of dairy farming in New Zealand. According to MacMillan *et al.* (1984) and Bryant (1982) this pattern is part of a system which involves: the maximum utilisation of pasture dry matter, *in situ*, with limited conservation of pasture as hay or silage; very little cropping, except as part of a development programme, and almost no use of high energy or protein feed supplements.

Because of the dependence on pasture growth, calving dates and the start of milk production coincide with changes in pasture growth rates. A good way to achieve this is to calve cows when there is enough feed to meet their requirements, as well as matching pasture growth rates with milk production throughout the year. The appropriate calving dates are during late winter-early spring (July and August) on seasonal supply farms, so that the start of lactation coincides with the start of rapid pasture growth (Holmes, 1987; Holmes, 1986; Phillips, 1983).

According to Holmes and MacMillan (1982), the terms "early" and "late" calving dates are related to herd feed requirements and pasture growth rates. A particular value for mean calving date might effectively be "early" on a highly stocked farm in a district with cool spring temperatures, but "average" or "late" for a farm with a lower stocking rate, in a district with warmer spring weather (Table 3.2).

Table 3.2. Average calving dates in commercial dairy farms in New Zealand (Holmes, 1993).

Region	Date at which calving starts
Northland	24 July
South Auckland	31 July
Bay of Plenty	2 August
Taranaki	6 August
Manawatu/Wairarapa	6 August
Horowhenua	6 August
South Island	18 August

Holmes and MacMillan (1982) state that if the herd calves too early, its requirements will exceed the daily growth of pasture to such an extent that the most probable effect is underfeeding of the cows in early lactation, unless pasture is supplemented. If, on the other hand, calving is too late, the cows can be well-fed in early lactation but the length of their lactation may be reduced because, in New Zealand, almost all the herd is dried off on the same date. However, an extensive Waikato survey (1984), shows that, within herd, each extra day increase in length of lactation, as a consequence of calving one day earlier, increased production by almost 0.7 Kg MF/cow (MacMillan, 1984a). Provided the cow can be well fed in early lactation, an earlier calving date promises higher milk production than a later calving date because a longer lactation is achieved (Thomson, Roberts, Judd and Clough, 1991).

Achieving high levels of milk production in early lactation clearly requires management that prevents this feed shortage becoming too severe. One alternative is delaying calving, so that the feed requirement curve of the herd coincides with the pasture growth curve. Calving should be manipulating in such a way as to maintain an adequate feed supply and high pasture quality and utilisation throughout the year. Another alternative is to increase the supply of feed (ie. by using N fertilizer, or supplements).

3.7.1.1. Herd calving "patterns" and milk production

Calving pattern will reflect, primarily, the conception pattern during the previous season's breeding programme, and study of the calving pattern will show how successful or unsuccessful the previous breeding programme has been. It will also help to diagnose deficiencies in the programme which should then be amended for the following season.

A concentrated calving pattern will reduce the number of late calving cows, and increase the average number of days in milk for the herd. Besides coinciding with the feed supply it will also concentrate the work of rearing calves into a short period of time (Holmes, 1987), making it possible for the farmer to streamline labour requirements because oestrus detection, mating and calving will occur over relatively short periods (Holmes, 1986).

The major factors producing differences between seasonal supply herds in average per cow production are quantity and quality of pasture, especially in the first half of lactation. Apart from these factors, the influence of calving date is primarily a "within herd" effect in terms of individual cow's calving date relative to the herd's planned start of calving date (PSC). Lactation lengths among cows in the same herd are affected by individual cow's calving date and the herd's level of feeding in early lactation. Because most cows are dried off together, giving differences in lactation length (Holmes, 1986).

3.7.1.2. Breeding programmes

To achieve all the above objectives the planning and implementation of an effective breeding program is critical to ensure a good reproductive performance of the herd, and consequently good levels of production.

Breeding objectives vary for different herd owners. However, some general priorities are as follows (Hughes, 1984):

- to have as many cows pregnant as possible;
- to have a seasonal concentrated calving pattern (New Zealand);
- culling of low producing cows while maintaining or increasing herd size; and
- genetic improvement.

The conception rate can be influenced by some factors beyond the herd owner's control (eg. semen quality, inseminator competence, diseases) but the submission rate is solely the herd owner's responsibility (MacMillan, 1984b; Holmes, 1987). A high submission rate is essential if the herd is to have a concentrated calving pattern, minimising the effects of an unexpectedly low conception on the calving pattern.

In a well managed herd, at least 80% of the herd will be inseminated during the first three weeks of the artificial breeding (AB) programme; 60% to 65% of these cows will conceive at the first insemination (Hughes, 1984). Nutrition influences submission rate mainly through its effect on the post-partum interval to first oestrus (MacMillan, 1984b; Holmes, 1987).

Each cow must conceive 80-85 days after calving in order to produce one calf every 365 days. Therefore, the majority of cows will have at least one heat and in some cases two heats during the period before mating (Holmes, 1986; Holmes, 1987).

Achieving a desired calving date and pattern essentially reflects the previous mating and is based on six factors:

- Cows reproductively fit at the start of mating.
- Good heat detection.
- Competent AB technician and/or effective bull.
- No significant pregnancy wastage (eg. abortion).
- Effective control of reproductive information.
- Good records, which are necessary for a continual analysis of breeding programmes (Holmes, 1986).

Older cows will normally recommence oestrus activity about 30-40 days after calving, while for young cows there is a delay of 10 days (Holmes, 1986; Holmes, 1987). Pre-mating heat dates are useful in diagnosing reproductive problems where cows have abnormal cycles ie. retained placenta, difficulties at calving, metabolic disorders, long anoestrus periods, cystic follicle conditions (Holmes, 1986; Holmes, 1987; MacMillan, 1984c).

To achieve a high submission rate it is necessary to have a premating period, where the methods selected for detecting oestrus during the breeding programme can be tested (tail painting, marking bulls) (MacMillan, 1984c; Holmes, 1987; Esslemont, 1979). These methods can be supported with veterinary assistance in order to identify reproductive anomalies in the herd, as well as ensuring good health on the farm.

Post-partum anoestrus interval can be higher with late calving cows causing decreases in submission and conception rates. Late calving cows, inseminated within 40 days of calving, will have a conception rate almost 20% lower than cows inseminated more than 40 days after calving (MacMillan, 1984b), because the cows do not have enough time to recover from calving and early lactation stress.

An additional practice to ensure a compact calving is to induce late calvers. If an induced parturition programme is used then its implementation will recognise the need to allow cows at least six weeks from calving to insemination (MacMillan, 1984c). It would be advisable to programme the induction with the assistance of a veterinarian in order to prevent any casualties.

In summary, the choice of calving date is a tactical decision on which the performance of a whole season will depend. Through its effects on level of feeding in early lactation and on length of lactation, it is probably second in importance only to choice of stocking rate in relation to farm productivity. The implementation of other practices such as supplementary feeding and irrigation are techniques that help to reduce the impact of

3.7.2. Drying-off date

Decisions about drying off of individual cows can be objectively based. Factors taken into account are daily milk yield, condition score (CS), pasture intake, calendar date and time of calving (Bryant, 1984). Some of these factors are explained as follow:

- Gross efficiency of milk production decreases towards the end of lactation, because a greater proportion of dietary energy is diverted to body tissues (Hutton, 1963).
- Condition score at calving has an effect on milk production in subsequent lactation (Grainger and McGowan, 1982). Further, the amount of feed required to achieve gain in condition is higher than that required to maintain condition.
- Pasture requirements of pregnant dry cows is lower than for pregnant milking cows, because they only require nutrients for maintenance and pregnancy.
- Because the dry period must be at least 40 days before calving, drying off can be programmed according to the calving date.

The above factors show the importance of drying off dates on the management decision making process (Wilson and Davey, 1982), especially at high stocking rates. The potential for extra milk production in the current lactation can be weighed against the possibility of a lower production in subsequent lactation. Gordon (1979) showed that heifers dried off four weeks early produced 320 litres of milk less in their first lactation, but 270 litres of milk more in their second lactation, than heifers dried off four weeks later. Similarly, Bryant (1980) cited by Holmes (1987) shows that cows dried off five weeks early produced 10 kg less milk fat, gained 26 kg more live weight and grazed less intensively than cows dried off later.

For farms with animals at low stocking rates (or high autumn/winter pasture growth rates) an optimum length of the dry period may be determined by estimating the minimum time it would take to restore body condition. Wilson and Davey (1982) assumed a fixed *ad libitum* intake and publishing estimates of the energy requirements pregnancy and live weight gain. The authors estimate that the length of the dry period would be between 40 (when gain in CS is not required) and 76 days (when gain of 2.0 CS units is required), resulting in lactation lengths between 290 and 320 days; at the moment the New Zealand average is about 226 days (Livestock Improvement, 1991/92).

Hence, an optimal length of dry period will allow for cows to be milked for a longer period and dried off at a condition score of 5.0, which ensures good productive and reproductive performance in the subsequent lactation. Further, it should be such that the available feed reserves for winter and early spring can meet the cows' total requirements, including the restoration of optimal body condition. Thus, drying off is one of the most critical decisions at high stocking rates (Bryant, 1981).

These data highlight several points. If cows are dried off too early there would be a loss in production; however it also shows that the animal ate less pasture. In periods, where there is a feed shortage, drying off can be practical to help maintain the animals in relatively good condition without having to cull. Feed demand will also be reduced. Animal, pasture and economic consequences should be taken into account for the choice of the drying off date.

The use of appropriate drying off dates will allow the farmer to match the feed requirements at the end of lactation, and/or ensure that the cow will have enough time to recover its CS.

3.7.3. Genetic merit of the cows

In New Zealand, a measure of animal genetic quality is the Breeding Index (BI). Evidence that high genetic merit cows produce more milk and are more efficient is shown by Grainger (1981) with Friesians, and by Bryant (1981) with Jerseys, at Massey University and Ruakura, respectively.

The Grainger experiment, carried out at Massey University, consisted of high genetic merit cows (average BI 126) and low genetic merit cows (average BI 102). The experimental programme started in September 1979 with Grainger presenting results obtained until May 1981. High breeding index (HBI) cows were 27 BI units greater than low breeding index (LBI) cows, this difference is reflected in more milk fat produced, 28% and 18% for the seasons 1979/80 and 1980/81, respectively. The authors point out that the extra milk fat production of the HBI cows can be explained by:

- an increased DM intake during lactation of the HBI cows;
- loss of body condition during lactation to support production of the HBI cows without being replaced; and
- an lower overall maintenance requirement of the HBI cows which were in lighter condition through lactation and the dry period.

Consequently, more feed was available for production. Comparing total milk production the high BI cows were 12-15% more efficient than low BI cows in converting feed into milk fat.

In the trial carried out by Bryant, at Ruakura, the productive performance of two herds of Jersey cows with different BI, were examined. One had an average BI of 125 (HBI), and the other 100 (LBI). Since a cow's BI is based on her own production and that of her ancestors, it was to be expected that cows of high BI produced more milk or milkfat than cows of low BI. The results show that HBI cows produced more milk, and had both a higher feed intake and a higher feed conversion efficiency during lactation, with a potential for a longer lactation because milkfat production at drying off was higher. However, they lost more condition during lactation. When not lactating, the amount of feed required to increase condition was also higher because more CS gain was required.

An alternative to increase farm production is improving both stocking rate and genetic merit of the cows provided that enough feed is available, because, for higher genetic merit, cow feed intake is higher (Garrick, 1991). In general, cows with a higher genetic merit, which have been selected for high yields of milk and milkfat, can convert feed into milk more efficiently.

3.8. Supplementary feeding

3.8.1. Pasture quality and availability

The nutritional deficiencies of pastures can be classified into two groups: qualitative deficiencies and quantitative deficiencies.

3.8.1.1. Qualitative deficiencies

Pasture quality can be measured in terms of its concentration of digestible nutrients, particularly energy, protein and minerals, and their balance. Sometimes these nutrients maybe insufficient or imbalanced.

In many grassland regions, livestock production maybe depressed during times of high feed availability, because nutrient intake can be reduced by low forage digestibility. Poppi, Hughes, and L'Huiller (1987), Ulyatt, Fennessy, Ratray, and Jagush (1980) and Hodgson (1990) point out that when pasture quantity offered is not limiting, the major nutritional factor influencing intake is digestibility of the pasture eaten.

Hodgson (1990) suggests that plant species or components can also differ in their rate of digestion at similar levels of digestibility. That is the case of legumes which have a lower ratio of cell wall material to cell content than grasses at any given level of digestibility. Thus, the rate of digestion and the amount eaten are usually higher for legumes than for grasses.

The combined effect of environmental factors (temperature, rainfall, solar radiation, soil moisture) on digestibility for different pastures in New Zealand and Australia is reported by Wilson (1981). There is a general trend of dry matter digestibility change between seasons where dry matter digestibility is highest in spring, then falling to a low value in mid-late summer, increasing somewhat in autumn and decreasing again in winter. However, there are some variations in this pattern depending on different climatic regions.

Typically the protein concentration in feeds used by dairy cattle varies from levels of 8% of the dry matter for whole crop maize to approximately 30% for legumes. The proportion of non-protein nitrogen (NPN) compounds, which are present in feed, may vary from between 5% and 10% of the N in pastures and up to 70% of N in silage (Holmes and Wilson, 1987). Of the total N found in herbage, 70-90% is in the form of proteins while the remaining portion is in the form of NPN, like peptides, amino acids, amides and inorganic nitrate. Brookes, Barry and Moughan (1992) suggest that most New Zealand pastures contain 12-25% crude protein. Thus, the major concern is with wastage of high quality protein, rather than a shortage. The requirements of the rumen microorganism for rumen degradable protein (RDP) depend on the amount of energy available from the rumen fermentation of dietary organic matter, assuming that minerals and vitamins are not a constraint. Perhaps there is a scarcity of undegradable protein (UDP) in pastures diets.

3.8.1.2. Quantitative deficiencies

Moore (1981) cited by Birrell (1987) classifies the grasslands of the world into four broad areas: humid temperate; semi-arid with summer rainfall (Continental); semi-arid with winter rainfall (Mediterranean); and subtropical, corresponding to the global climatic regions (Figure 3.6). Each of these regions has a typical pattern of pasture production because of seasonal changes in pasture growth.

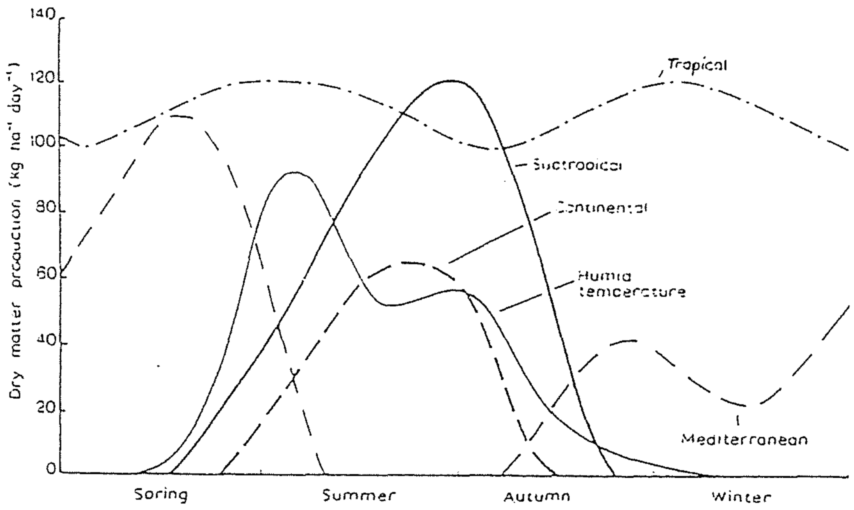

Figure 3.6. *Seasonal pattern of pasture production in several climatic zones (Birrel, 1987 from Snaydon, 1987b)*

In New Zealand, Radcliffe and Baars (1987) examined the seasonal pattern of perennial ryegrass/clover pasture which received P but no N fertilizer. Pasture grew rapidly in the spring and early summer but slowed down in winter and, in some districts, during summer.

Under grazing conditions, when the animals are forced to graze at low levels of pasture availability, the herbage intake is reduced, hence animal performance is also affected. The relationship between pasture allowance (pasture available to an animal) and pasture intake is shown by Poppi *et al.* (1987) (Figure 3.7). Commonly, low pasture allowances, the lower digestibility of stem and dead material, the bite size, and the reduced time spent grazing explain the lower animal intake. The relationship between pasture allowance and dry matter, intake is extensively demonstrated for beef cattle (Nicol and Nicoll, 1987; Meijs, 1981), and for dairy cattle (Holmes, 1987; Meijs, 1981; Hodgson, 1990).

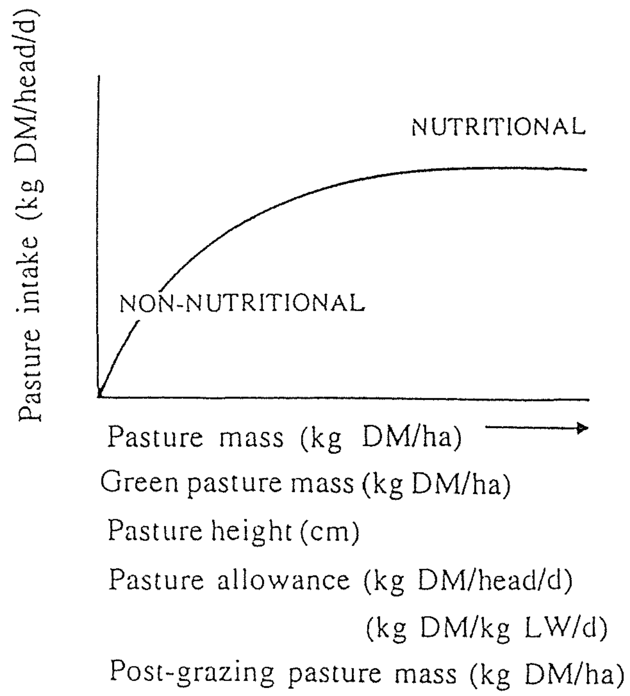

Figure 3.7. The relationship of pasture intake to various pasture characteristics and methods of pasture allocation (Poppi et al., 1987)

Allden (1981) suggests that when pastures are sparse the grazing animals may not be able to harvest sufficient herbage to meet daily needs, even though the plant material has high digestibility. However, supplements (hay, silage, concentrates, or crops) may be used to balance the diet of the animals. In temperate countries, this latter practice is commonly used in intensive systems.

3.8.2. Effects of supplementation of herbage intake

3.8.2.1. Substitution effect

Animals fed with supplements will eat a smaller amount of pasture DM than would have been predicted from the general relation between pasture allowance and DM intake for unsupplemented animals (Holmes and Wilson, 1987; Hodgson, 1990). Figure 3.8 shows the substitution and supplementation effects on animal intake.

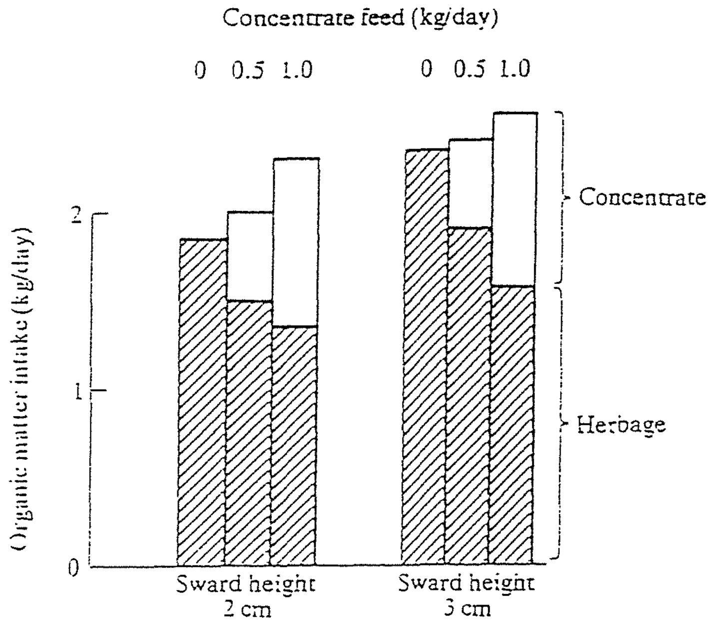

Figure 3.8. Supplementary feeds and substitution effects (Hodgson, 1990)

Several experiments show that supplementing with concentrates or high quality forages in grazing systems results in a substitution effect between 0.4 and 0.6 Kg DM of pasture per each extra Kg of concentrate or supplement (Meijs, 1981; Meijs, 1985; and Skatelum, 1986). Another major factor is the partitioning of nutrients into milk and into body weight, where not necessarily all the nutrients offered in the feed will go into milk production.

Several major factors influencing the substitution rate have been identified: herbage availability and seasonal changes in herbage quality and/or sward structure (Mayne, 1990 and Meijs, 1981); sward height (Hodgson, 1990); the type of concentrate (Meijs, 1985); and stocking rate (Leaver, 1985b: Phillips, 1988; and Phillips and Leaver, 1985a,b).

3.8.2.2. Effects on pasture cover and ingestive behaviour

Supplementary feeding has several effects on ingestive behaviour, including a major effect on grazing time (Leaver 1985; Hodgson 1990). Sanker and Holmes (1979) cited by Leaver (1985) and Jennings and Holmes (1984) obtained a reduction in grazing time between 3 and 20 minutes per Kg of concentrate DM depending on the sward conditions. Forage supplements showed similar effects to hay, but with silage supplements, greater effects were recorded (Phillips and Leaver, 1985a, cited by Leaver, 1985; and Krysl and Hess, 1993).

As a result of the substitution effect on herbage intake, pasture is spared which can be grazed by extra stock or conserved for the next season as silage or hay (Rogers, 1985).

3.8.3. Supplementary feeds

3.8.3.1. Conserved herbage

The objective of feed conservation is to convert a temporary surplus of pasture into a well-preserved product, with minimal losses of material and quality, at a reasonable cost. Hughes (1992) notes that the main objective of using supplements during winter is to ration grass, restricting cow intake and to achieve the desired target pasture cover at calving.

Techniques and methods of hay and silage making have evolved through time; however, principles of pasture conservation remain the same. Steele and Lewis (1980) listed four important factors that determine the quality and quantity of a conserved product. Some of these factors can be more relevant for hay than for silage or *viceversa*:

- stage of maturity of the crops at cutting;
- mechanical and curing treatments between cutting and storing;
- method of storing; and
- weather at time of conservation.

The effect of these factors will vary between regions. As well as soil type, species to be conserved, type of enterprise and availability of resources are factors which will influence the ways in which hay or silage are made. In general, a rule to consider seriously: hay or silage can never be a better feed than the herbage from which they are made. It should also be noted that, given the same quality of pasture of which hay or silage could be made, silage has a better nutritive value than hay.

3.8.3.1.1. Silage

The purpose of ensiling is to compress the harvested material so that most of the air is excluded. This creates the appropriate conditions for anaerobic fermentation of some of the plant nutrients under condition of low pH (Barry *et al.,* 1980).

According to Barry *et al.* (1980) in order to ensure a product with a high nutritive value, practices and techniques of silage making should aim to:

- control proteolytic clostridial action;
- minimise lactic acid formation; and
- reduce degradation of protein in the silo.

There are several methods which are used to control anaerobic degradation of protein. These include relatively simple practices such as wilting and fine chopping (Barry *et al.*, 1980), the addition of organic and inorganic acids such as formic acid (Barry *et al.*, 1980; Lancaster *et al.,* 1976 and 1977 cited by Barry *et al.,* 1980), and formaldehyde, or the soluble carbohydrates, enzymes. Other methods to control clostridial activity, such as the use of enzymes (Jacobs *et al.*, 1991), or bacterial inoculants (Chamberlain, Martin, Robertson and Hunter, 1992), have also been reported in the literature.

3.8.3.1.2. Hay

Haymaking is a fodder conservation method used for many years. It has evolved from manual handling (which is still used in some countries) to very modern machinery. Regardless of the method of handling the principles of haymaking are the same.

Weather can delay specific cutting times. Generally, hay is cut at a later stage of grass maturity than silage (Frame, 1992). The objective of cutting a more mature grass is to facilitate curing, but the quality of hay may be compromised relative to silage (Thomas and Mathews, 1991).

The principal aim in haymaking is to reduce the moisture content from 70-80% to 15-20% (Frame, 1992). The drying process is mainly in the field but storage in an open shed allows further dehydratation.

The initial drying process is very important to ensure a good quality hay. According to Frame (1992) during the initial drying period, respiration is greatest when plant sugars are oxidized into carbon dioxide. There is an additional degradation of proteins into amino acids which may subsequently be leached. All these effects highlight the importance of planning the cutting and drying process. A cutting height of 4 to 6cm, will ensure good regrowth, and prevent damage to the sward by "scalping" the soil (Frame, 1992; Barry *et al.*, 1980). Once the sward is cut, and depending on the weather, it is advantageous to ensure a fast drying by conditioning (abrading, bruising, or crushing) and turning the cut grass several times (Frame, 1992).

3.8.3.1.3. Losses of dry matter with silage and hay

According to Barry *et al.* (1980) losses of dry matter during conservation can be divided into four broad categories:

- Material that is not cut by the harvesting machinery (i.e. stubble).
- Other field losses incurred during the harvesting of both hay and silage.
- Losses during storage.
- Losses occurring during feeding out operations.

Figure 3.9 shows the general pattern of field and storage losses of dry matter in different conservation systems as a function of moisture content at the time of harvesting. It can be seen that silage losses in the field are not as significant as storage losses, whereas, with the hay, field losses are more important than storage losses. Ashbell (1991) mentions that air (oxygen) is the major cause of spoilage in silage. If weather conditions are not suitable for haymaking, they maybe suitable enough to make silage without endangering pasture quality to any extent. There are other ways to conserve herbage when weather conditions are unfavourable (ie. balage).

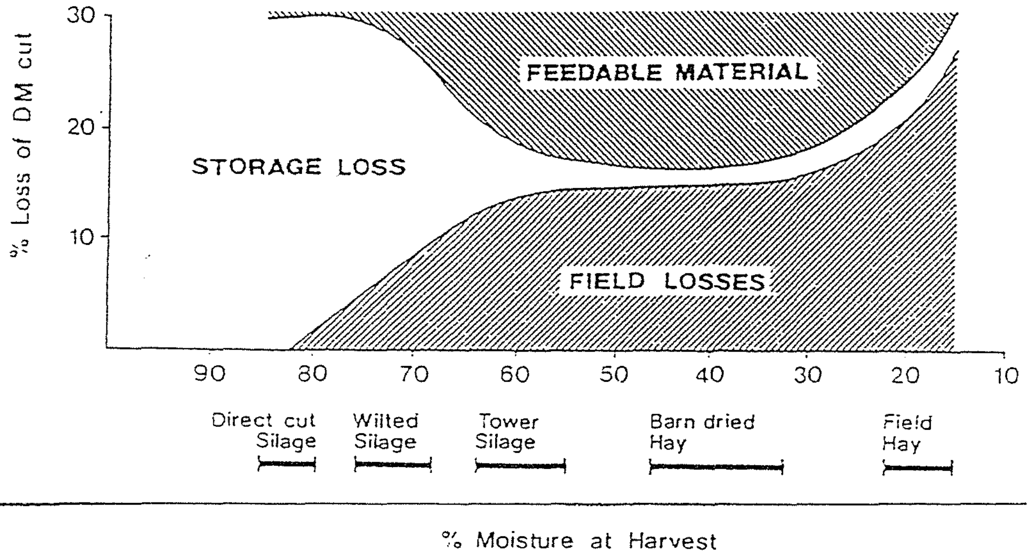

Figure 3.9. *Outline of the general pattern of field and storage losses of dry matter in different conservation systems as a function of moisture content at the time of harvesting. Losses are expressed as a percentage of the material that was actually cut (Barry et al., 1980)*

Dry matter loss as stubble increases with the height of defoliation. However, as mentioned above, if cutting height is too low there would be a risk of "scalping" the ground contaminating the pasture to be conserved. A more important point is that the low nutritive value of the stubble may not justify the risk of conservation. Field losses can be due to several factors such as respiration, leaching and mechanical inefficiencies, and tend to increase with wilting time and DM content of harvested material. Estimations of losses during hay and silage making, were cited by Barry *et al.* (1980) (Table 3.3). These data coincide with a 25-50% losses estimated by Frame (1992), and losses of 26-30% cited by Thomas and Mathews (1991).

Table 3.3. Losses during hay and silage making and storing (Barry et al., 1980).

	PERCENT (%)		PERCENT (%)
Silage Losses:		**Hay Losses**	
Field		Field	
- Respiration	5-8	- Cutting	10
- Wilting	5	- Wilting	5-10
- Turning	3	- Bailing	10
- Mechanical	2-3		
Storage		Storage	
- Lactic fermentation	4	- Bale storage	4-15
- Clostridial fermentation	5-8	- Chemical and	
- Spoilage and oxidation	15-22	nutritional value	4-14
TOTAL	39-53	TOTAL	33-59

Feeding out the conserved feed is another source of loss. In the case of silage, feeding can be either mechanical or manual. Wallace and Parker (1966) cited by Phillips (1988) found that feeding silage in the field without a trough increased the proportion of pasture wasted to 23% compared to 5% when fed indoors.

With silage, chopping, high dry matter content, and anaerobic conditions (compactation and sealing) will reduce field and storage losses. Feeding losses can be high if the feeding system is inappropriate.

3.8.3.2. Concentrates

Concentrates are feeds that contain high concentrations of energy and/or protein. They are made from several sources such as cereal grains, milling by-products, and/or protein supplements derived from meat, fish, milk or plant sources. Concentrates can be used as milk replacers, as a feeding supplement to growing or lactating animals during periods of feed shortage, and in commercial cattle breeding where a high performance and appearance are essential (Holmes and Wilson, 1987).

In some grazing systems concentrates are usually used as supplements to pasture (New Zealand), whereas in some European countries and the USA they complement conserved feeds and larger amounts are fed. Often concentrates are fed to balance nutritional deficiencies of grazed pasture, which is the case in tropical regions were pasture protein concentration is the major constraint; then higher protein concentrates are more appropriate. On the other hand, in New Zealand, where pastures are high in protein, the diet could be balanced considering protein quality (UDP or NDP), energy, and mineral concentrates.

Concentrates can be broadly classified as high energy concentrates, and high protein concentrates. High energy concentrates are generally made from barley, maize, wheat, oats, and other grains. However, milling by-products, such as bran, molasses, and/or animal fats are also used in high energy concentrate making. Holmes and Wilson (1987) reports that, in general, these products have low concentration of protein (8-13%) and low fibre concentrations (3.4-8%). Additionally, the metabolizable energy concentrations are all high (13 MJ/kg DM) and are inversely proportional to fibre concentration.

High protein concentrates are generally made from the residues of soyabeans, linseed, cottonseed, after the removal of oil, together with the above animal products, such as fish, meat or milk products which are often used in concentrates. In New Zealand, some crops, such as lucerne and peas, are also used as ingredients in concentrates because of their low cost and high protein concentration (Holmes and Wilson, 1987). On average high protein concentrate feeds contain protein levels between 20 and 50% of the dry mater content.

A number of studies indicate that supplement type can have a major effect on both substitution rate and animal performance. In general, cereal grains form the large proportion of concentrates fed to cows, because they are high in energy and low in protein, which may lead to substitution effects and milkfat depression.

3.8.3.3. Forage crops

Home-feed crops, hay and silage, make up a greater proportion of the home-grown feed in town supply farms than in seasonal supply farms (Brookes and Holmes, 1988; Mathieu, 1989). Forage crops can also be used to match pasture growth rates and the feed requirement of the animals.

Another alternative is cropping or buying feed from outside the farm, rather than conserving feed produced on the home farm. Some estimated yields of these crops are presented in Table 3.4 (Holmes and MacMillan, 1982).

Table 3.4. Alternative forage crops - Estimated yields and harvesting dates (Douglas, 1980 in Holmes and MacMillan, 1982).

Crop	Production tons DM/ha	Month
Maize	20	March
Sorghum	12	March
Rape	5	March
Kale	12	May
Swedes	8	May-July
Oats	8	September

Therefore, according to the period of undersupply the farmer can plan to sow the appropriate crop, for harvesting or feeding as required.

3.8.3.3.1. Maize

Maize is strictly a summer crop since it requires a frost free growing period with warm temperatures for up to five months. To achieve this, maize can be sown in early November for the North Island, and late November or December for the South Island. Additionally, maize has several advantages; it can be used as either greenfeed, silage or grain.

In the sowing it is important to consider the density of the plants, for a higher density gives a higher dry matter production. According to Barry *et al.* (1980) and Holmes *et al.* (1987) a desirable plant population for silage is 100,000 plants/ha, but for greenfeed, where the crop is normally utilised before grain filling, the population should be two or three times the above figure. The advantages of a greater plant population are more noticeable before 2-3 months. But, as the crop matures, this effect diminishes, and production can reach about 30 tonnes DM/ha.

Greenfeed maize can adequately replace 25 to 30% of pasture DM intake without affecting milk production (Holmes *et al.,* 1987). Protein and mineral requirements of the animals may not be met with a diet containing a large proportion of maize.

3.8.3.3.2. Brassicas

According to Barry *et al.* (1980), Holmes and Wilson (1987) and Millner (1993), brassicas are an important forage crop in New Zealand. These are distributed 70% as swedes and turnips, and about 20% as kale, and characterised by low DM content (8-14%), a high sugar concentration (20%) and organic matter digestibility (90%). The crude protein concentration is low (8-15%) (Holmes *et al.,* 1987).

Brassicas can either be used in winter or autumn. The harvesting time is 120-220 days (4-7 months) after sowing for kale, 180-240 days (6-8 months) for swedes, and 100-120 days (3-4 months) for turnips. In the case of kales the time of sowing will be between October and December, swedes in November or December, and turnips being planted in October and November for summer feed, or in January and February for winter feed, as they are quicker maturing.

However, the feeding of brassicas may bring a number of animal health problems concerning to the health of the animals. Holmes *et al.* (1987) noted the following possible problems: acidosis; haemolytic anaemia; nitrate poisoning; goitrogenic substances; and oxalate poisoning. It is more likely that these problems will occur if the animals are only fed on brassicas.

The average DM production of brassicas is 5-7 tonnes DM/ha at 100-120 days grown under reasonable conditions, and 7-9 tonnes DM/ha under good conditions (Barry *et al.,* 1980). As brassicas are highly sensitive to diseases and pests, breeding of more resistant varieties is necessary. Millner (1993) compared six autumn sown brassicas. The results show significant differences in DM production where Neris and Emerald had the higher yields at 133 days after sowing, while at 76 days Neris and Pasja had the highest yield (Table 3.5).

Table 3.5. Mean yield (kg DM/ha) for each cultivar at 76 and 133 days after sowing (DAS)(Millner, 1993).

Cultivar	Yield 76 DAS	Yield 133 DAS
Neris	2791	6562
Pasja	2704	5440
Appin	2416	6020
York Globe	1994	4798
Emerald	1895	6198
Winfred	1344	4400
Significance	0.004	0.002
LSD (0.05)	699	1010

From the above results it can be seen that autumn forage crops can be quickly established giving high yields, and allowing high intakes by grazing animals.

3.8.4. Supplements and animal performance

The use of supplements generally results in an increase in milk production, an increase in bodyweight gain, or in a reduction of bodyweight loss. However, it depends on the type of management given to the animals and how the supplement is offered.

3.8.4.1. Factors affecting the response of cows to supplements

Supplement use is justified in a farming system if the feed conversion efficiency is improved. According to Rogers (1985) there is a large number of factors affecting the response of cows to supplementary feeding. The major ones are: stage of lactation; level of production; cow condition; pasture allowance; quality of pasture; type of supplement (forage or concentrate); amount of supplement; and quality of supplement (Figure 3.10).

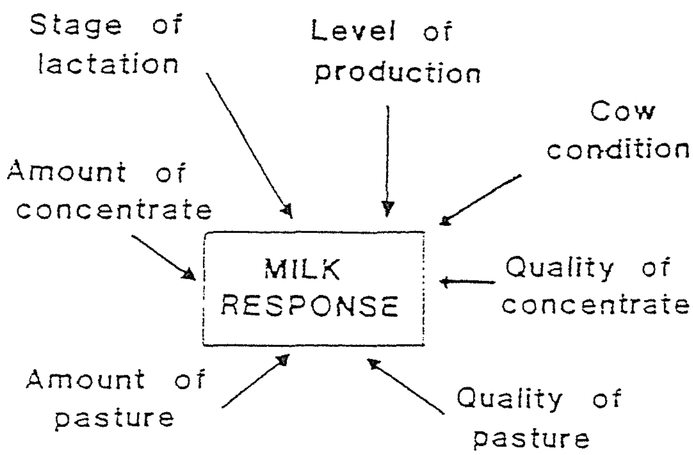

Figure 3.10. *Factors affecting the response of cows to supplements (Rogers, 1985)*

Supplementary feeding generally affects dry matter intake, substitution rate, live weight change and milk production. These effects can be measured in the short and long-term. However, most of the research done has been on a short-term basis. Thus, there is always some uncertainty about the long term effects of such practices. All of the above factors interact with each other not only affecting the immediate response but also subsequent production.

3.8.4.1.1. Stage of lactation

Responses to concentrate feeding at different stages of lactation are summarized by Bryant and Trigg (1982), early lactation; Wilson and Davey (1982), mid-late lactation; and Rogers (1985), whole lactation.

Within the stage of lactation and the level of production the partitioning of the nutrients is a major issue on the response to supplementary feeding. That is, at different stages of the lactation the animals are more or less likely to deposit nutrients into their body, rather than milk production. It is accepted that cows convert a greater proportion of the energy consumed into tissue rather than milk during late lactation. Hence the marginal response in milk production to supplementary feeding is lower in mid-late lactation than early lactation (Rogers, 1985; Stockdale and Trigg, 1989).

The effects of supplementation during early lactation have been studied by several authors Holmes and Wilson (1981), Bryant and Trigg (1982), and Phillips and Leaver (1985). Supplements are usually fed in early lactation with the objective of reducing the effects of underfeeding when pasture supply does not met the requirement of herd.

In general, early lactation is a critical period where the animals are overcoming postpartum stress and are more efficient in converting feed into milk. Hence, the feeding regime becomes an issue of major importance, if higher levels of milk production are expected. The level of supplementation should be according to the amount and the quality of pasture available.

In the major temperate dairying areas of Australia and New Zealand, the period of mid-late lactation coincides with summer and autumn, where pasture quality initially declines and ultimately pasture quantity also falls to a level where the quantity and quality of available pasture limits intake and production. In such periods supplementary feed would also be of great importance.

Underfeeding in late lactation will have carryover effects on the following lactation (Holmes and Wilson, 1981; Cowan and Davison, 1978). Supplementary feeding during feed shortages reduces the loss of body weight past the end of lactation, allowing the cows to have an adequate body condition at drying off and at calving, ensuring good productive performance in the subsequent lactation. During summer and autumn, supplementary feeding also influences the pasture management so that either pasture growth and quality during winter can be improved or pasture can be saved for grazing in winter and early spring.

3.8.4.1.2. Level of production

Studies summarized by Journet and Demarquilly (1979) indicate that cows with high genetic merit show a higher response to concentrate than low genetic merit cows. While the response for low yielding cows is about 0.23 litres milk/kg concentrate, for high yielding cow the response is about 0.40 litres milk/kg concentrate. Similar findings are reported by numerous authors. Bryant (1982), and Phillips and Leaver (1985a) studied the difference between high and low breeding index cows of Jersey cows, while Grainger (1981) studied these effects on Friesian cattle.

The differences between cows of high and low genetic merit can be due to greater partitioning of feed to body condition in low breeding index cow, especially late in lactation, or even different levels of feed intake. Cows of high genetic merit will direct more food into milk production.

3.8.4.1.3. Cow condition

The level of body reserves at calving is dependent on the condition of the cow at the start of the dry period, and on the level of feeding during this period. Additionally, the level of milk production is strongly determined by body condition at calving and by the feeding level in early lactation. Measurements made in the pre-calving period indicate that an extra 207 kg pasture DM above maintenance is required to increase body condition by one unit or 35 kg. This subsequently resulted, at the high level of feeding in early lactation, in 8.5 kg extra milkfat or 24.4 kg DM being required to produce an extra kg milkfat (Grainger and McCowan, 1982).

Cows with extra feed before calving had a higher body condition score at calving, producing more milk, while body condition decreased or was maintained during lactation. During early lactation cows in better body condition at calving lose more condition than cows with low condition scores, because cows at a higher condition score will allocate more energy from their body reserves into milk production (Grainger and McCowan, 1982).

3.8.4.1.4. Pasture allowance

Mayne (1990) examined the relationship between herbage allowance and the response to the supplements (Table 3.6). The substitution rate decreases from 0.69 at the highest herbage allowance to 0.105 at the lowest herbage allowance. The reduction in pasture intake is manifested by a reduced time spent grazing. These results are similar to the ones found by Grainger and Mathews (1989) and Meijs and Hoekstra (1984). Diverse responses to high quality concentrates were also found by Stockdale and Trigg (1989) and Phillips (1988). At low pasture feeding level, the response of milk and milkfat to supplement was higher than at high pasture feeding. In general, greatest responses to concentrates are achieved when herbage allowance is restricted, as a result of the lower substitution rate of concentrate for herbage.

Table 3.6. Effect of supplementation at different herbage allowances on substitution rate and animal performance (Mayne, 1990)

Herbage allowance (kg OM/cow/day)	Substitution+ rate (kg past.OM/kg conc.OM)	Increase in# ME intake (MJ/day)	Predicted* response (kg milk/day)
15	0.105	11.90	1.01
20	0.30	9.31	0.79
25	0.50	6.65	0.56
30	0.69	4.12	0.35

+ From Meijs and Hoekstra (1984).
# Assumes ME content of herbage and concentrate of 13.3 J/kg OM.
* Assuming incremental increase in ME intake of 1 MJ/day will increase milk yield by 0.085 kg/day from Steen and Gordon (1980).

3.8.4.1.5. Quality of pasture

Quality of pasture is strongly affected by its digestibility and its effect on substitution, which in turn is affected by maturity (Hodgson, 1990). Digestibility or metabolizable energy is important because the efficiency of use of energy by the animal varies directly with the metabolizable energy content of the feed, and because digestibility affects intake. Hodgson also cites examples for dairy cows under continuous grazing with digestibility between 75-80% of the herbage consumed. Herbage allowances for cows in early lactation, grazing freshly grown pasture, will produce more milk than cows grazing a more mature pasture.

3.8.4.1.6. Type and quality of supplement

Several experiments show a large variability in the responses to supplementary feeding. In many cases this variation is as a result of the quality of the supplement offered to the animals. These variations were between 0.15-2.0 kg extra milk/kg concentrate (Leaver, Campling and Holmes, 1968; Rogers, 1985; and Meijs, 1985).

Osbourn (1980), indicates that the effects of supplements are dependent upon the nature of the pasture and the supplement, and the extent to which mixed diets meet the requirements of the rumen micro-organisms for active growth and the requirements of the animal for nitrogen and energy.

Milk production from cows grazing high quality white clover/ryegrass pasture, which contain 18% crude protein, is assumed to be limited by energy rather than protein. Rogers (1985) studying the effect of energy and protein supplements on milk production shows that cows fed good quality pasture had modest increase in milk yield when given protein concentrates. However, when cows were restricted in pasture, the response to a protein supplement was significantly higher than to an energy supplement. It is also suggested that protected proteins in supplementary feeds may be beneficial for grazing animals in early lactation (Journet & and Demarquilly, 1979) and in high yielding animals (>30 kg/day) (Leaver, 1981; Holmes and Wilson, 1987; Jennings and Holmes 1984; Castle, Watson and Leaver, 1979).

In summary, responses to either a protein or an energy concentrate depend on the pasture quality, the substitution effect, and on the balance of nutrients such as protein, energy, vitamins and minerals.

3.8.4.2. Reproduction in dairy cows and supplementary feeding

The importance of body condition at calving on milk production is well established (McDougall, 1992; Wright, Rhind and Whyte, 1992). Rogers (1985) mentioned that there is lack of information on the interaction between CS and supplementary feeding; however, he concluded that if pasture is limiting, the requirement for supplementary feeding will be considerably reduced by a higher CS.

Cow condition at calving and the level of feeding after calving, are the most significant factors on the post-partum anoestrus interval. Moreover, CS at mating, which is principally affected by CS at calving and feeding level between calving and mating is very closely related to conception rate (Haresign, 1981). Accordingly, animals fed a high level of nutrition prior to calving had a shorter interval to first oestrus than cows fed on a low level of nutrition *prepartum* irrespective of the post-calving level of nutrition. Further, supplementary feeding in early lactation will also improve CS at mating, and will reduce infertility induced by acute energy deficiency in lactating cattle.

3.9. Summary

In summary it can be seen that pastoral dairy farming is a very complex system involving a close relationship between soil, plants and animals. Pastures are recognised for being a low cost feed supply for ruminants getting high levels of production (12 to 16 tonnes/year under New Zealand conditions with no fertilizer). The total pasture production will vary largely within pasture species and seasons. Another important aspect is the utilization of the pasture where wastage can be minimised. In New Zealand a well managed dairy farm can achieve 80-90% of pasture utilization. The level of utilization is highly dominated by the stocking rate on the farm.

The grazing management of the farm consists of getting an appropriate method to harvest the pasture, ensuring that frequency, intensity and the timing of defoliation will maximise the production and harvesting efficiency of the pastures. The evidence shows that there has been no significant differences specific to rotational or continuous grazing methods. When differences are reported they result from improving harvesting efficiency by manipulating stocking rate. Consequently, attention should be paid to simplicity and convenience of operation and to their effect in maintaining the harvesting efficiency and productivity of the pastures.

The choice of calving date is a tactical decision on which the performance of a whole season depends. Through its effects on level of feeding in early lactation and on length of lactation, it is probably second in importance only to choice of stocking rate in relation to the farm's productivity. An optimum calving date depends on the relation of the herd feed requirements and the pasture growth rates. Under systems similar to New Zealand, a concentrated calving pattern is also very important, reducing the number of late cows and increasing the average number of days in milk for the herd.

Drying off dates determine the extent of loss (or gain) in cow condition score prior to calving. It also affects the present and subsequent level of milk production, and alters significantly the amount of feed consumed during the current lactation. As a consequence the quantity of pasture on hand is affected, and also the time available to accumulate further pasture reserves for use at calving time.

The use of fertilizers results in an increase in pasture production; this extra pasture production can be synchronized according to the feed requirements of the animals, or to increase the amounts of feed to be conserved, or to exploit the extra pasture production. An appropriate fertilizer program should be developed according to the climatic conditions and soil tests of each specific farm or even each paddock. Pasture response to nitrogen has a large variation within seasons and regions. Responses for New Zealand can range between 5-25 kg DM per kg of nitrogen. Phosphorus fertilizer is the second most important on a fertilizer program, besides going into the pastures, it also enhances legume growth. Thus, there will be a positive effect by improving nitrogen fixation into the soil. The role of lime in agriculture is mainly in correcting the soil pH, so other nutrients will be more available to the plant.

Practices such as the use of supplements and concentrates help to meet the feed requirements of the animals during these periods. An additional use of supplements and mainly concentrates is to balance the feed ratio to the animals, where deficiencies of energy, protein or any other nutrient can occur.

The use of supplements or concentrates in a grazing system result in a substitution effect on the pasture intake, and is largely determined by the feed availability and/or pasture height, and the quality of the pasture. At the farm level the use of supplements should be carefully assessed, considering the sparing effect on pasture, the losses involved with the supplement and the pasture, and the costs of the feeds and the milk payout. Hence, it is necessary to keep high levels of utilization of both the pasture and the supplements.

There are several alternatives in a grazing system to match the feed available on the farm with the feed requirements of the animals, such conserving forages as hay or silage, the use of concentrates feeds, or by the use of crops such as maize or brassicas.

CHAPTER 4

METHODOLOGY

4.1. Selection of method

An evaluation of management alternatives available to dairy farmers facing the new milk payment system involves the selection of a commercially available computer simulation model -UDDER- as a vehicle for exploring alternatives, and the selection of a case study approach using farms from TMP and other regions with different geographic and physical conditions.

4.1.1. The use of simulation models

The term *simulation,* like *systems,* can be a source of some confusion through lack of definition. *Simulation* has been defined as a duplication of a *system* from the real world. It is based in the description of a *system,* where its behaviour is described under a determined set of assumptions.

Poole and Szymankievicz (1977) describes a simulation model as a simplified representation of real life which allows the *understanding* and solution of a problem by the trial and error approach. Similarly, Dent and Anderson (1971) noted *simulation* as a technique that involves setting up a model of a real system, and then performing experiments on the model. However, this definition allows all research involving models to be classed as *simulation.* Further, Ravindran *et al.* (1987) define simulation as "a numerical technique for conducting experiments on a digital computer, which involves logical and mathematical relationships that interact to describe the behaviour and structure of a complex real-world system over extended periods of time".

On the other hand, linear programming (LP) models are concerned essentially with static rather than dynamic situations, and, generally, with deterministic rather than stochastic situations. The management of agricultural production *systems* over a period of time involves making many decisions to obtain an optimal overall strategy. Optimisation methods of this type are part of a dynamic programming method (Brockington, 1979). Swartzman and Van Dyne (1972) and Crabtree (1972), both cited by Brockington (1979), give examples of iterative uses of LP reactions, coupled to simulation models, as an alternative approach to problems within a dynamic and stochastic situation. In their approach, the LP routine was used at intervals throughout a run of the simulation model, by collecting information on the current structure of the system from the simulation to devise the next run (Brockington, 1979).

Simulation models give a description of a system and optimization models give the "optimum" solution. Simulation can be employed either when tools, like linear programming, cannot adequately deal with a problem, or when exploration of the system and its sensitivities in greater depth and flexibility, than is possible with optimizing models, is desired (Dent and Anderson, 1971). Sometimes modified linear programs are considered simulation models. However, Wright (1970) mentions that these models cannot be considered as true simulation models. As in the case of simulation experiments, each encounter with the model takes a very short period of time, reproduction of an exact environment could be possible. Of course, the mode of operation of the computation is to evaluate treatments one at a time, that is, sequentially rather than simultaneously.

The use of simulation methods allows considerable insight into the operation and control of systems. Simulation should consider two distinct operations: the development or synthesis of a model that adequately represents the system under study; and an observation of the behaviour of the model in reaction to changes in its structure or managerial policies (Dent and Anderson, 1971). Hence, simulation allows the researcher, to improve the understanding of the system and its responses under different conditions, as well as the construction of the model.

4.1.1.1. Advantages of simulation models

There are several advantages a simulation approach to modelling gives:

- Allows the modelled problem to be developed from first principles with an understanding of its behaviour acquired by a simple question and answer approach (Arcus, 1963; Poole, 1977; Ravindran *et al.,* 1987). That is, through the use of simulation models it is possible to have a better understanding of a system's performance and its behaviour under different conditions.

- Makes it possible to study and experiment with complex interrelationships of stochastic variables of a given system or subsystem (Ravindran *et al.,* 1987). Thus, it is possible to explore the potential output of a system by manipulating one or more variables.

- Simulation models provide strategies for a period of time and differ according to the type of problem and the model design; they contain rules to find a good solution (not necessarily optimal) and, therefore, a so-called heuristic strategy (Van Elderen, 1992). Thus, it gives scope to assess and evaluate several strategies that can be suggested from the experience of the model user.

- Simulation analysis can be performed to verify analytical solutions (Ravindran *et al.,* 1987). Like the previous advantage, a simulation model can be used to confirm and compare results obtained from an experiment or another model.

- Enables the study of dynamic systems in either real time, compressed time, or expanded time (Arcus, 1963; Ravindran *et al.,* 1987). Being a dynamic approach, *simulation* allows the user evaluate and obtain the responses of a system through time, including the relationships and effects of time on the performance of some of its variables.

- Simulation approach can be used to foresee the consequences resulting from changes of certain information, organizational, and environmental variables of a system.

4.1.1.2. Disadvantages of simulation models

The use of simulation, in place of other techniques, has some disadvantages or limitations:

- *Simulation* is not precise, for it does not give a unique answer but merely provides a set of system responses to different operating conditions (Levin *et al.,* 1986). That is, *simulation* gives the expected response of the system to changes of its elements. However, the relationships are not specific for every system, since it relies on research done over the time. If there is a lack of information from research, the relationships could be assumed from the experience of the modeller(s).

- A good simulation model is expensive to develop. Often it takes years (Levin *et al.,* 1986) and requires a wide range of skills (Ravindran *et al.,* 1987). The building of a simulation model requires a wide knowledge of the particular system, dairy farming for example, as well as computer techniques. Thus, a team approach to its construction will give a broader analysis and description.

- Not all situations can be evaluated using *simulation.* Only situations involving uncertainty are candidates, and without a random component, all simulated experiments would produce the same answer (Levin *et al.,* 1986). A large number of variables and their relationships can be included in a simulation model; risk and uncertainty generally are not included. However, a general estimation can be calculated by manipulating the input data.

- *Simulation* generates a way of evaluating solutions but does not generate the solution techniques. Managers must still generate the solution approaches they want to set (Levin *et al.,* 1986). The results from the simulation do not solve the problems, they only give what would happen if determined changes to some elements occur. Thus, the problem would require management skills to understanding and interpreting the results, and the system.

- Because *simulation* is a two-phase technique involving modelling and experimentation, some studies do not progress beyond the modelling phase (Wright, 1970), because of the high levels of cost and time involved in evaluating the output of the model.

4.1.2. The use of case studies

Case studies can give detailed information from a small number of cases to validate results from other research, or to establish the viability of a management practice. A case study also provides information that would be difficult to obtain by other means, such as telephone or mail survey.

Not being able to generalise the findings of the study in terms of the whole population is a constraint. Thus, it is important to be aware that the results obtained are particular to the situation. Among other reasons, the samples are not selected randomly, and because they are only a small proportion of the total population, are not a representative sample.

The farms chosen for this case study are from the "focus farm" programme implemented by Tui Milk Products (TMP, 1991). The company sponsors four focus farms amongst their seasonal suppliers. Each farm is located in a different area of the Manawatu, Eketahuna and Wairarapa regions, is considered representative of these districts and provides contrasting performance under different climatic conditions. The objectives are to educate and motivate farmers to increase production, with a target increase of 85 kg milksolids/ha over a period of five years. To achieve this, monthly comparative information for farmers is reported in the company newsletter. Further, a series of field days show the performance of each farm, through time. The programme also includes the assistance of a consultant who is involved in monitoring the information, preparing reports for the newsletter, giving advice to the farmers, and attending to the field days.

The focus farms are representative of the district (soil types, rainfall), have minimal developmental limitations, and a reasonable history of herd and farm records (TMP, 1991).

4.2. Description of the simulation model udder: a desktop dairy farm for extension and research (UDDER)

UDDER is a computer simulation model of a dairy farm where the major feed supply is pasture while herd milk production is predicted at 10-day intervals. The predictions are driven by monthly net pasture accumulation rates and a description of the farm provided by the information collected (Larcombe, 1989; Larcombe, 1990a and 1990b).

The model requires the following input data:

- Farm size (ha)
- Cow numbers
- Calving pattern (% at each ten day period)
- Drying-off pattern (% at each ten day period)
- Supplementary feeding (kg DM/animal/day)
- Management of dry stock (location of animals through the year)
- Fodder conservation (cutting dates, area cut, cutting height)
- Rotation Lengths (days)
- Pasture growth rates (kg DM/ha/day)
- Fat produced per cow (kg milkfat)
- Fat produced per hectare (kg milkfat)

- Milk price (¢/kg milkfat)
- Variable costs (NZ$).

Cows are grouped in classes based on stage of lactation. Pasture intake of each class is calculated using a relationship including pasture mass, pasture allowance, digestibility, stage of lactation, and animal live weight. These relationships are based on data from grazing experiments at the Ellinbank Dairy Research Institute (Victoria, Australia), Kyabram Research Institute (Victoria, Australia), Macalister Research Farm (Victoria, Australia), and Ruakura Animal Research Centre (New Zealand). UDDER nutritive calculations are based on the movement of energy within cattle, and it is considered that protein would not be the limiting nutrient determining milk production on ryegrass-clover swards. Animal requirements for maintenance, pregnancy, growth, and milk production are estimated according to the recommendations of the Agricultural Research Council (ARC), 1980, (Larcombe, 1990).

The program also stores results from several simulations, which can be compared graphically by pairs. For each 10-day period, net pasture accumulation rates, herd feed intakes, milk production, body condition, and farm income are available for analysis using 50 graphics screens. The model also offers an optimization module where an optimal alternatives can be calculated. This enables the results to be compared and analyzed to obtain a guide for adjustment of the management of the farms according to the new milk payment implemented by TMP in 1994/95. UDDER has already been used to represent the events on a dairy farm under New Zealand conditions (Lewis, Neil and Phillips, 1992; McLean, 1993).

4.3. Description of the farms

4.3.1. Farm A

Farm A is located 5km from Foxton, in the Manawatu region (Figure 4.1 pg 99). The farm consists of 162 hectares of which 132 ha are used for milking, divided into 58 paddocks. Olsen P levels in July 1992 were approximately 25-30 units. The climate is characterised by cold, wet winters and warm, dry summers. The area receives approximately 880 mm of rainfall per year, and is very susceptible to summer drought.

The topography is flat; soil types are Pukepuke Black, Himatangi, and Hokio Sands with a moderately low water table and heavy textured sub-soils which impede drainage during the winter. The majority of the farm offers good drainage.

Herd size is 285 milking cows, wintered, predominantly Friesian (80%) and Jersey (20%) with an average Breeding Index (BI) of 127. Calving starts on July 15 with a mean calving date of August 9, a spread of ten weeks. Mating commences in mid-October, with the cows dried-off in the first week of May.

Production levels for the 1992-93 season were 275 kg milksolids per cow, 564 kg milksolids per hectare, with a total milksolids production of 74,500 kg. Comparing the farm with average figures for the district, production per cow and per hectare are very similar, even though farm and herd size are larger than the average (Table 4.1 pg. 98).

4.3.2. Farm B

Farm B is located at Rongotea, 30 km from Palmerston North, in the Manawatu region (Figure 4.1 pg 99). The farm consists of 94 hectares, of which 90 ha are used for milking divided into 49 paddocks. Olsen P levels in July 1991 were approximately 38 units. The climate is characterised by wet winters and dry summers. The area receives approximately 1000 mm of rainfall per year, and is susceptible to a summer dry period.

The topography is flat; soil type is a Tokomaru Silt Loam with a moderately high water table and heavy textured sub-soils which impede drainage. There is also a Rongotea Peaty Loam, a yellow brown earth with slow drainage.

Herd size is 225 milking cows wintered, predominantly Friesian with an average BI of 128. Calving starts on July 20 with a mean calving date of August 10, spread over nine weeks. Mating commences at the beginning of October and cows are dried-off in the first week of May.

Production levels for the 1992-93 season were 285 kg milksolids per cow, 715 kg milksolids per hectare, with a total milksolids production of 64,556 kg. Comparing Farm B with average figures for the district shows that production per cow is similar, whereas production per hectare is significantly higher, Even though farm size was only 18 ha larger, herd size was 51 cows larger than the average (Table 4.1 pg 98).

4.3.3. Farm C

Farm C is located near Eketahuna, in the Eketahuna region (Figure 4.1 pg 99). The farm consists of 80 hectares of which 70 ha are used for milking divided into 40 paddocks. Olsen P levels in July 1992 were 17 units. The climate is characterised by cold winters and wet summers. The area receives approximately 1800 mm of rainfall per year.

The topography is rolling country; soil type is Manawatu Silt Loam with a moderately high water table and heavy textured sub-soils which impede drainage. There is also a Dannevirke Silt Loam, a yellow brown earth which is moderately flat with slow drainage. Most of the home farm has been drained.

Herd size is 150 milking cows wintered, predominantly Holstein with an average BI of 127. Calving starts on August 10 with a mean calving date in late August-early September, spread over ten-weeks. Mating commences on November 1. Drying-off occurs during the first week of July.

Production levels for the 1992-93 season were 263 kg milksolids per cow, 537 kg milksolids per hectare, with a total milksolids production of 37,630 kg. Comparing the farm with average figures of the district production shows that per cow and per hectare, and farm and herd size are similar to the district, average (Table 4.1 pg 98).

4.3.4. Farm D

Farm D is located 5 km from Greytown, in the Wairarapa region (Figure 4.1 pg 99). The farm consists of 154 hectares (56 ha owned, 98 ha leased) of which 140 ha are used for milking divided, into 34 paddocks, with the leased block less intensively developed. Olsen P levels in July 1992 were between 8 and 14 units. The climate is characterised by a wet winters and dry summers. The area receives approximately 1100 mm of rainfall per year, and is susceptible to dry summers.

The topography is flat, soil type is an Arlington Silt Loam with a moderately high water table and heavy textured sub-soils which impede drainage. There is also a Raumati Silt Loam, a yellow brown earth which is moderately flat with slow drainage. Most of the home farm has been drained.

Herd size is 265 milking cows wintered, predominantly Jersey (80%) and Holstein (20%) with an average BI of 127. Calving starts on the July 14 with a mean calving date at the end of July, a spread over ten weeks. Mating commences on October 9. Cows are dried-off at the beginning of April.

Production levels for the 1992-93 season were 237 kg milksolids per cow, 448 kg milksolids per hectare, with a total milksolids production of 69,000 kg.

Comparing the farm with average figures for the district shows that production per cow and per hectare are lower for Farm D, whereas farm and herd size are larger than the district average (Table 4.1 pg 98).

Table 4.1. Comparison between district averages and the farm and herd size, and milksolids production.

	Farm				District Average			
	A	B	C	D	A	B	C	D
Farm size	132	90	70	140	82	72	69	88
Herd size	285	225	150	265	175	174	152	192
Milksolids								
per cow	275	285	263	237	279	279	266	261
per hectare	564	717	537	448	611	682	586	591

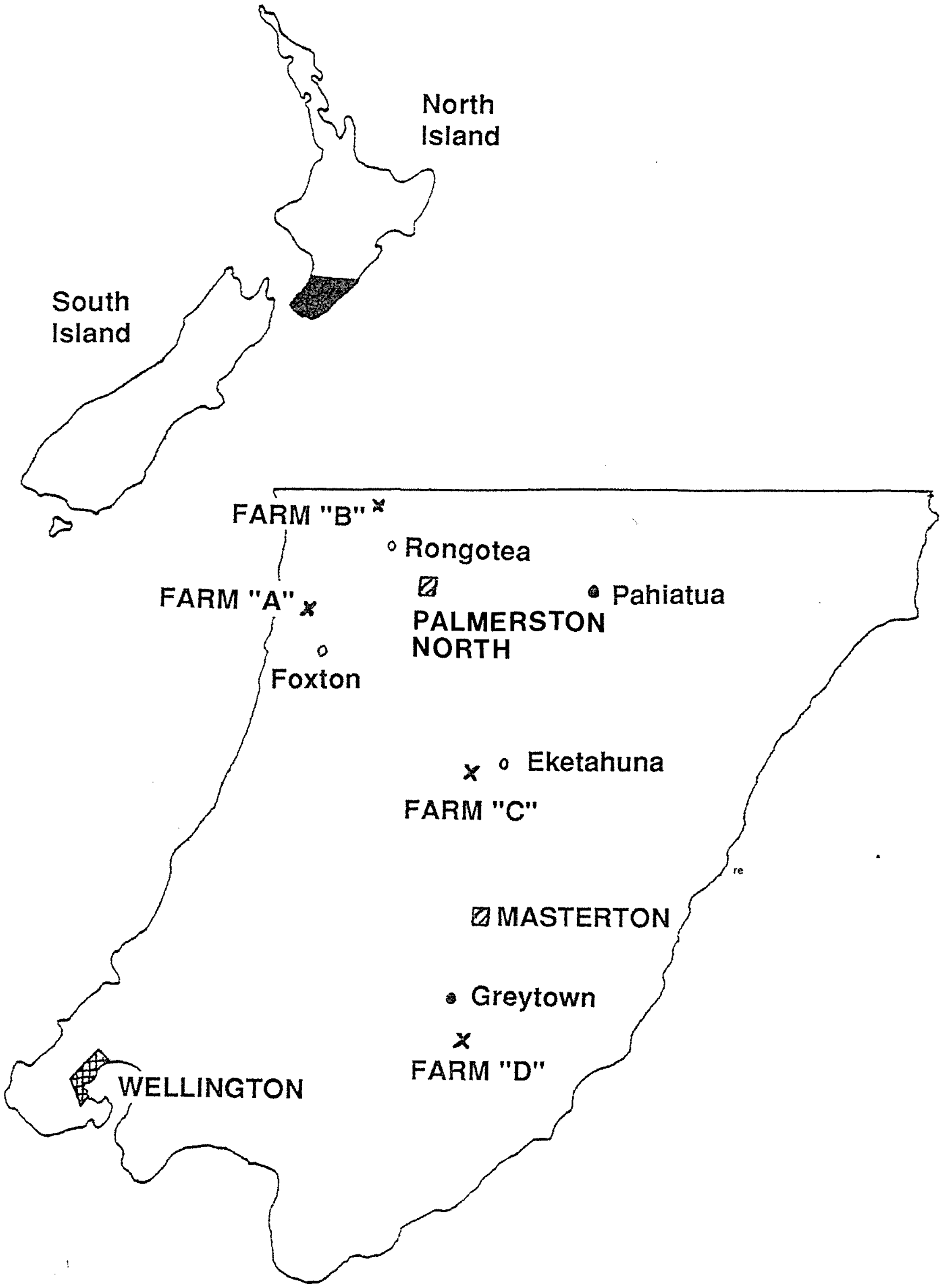

Figure 4.1. Map of the Manawatu, Eketahuna and Wairarapa regions showing locations of farms A, B, C and D.

4.4. Method of study

To achieve the stated objectives, it is necessary to have an overview of the New Zealand dairy industry. This was achieved by studying its development, and its situation as of 1993, at both national and international levels, describing the milk payment system for 1993, and the seasonal milk payment system proposed by TMP.

The process of the research can be summarised in four steps:

- The extension department of TMP was contacted in order to obtain their approval and support to work with some of their suppliers.
- Four farms from the "focus farms" programme of the company were chosen because of their location and the information available.
- The information was obtained from the farmers and was verified with the consultants.
- Several management alternatives were evaluated and defined using the simulation model (UDDER) as a guide for maximising gross margins.

Information about the management of the farms for the 1992/93 season was collected and verified. Subsequently, the data were loaded into UDDER to simulate the actual situation for the 1992/93 season. This simulation was carried out to verify the predictions given by the model in relation to the actual data. The variables studied during the verification process were the average pasture cover, body condition score, and milk production. When the initial predictions did not matched with the actual data, a tuning of the pasture allocation (rotation lengths and fodder conservation strategies) and supplementary feeding were necessary. Further, the stock reconciliation, animal live weight, condition score at calving, initial pasture cover and milk composition were also reviewed and adjustments made.

The verification process involved returning to the consultants associated with each farm to review the accuracy of the initial data, which in several cases required adjustment.

Some of the internal parameters were also adjusted in order to match environmental effects with farm performance.

After the actual simulation had been verified, then several different management strategies were studied. Simulation of the actual situation was modified on yearly runs to identify an improved management strategy in order to obtain higher gross margins per farm.

Evidence from the literature review shows that stocking rate, calving and drying-off dates, use of supplements, and the application of fertilizer are factors of major relevance to farm management. These were grouped together in two main groups: animal factors, and feeding and fertilizer factors.

Animal factors included:

- Calving Date and Drying-off Dates
- Stocking Rate

Feeding and fertilizer factors included:

- Concentrate Feeds
- Supplementary Feeds
- Nitrogen Application

The process of obtaining an improved strategy, is explained as follows:

- Start of calving dates were the first variables to be manipulated, using three different dates: the current date, advancing calving by 10 days, and delaying calving on by 10 days. While calving dates were shifted, the calving patterns of the actual system were maintained. After defining calving dates, drying-off dates were also manipulated.

- The next variable to be changed was the number of animals in the farm (stocking rate), which was manipulated in order to improve the farm gross margin.

- Finally, concentrates, supplements and nitrogen were varied, simultaneously, in order to improve gross margins.

The simulations as listed below were then compared with the actual situation.

Actual Strategy, which represents the simulation of the actual situation.

Current Strategy, which involves keeping the same calving dates, and changing all other management variables.

Early Strategy, which involves advancing calving date by 10 days, and changing all other management variables.

Late Strategy, this strategy involves delaying calving date by 10 days, and changing all other management variables.

Throughout all simulations, it was considered that both the animals and the pastures would not deteriorate into critical conditions. In addition, average pasture cover for the beginning and the end of the season were similar to the ones obtained from the actual farm information. The simulations were manipulated in such a way that the behaviour of its elements were kept close to actual levels. Appendix 1 shows the assumptions taken on the supplement details, responses to nitrogen application, and the prices involved in the inputs and outputs in the farm.

CHAPTER 5

RESULTS

In this chapter, results for all the farms are presented, considered major elements in pastoral dairy farming. More detailed information is presented in Appendices 2, 3, 4 and 5, for farms A, B, C and D, respectively.

5.1. Farm A

5.1.1. Herbage Accumulation Rate (HAR)

Herbage accumulation rates (HAR) for the four strategies are shown in Figure 5.1. During April and May, HAR for the "actual" strategy was lower than for the other three strategies. Over the first nine months (July to March), pasture growth seemed not to be affected by different strategies or their respective spring and winter nitrogen applications. There were differences between strategies in winter nitrogen applications (Table 5.1).

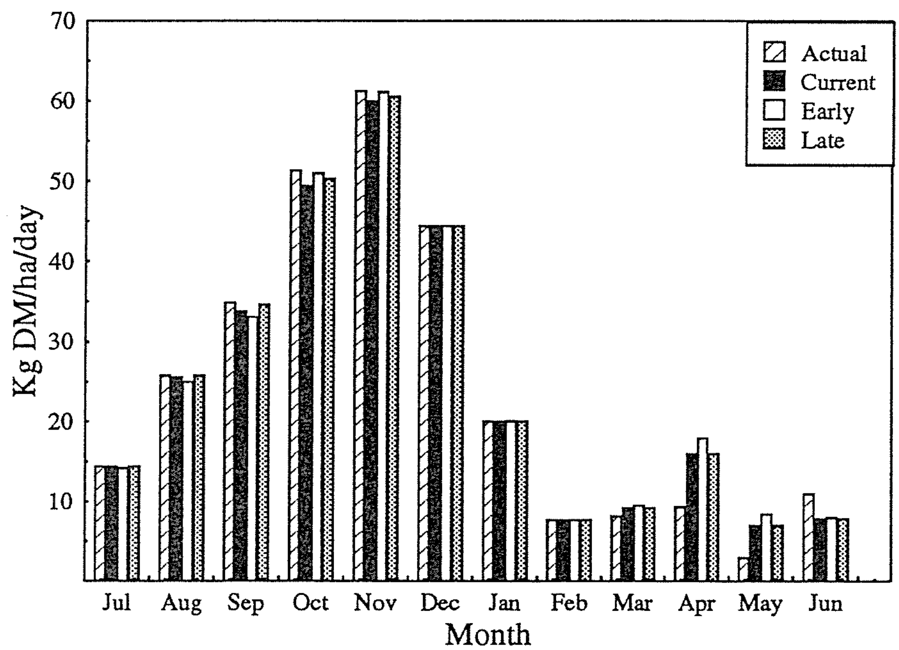

Figure 5.1. Effects of the different strategies on herbage accumulation rate in farm A

HAR during April and May for the "current", "early" and "late" strategies seemed to be higher, probably as a result of the different nitrogen applications over the autumn. However, June's HAR seemed to be higher for the "actual" strategy than for the other three strategies (Table 5.1). This difference in HAR probably occurred because, in the "actual" strategy, winter nitrogen applications were higher.

Table 5.1. Nitrogen application during spring, autumn, and winter. Estimated herbage accumulation rates during April, May, and June

Strategy	Nitrogen application (kg N/ha)				Herbage accumulation rate (kg DM/ha/day)		
	Spring	Autumn	Winter	Year	April	May	June
Actual	11	13	33	57	9.3	2.9	10.8
Current	0	40	9	49	16.0	7.0	7.8
Early	10	50	10	70	17.8	8.4	7.8
Late	5	40	10	55	16.0	7.0	7.9

Total pasture accumulation, pasture utilization rates, and stocking rates are shown in Table 5.2. It can be seen that pasture utilization was higher as SR increased.

Table 5.2. Total pasture accumulation, pasture utilization, and stocking rate for the "actual", "current", "early", and "late" strategies

Strategy	Total Pasture Accumulation (t DM/ha/year)	Pasture Utilization (%)	Stocking Rate (cows/ha)
Actual	8.7	88.2	2.15
Current	8.8	92.6	2.27
Early	9.0	91.0	2.21
Late	8.9	91.8	2.30

5.1.2. Average Pasture Cover (APC)

Average pasture cover (APC) for the four strategies is shown in Figure 5.2. Major differences between strategies in pasture cover appeared at the beginning and end of the season. At the end of September the simulation values for the "early" calving strategy reached the lowest APC of any strategy at any time (1,557 kg DM/ha), while the other strategies had APC of 1,825, 1,737 and 1,919 kg DM/ha for the "actual", "current", and "late" strategies, respectively.

APCs were similar during mid-lactation on all four strategies, with the highest cover for each strategy being achieved at the end of December. During autumn and early winter the "early" strategy had the highest covers, whereas the "actual", "current" and "late" strategies had similar APCs. This difference could be due to: APC in spring (September) could be affected by APC at calving; pasture growth over spring; or the extra growth could result from nitrogen application.

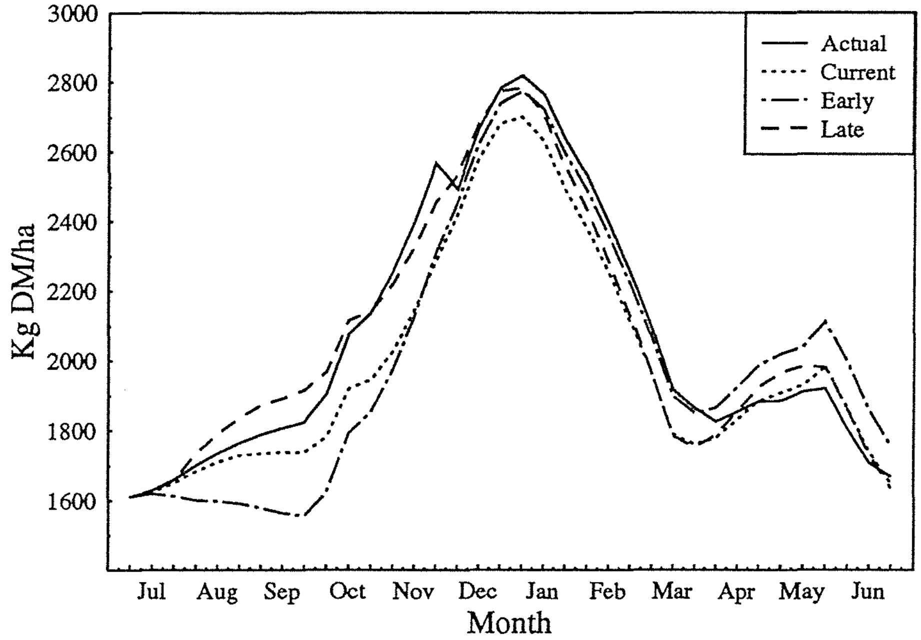

Figure 5.2. Effects of the different strategies on average pasture cover in farm A

APC at calving date for the four strategies is shown in Table 5.3. "Actual", "current" and "early" strategies were lower than the "late" strategy. Further, APC at calving in the "actual", "current" and "early" strategies were similar.

Table 5.3. Average pasture cover and condition score at planned start of calving for Farm A

Strategy	Period of planned start of calving (dates)	Average pasture cover (APC) (kg DM/ha)	Condition Score (units)
Actual	11-07	1,630	4.9
Current	11-07	1,625	4.9
Early	01-07	1,612	4.8
Late	21-07	1,734	5.0

5.1.3. Condition Score (CS)

Condition score (CS) for the four strategies is shown in Figure 5.3. CS tended to drop towards the end of the summer. In addition, the CS estimated in the simulation was similar for all the strategies with a variation of less than 0.3 units. It can also be seen that CS for the "late" strategy was higher in spring, and lower during autumn and winter.

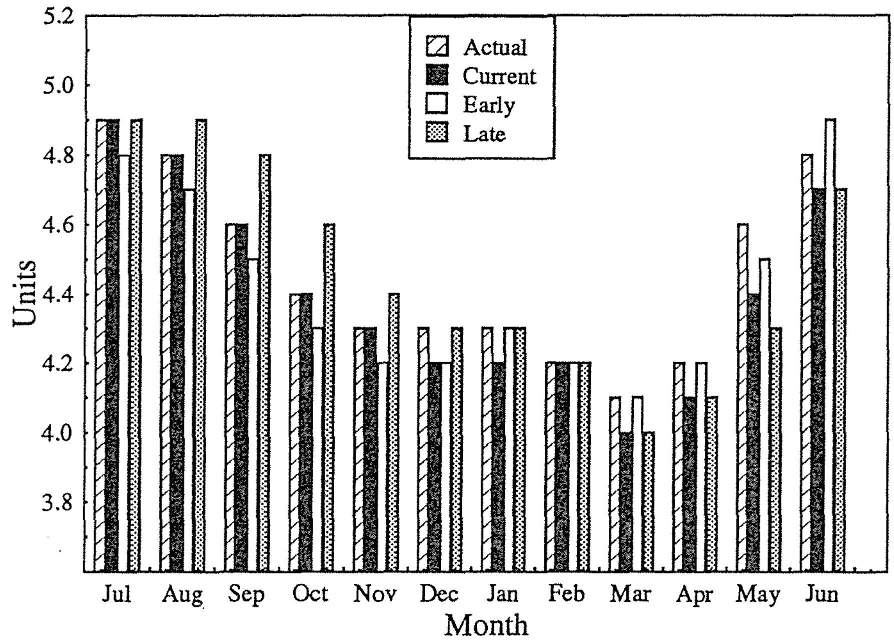

Figure 5.3. Effects of the different strategies on condition score per cow in farm A.

5.1.4. Daily Milksolid Production

Average milksolids production per cow for the four strategies are shown in Figure 5.4. The "early" calving strategy tended to have a higher production than the "actual" strategy (Table 5.4). The variations between strategies can be attributed to lactation lengths and better feed allocation.

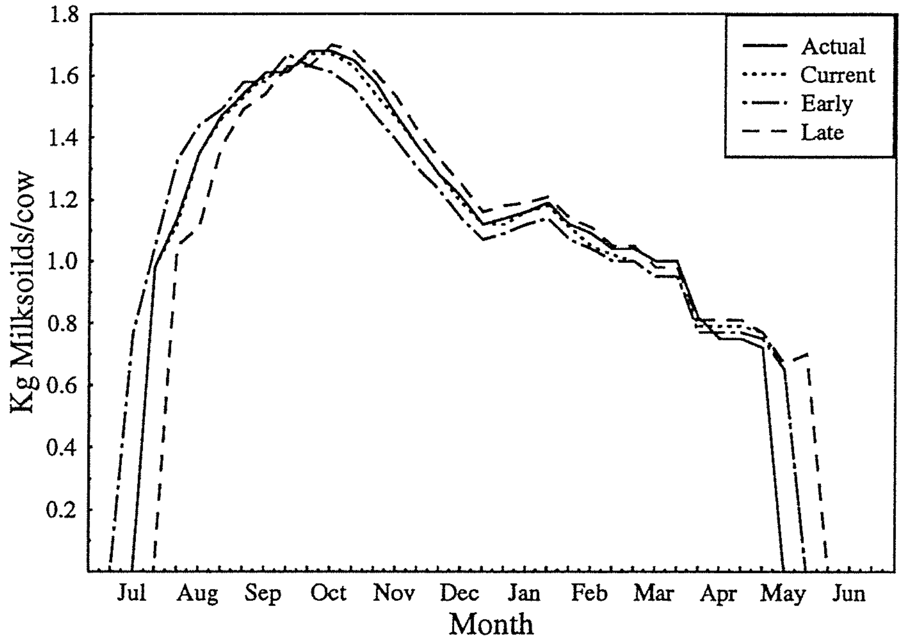

Figure 5.4. *Effects of the different strategies in milk production per cow for Farm A.*

Table 5.4. *Total milk production for the "actual", "current", "early", and "late" strategies for farm A*

Strategy	Actual	Current	Early	Late
Milksolids/farm	79,872	82,967	83,051	82,232
Milksolids/ha	605	629	629	623
Milksolids/cow	280	277	284	270
Days in milk	219	215	226	208

Milk production per farm for the four strategies is shown in Figure 5.5. Milk production was higher for the "early" strategy, followed by the "current" and "late" strategy, with the "actual" strategy having the lowest production (Table 5.4). The reasons for the higher production in the "current", "early" and "late" strategies could be due to a higher stocking rate, a better feed allocation and the use of nitrogen fertiliser.

The differences in total farm production relative to the "actual" strategy were 3,095, 3179, and 2,360 kg MS/farm for the "current", "early" and "late" strategies, respectively. Total production over the peak months (October and November) varied as follows: 24,760 (31%), 24,890 (30%), 23,254 (28%), and 23,847 (29%) kg MS per farm for the "actual", "current", "early" and "late" strategies, respectively.

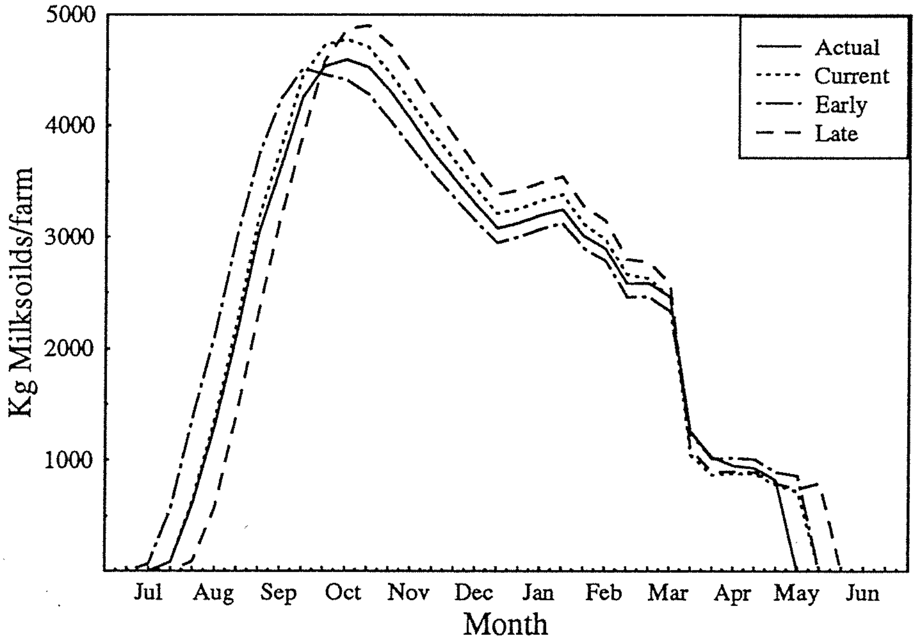

Figure 5.5. *Effects of the different strategies in total milk production per farm for Farm A*

5.1.5. Physical Performance

A summary of the physical performances for the four strategies is shown in Table 5.5. Animal feed and nitrogen use are also shown. Concentrates were not used in the "actual" strategy, nor did they seem to be profitable in any of the other strategies. The quantity of supplements fed were lower for the "current", "early" and "late" strategies, in relation to the "actual" strategy. Supplement feeding for the "early" strategy was spread over autumn (March and April) offering 0.5 kg DM/cow/day, compared with the "actual" strategy where supplements were offered at a rate of 5 kg DM/cow/day only during April.

It appeared that the increase in stocking rate (SR) was directly related to net pasture used. The "early" strategy had the highest use of nitrogen of all the strategies, while the "current" and "late" strategies had lower applications than the "actual" strategy.

Table 5.5. A summary of the physical performance of the "actual", "current", "early" and "late" strategies for farm A

Strategy	Actual	Current	Early	Late
Area (ha)	132	132	132	132
Cows milked	285	300	292	304
Stocking Rate (cows/ha)	2.15	2.27	2.21	2.30
Net pasture used (t DM/ha)	7.7	8.2	8.2	8.2
Feed concentrate (t DM)	0	0	0	0
Supplements used (t DM)	36.9	23.2	20.7	29.9
Hay used (t DM)	42.4	44.6	40.5	46.6
Nitrogen used (t of N)	7.6	6.5	9.2	7.3
Dry matter cut (t DM)	62.5	56.4	54.7	62.3

5.1.6. Financial Performance

A summary of the financial performance of the four strategies is shown in Table 5.6. Total milk and farm income tended to be lower for the "actual" strategy, while the "early" strategy had the highest income. Supplements, hay and nitrogen costs varied in a similar way to the physical performance of the strategies (Table 5.5). Herd costs tended to be higher for the "current", "early" and "late" strategies, as a result of the higher number of cows milked. The "early" strategy showed the highest gross margin per farm, per cow and per hectare.

Table 5.6. Financial performance of the "actual", "current", "early" and "late" strategies for farm A

Strategy	Actual ($)	Current ($)	Early ($)	Late ($)
Milk income	291,986	303,828	304,606	299,944
Total farm income	321,136	334,002	334,226	331,274
Farm expenses:				
Supplements fed	9,516	7,491	6,261	8,742
Nitrogen	7,624	6,468	9,240	7,260
Herd costs	99,750	105,000	102,200	106,400
Total farm costs	116,890	118,959	117,701	122,402
Farm gross margin	204,246	215,043	216,525	208,872
Gross margin/cow	717	717	742	687
Gross margin/ha	1,547	1,629	1,640	1,582

Table 5.7. shows the difference in gross margin between the "actual" strategy and the "current", "early" and "late" strategies. The "early" strategy had the highest margin, closely followed by the "current" strategy, with the "late" strategy having the lowest margin.

Table 5.7. Difference in gross margin between the "actual" strategy and the "current", "early" and "late" strategies for farm A

Strategy	Current ($)	Early ($)	Late ($)
Net farm margin	10,797	12,279	4,626
Net margin per cow	36	41	15
Net margin per hectare	82	93	35

5.2. Farm B

5.2.1. Herbage Accumulation Rate (HAR)

Herbage accumulation rates (HAR) for the four strategies are shown in Figure 5.6. During December and January the "actual" strategy showed higher HAR than the other three strategies. It appeared that, over the first five months (July to November) of the season, pasture growth was not affected by different strategies nor by their spring nitrogen applications. Winter nitrogen was applied only in the "actual" strategy (Table 5.8.). HAR dropped to less than 5 kg DM/ha/day in February in all strategies. During March and April in the "early" strategy HAR was higher than the other three strategies, whereas, in May HAR for the "late" strategy was the highest. During June all the strategies showed similar HARs.

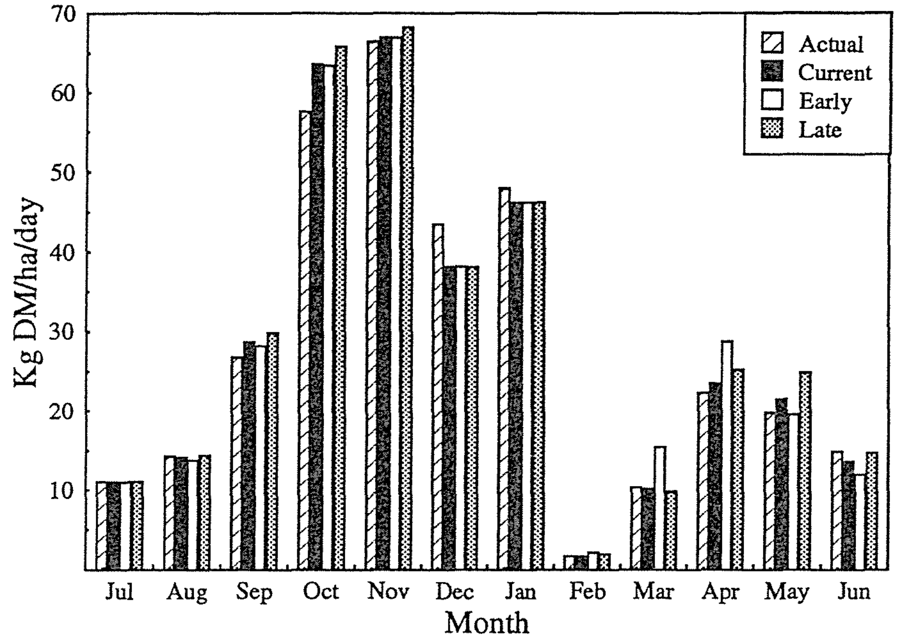

Figure 5.6. Effects of the different strategies on herbage accumulation rate in Farm B

HAR for the "actual" strategy during December and January seemed to be higher, because of higher nitrogen applications over the late spring (Table 5.8). The drop in herbage accumulation in February coincides with the period when some paddocks were deferred, where probably rates of senescence and decay of the pasture were higher at high herbage mass.

HAR for the "early" strategy during April and for the "late" strategy during May seemed to be higher, probably as a result of the different nitrogen applications rate over the autumn (Table 5.8).

Table 5.8. Nitrogen application during spring, autumn and winter. Estimated herbage accumulation rates during March, April and May

	Nitrogen application (kg N/ha)				Herbage Acc. Rate (kg DM/ha/day)		
	Spring	Autumn	Winter	Year	March	April	May
Actual	36	20	15	71	10.3	22.3	19.8
Current	40	30	0	70	10.1	23.5	21.5
Early	40	50	0	90	15.4	28.7	19.5
Late	50	50	0	100	9.8	25.1	24.6

Total pasture accumulation, pasture utilization rates and stocking rates are shown in Table 5.9. It can be seen that pasture utilization was higher as SR increased.

Table 5.9. Total pasture accumulation, pasture utilization and stocking rate for the "actual", "current", "early" and "late" strategies

Strategy	Total Pasture Accumulation (t DM/ha/year)	Pasture Utilization (%)	Stocking Rate (cows/ha)
Actual	10.1	85.1	2.50
Current	10.1	86.4	2.55
Early	10.3	86.3	2.55
Late	10.5	85.6	2.55

5.2.2. Average Pasture Cover (APC)

Average pasture cover (APC) for the four strategies is shown in Figure 5.7. Major differences in pasture cover between strategies appeared during the spring and late autumn-early winter months. At the end of August, the simulation values for the "early" strategy reached the lowest APC (1,321 kg DM/ha) of any strategy at any time. During December, all strategies achieved their highest APC and showed the largest differences between strategies. These APC were, 2,625, 2,765, 2,752, and 2,913 kg DM/ha for the "actual", "current", "early" and "late" strategies, respectively.

APCs were similar during mid-lactation for all four strategies. During autumn the "actual" and "early" strategies had the highest APC, while during early winter the "actual" and "late" strategies had the highest cover, probably due to the extra growth from nitrogen application.

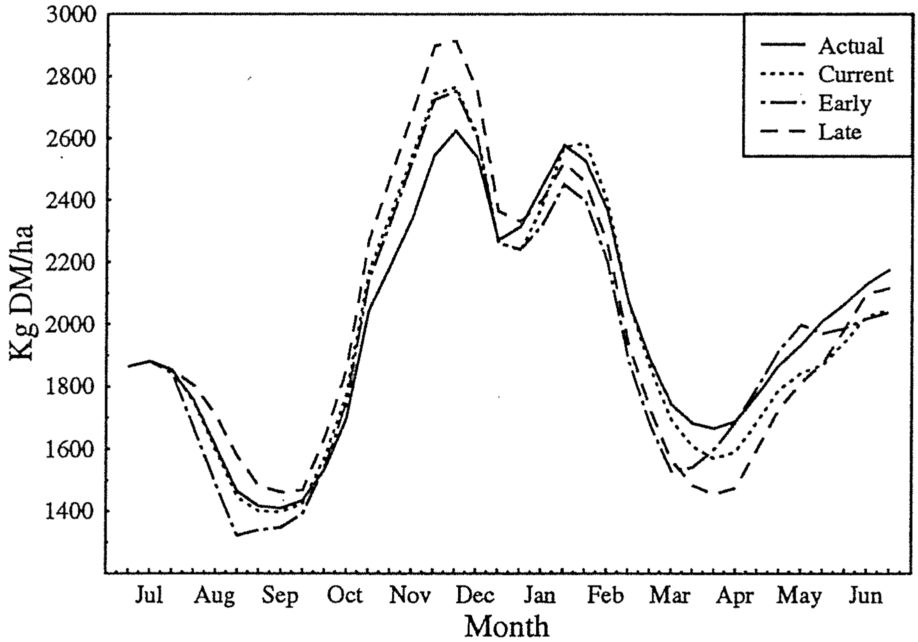

Figure 5.7. Effects of the different strategies on average pasture cover for Farm B

APC at calving date for the four strategies is shown in Table 5.10, where only small differences between strategies are evident.

Table 5.10. Average pasture cover and condition score at planned start calving for Farm B

Strategy	Period of planned start of calving (dates)	Average pasture cover (APC) (kg DM/ha)	Condition Score (CS)
Actual	11-07	1,882	4.5
Current	11-07	1,882	4.5
Early	01-07	1,864	4.5
Late	21-07	1,853	4.6

5.2.3. Condition Score (CS)

Condition scores (CS) for the four strategies are shown in Figure 5.8. CS tended to drop during spring. In addition, it seems that CS was similar for all the strategies with a differences of less than 0.4 units, with the exception of the "early" and "late" strategies in September and October, which showed differences of 0.7 and 0.5 units, respectively. It should also be noted that, in comparison to Farm A, CSs on Farm B are markedly lower, but given that CS is measured subjectively, they cannot be compared directly, unless both groups of animals are assessed under the same conditions.

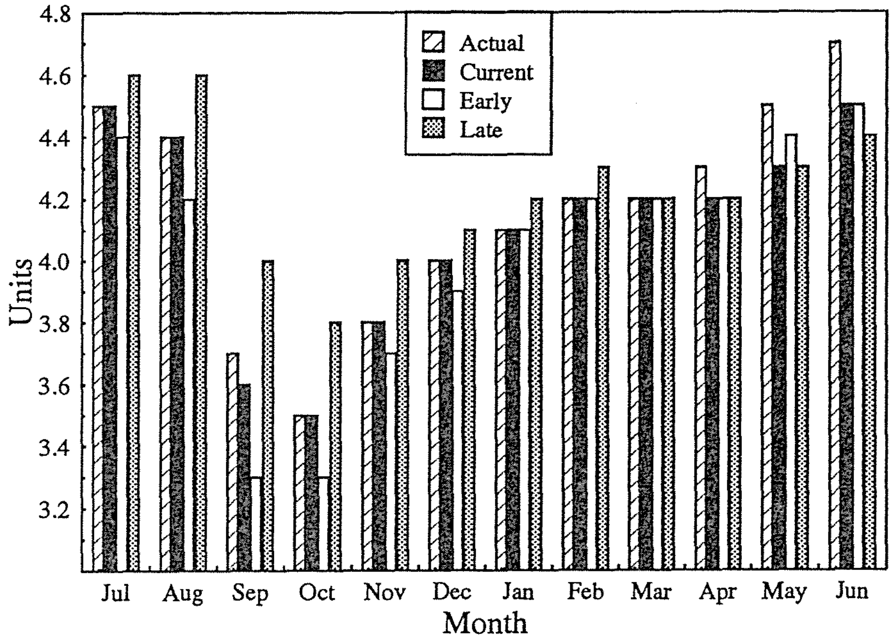

Figure 5.8. Effects of the different strategies on condition score per cow for Farm B

5.2.4. Milk Production

Average milksolids per cow for the four strategies are shown in Figure 5.9. The "late" calving strategy tended to have a higher production as compared with the "actual" strategy (Table 5.11). The variations between strategies can be attributed to the combination of lactation lengths and better feed allocation.

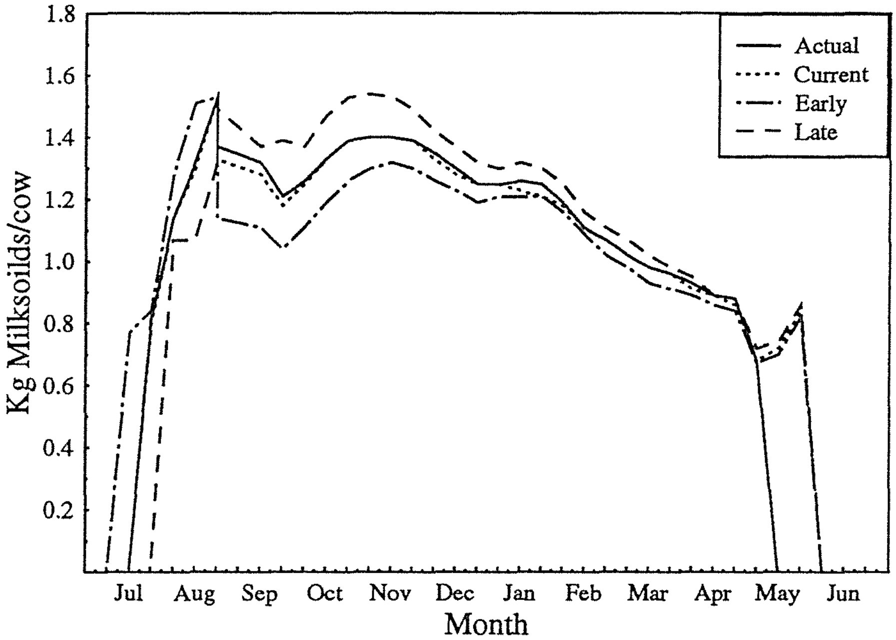

Figure 5.9. *Effects of the different strategies on milk production per cow for Farm B*

Table 5.11. *Total milk production for the "actual", "current", "early" and "late" strategies for Farm B*

	Actual	Current	Early	Late
Milksolids/farm	64,556	67,312	65,785	67,631
Milksolids/ha	717	747	730	751
Milksolids/cow	287	292	286	294
Days in milk	238	248	254	235

Average milk production per farm for the four strategies is shown in Figure 5.10. Milk production was higher for the "late" calving strategy, followed by the "current" and "early" strategies, with the "actual" strategy having the lower production (Table 5.11). The reasons for higher production in the "current", "actual" and "early" strategies is possibly because as a result of a higher stocking rate, better feed allocation and the use of nitrogen fertiliser.

The differences in total farm production relative to the "actual" strategy were 2,756, 1,202, and 3,075 kg MS/farm for the "current", "early" and "late" strategies, respectively. Total production over the peak months (October and November) varied 18,140 (28.1%), 18,578 (27.6%), 17,169 (26.1%), and 20.221 (29.9%) for the "actual", "current", "early" and "late" strategies, respectively.

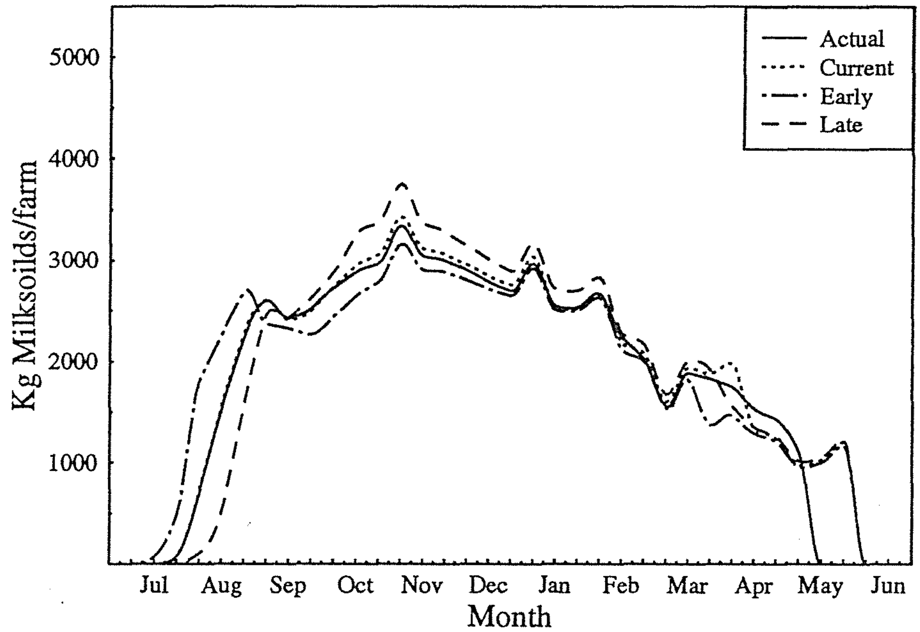

Figure 5.10. Effects of the different strategies in total milk production per farm for Farm B

5.2.5. Physical Performance

A summary of the physical performance for the four strategies is shown in Table 5.12. Animal feed and nitrogen use are also shown. Concentrates were not used in the "actual" strategy, nor did they seem to be profitable in any of the other strategies. The amount of supplements fed were lower for the "early" and "late" strategies, in relation to the "actual" and the "current" strategies. Supplement feeding for the improved strategy was over the late summer-early autumn offering 3, 4 and 5 kg DM/cow/day during February, March and April, respectively, compared with 4, 5 and 5 kg DM/cow/day during February, March and April, respectively, in the "actual" strategy.

It appeared that the increase in SR was directly related to net pasture used. The "early" and "late" strategies had the highest use of nitrogen of all the strategies, while the "current" strategy had lower applications than the "actual" strategy.

Table 5.12. A summary of the physical performance of the "actual", "current", "early" and "late" strategies for Farm B

	Actual	Current	Early	Late
Area (ha)	90	90	90	90
Cows milked	225	230	230	230
Stocking rate (cows/ha)	2.50	2.55	2.55	2.55
Net pasture used (t DM/ha)	8.6	8.8	9.0	9.0
Feed concentrate (t)	0	0	0	0
Supplements used (t)	75.1	78.6	51.6	60.5
Hay used (t)	10.1	10.4	10.4	10.4
Nitrogen used (t of N)	6.5	6.3	8.1	9.0
Dry matter cut (t)	53.7	56.0	55.6	58.5

5.2.6. Financial Performance

A summary of the financial performance of the four strategies is shown in Table 5.13. Total milk and farm gross margin tended to be lower for the "actual" strategy. The "late" strategy had the highest income. Supplements, hay and nitrogen costs varied in a similar way to the physical performance of the strategies (Table 5.12). Herd costs tended to be higher for the "current", "early" and "late" strategies, as a result of the higher number of cows milked. The "late" strategy showed the highest gross margin per farm, per cow and per hectare.

Table 5.13. Financial performance of the "actual", "current", "early" and "late" strategies for Farm B

	Actual ($)	Current ($)	Early ($)	Late ($)
Milk income	236,941	247,207	242,015	247,723
Total farm income	269,981	280,857	275,665	281,373
Farm expenses:				
Supplements fed	13,076	13,660	7,230	8,992
Nitrogen	6,460	6,300	8,100	9,000
Herd costs	78,750	80,500	80,500	80,500
Total farm costs	98,286	100,460	95,830	98,492
Farm gross margin	171,695	180,397	179,835	182,882
Gross margin/cow	763	784	782	795
Gross margin/ha	1,908	2,004	1,998	2,032

Table 5.14 shows the difference in gross margin between the "actual" strategy and the "current", "early" and "late" strategies. The "late" strategy had the highest margin, closely followed by the "current" strategy, with the "early" strategy having the lowest margin.

Table 5.14. Difference in gross margin in relation to the "actual" strategy for the "current", "early" and "late" strategies for Farm B

	Current ($)	Early ($)	Late ($)
Net farm margin	8,702	8,140	11,187
Net margin per cow	21	19	32
Net margin per hectare	97	90	124

5.3. Farm C

5.3.1. Herbage Accumulation Rates (HAR)

Herbage accumulation rates (HAR) for the four strategies are shown in Figure 5.11. During August, September and October, HAR for the "actual" strategy was lower than for the other three strategies. Over the rest of the season, pasture growth seemed not to be affected by different strategies or their respective spring, autumn and winter nitrogen applications. There were differences between strategies in winter nitrogen applications (Table 5.15).

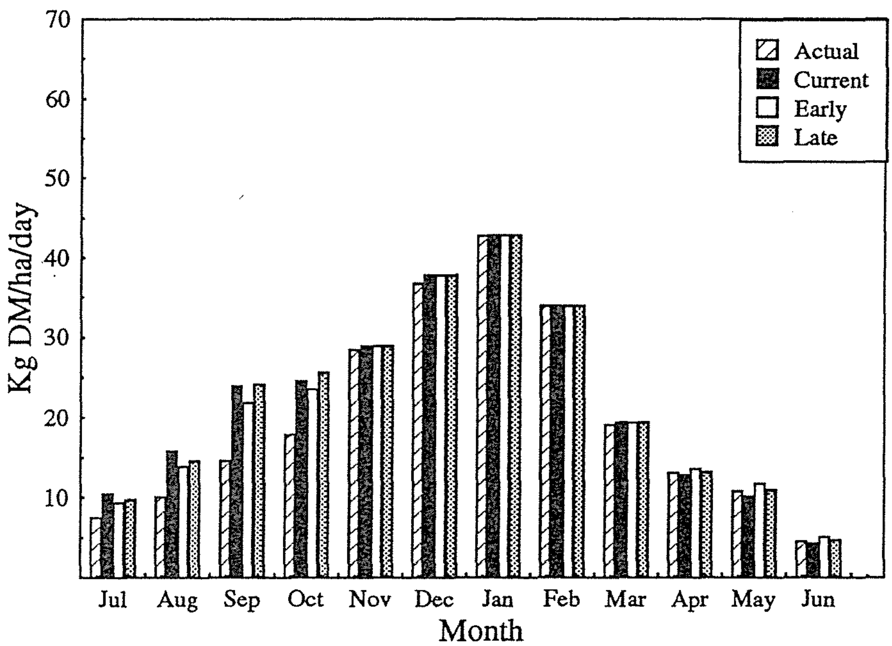

Figure 5.11. Effects of the different strategies on herbage accumulation rate for Farm C

HAR during August, September and October for the "current", "early" and "late" strategies seemed to be higher, probably as a result of the different nitrogen applications (Table 5.15).

Table 5.15. Nitrogen application during spring, autumn and winter. Estimated herbage accumulation rates during August, September and October

	Nitrogen application (kg N/ha)				Herbage Acc. Rate (kg DM/ha/day)		
	Spring	Autumn	Winter	Year	Aug.	Sep.	Oct.
Actual	13	33	7	53	10.0	14.6	17.9
Current	45	30	50	125	15.8	23.8	24.5
Early	40	40	35	115	13.8	21.8	17.1
Late	50	35	40	125	14.6	24.0	25.6

Total herbage accumulation, pasture utilization rates and stocking rates are shown in Table 5.16. It can be seen that pasture utilization was higher as SR increased.

Table 5.16. Total herbage accumulation, pasture utilization and stocking rate for the "actual", "current", "early" and "late" strategies

Strategy	Total Herbage Accumulation (t DM/ha/year)	Pasture Utilization (%)	Stocking Rate (cows/ha)
Actual	7.1	98.0	2.21
Current	7.9	96.9	2.22
Early	7.8	98.0	2.22
Late	7.9	97.9	2.22

5.3.2. Average Pasture Cover (APC)

Average pasture cover (APC) for the four strategies is shown in Figure 5.12. All strategies show two peaks of APC, with the "actual" strategy showing the lowest APC of all strategies. This can be explained because N inputs in the actual strategy were at least half of the other strategies (Table 5.15).

During December, the APC estimated by the simulation of the "actual" strategy reached the lowest APC of any strategy at any time (1,627 kg DM/ha), while the other strategies had APC of 2,075, 1,920, and 2,068 kg DM/ha for the "current", "early" and "late" strategies, respectively. These differences could be due to the variation in growth resulting from different nitrogen application rates.

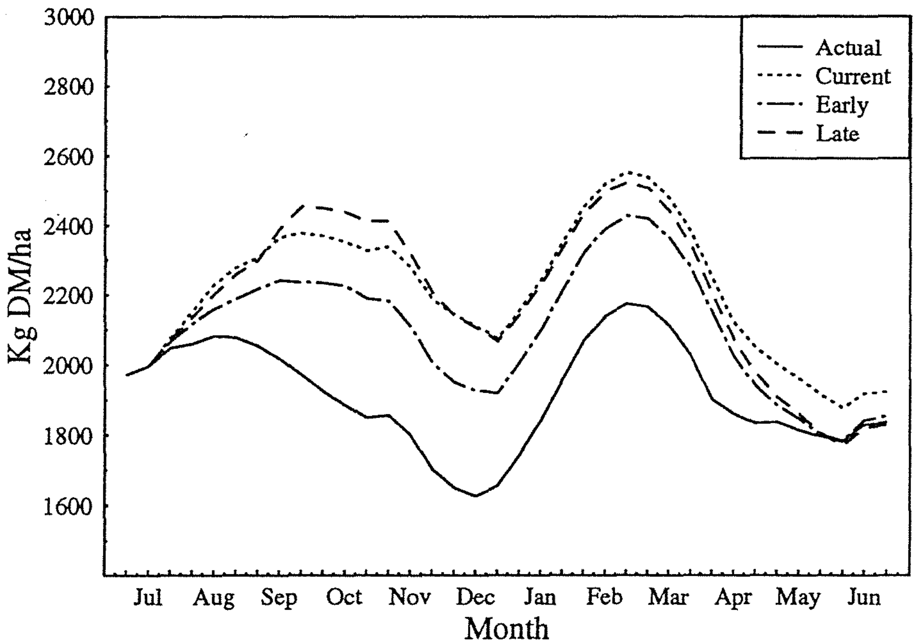

Figure 5.12. Effects of the different strategies on average pasture cover in Farm C

APC at calving date for the four strategies is shown in Table 5.17. Both CS and APC at calving were similar between strategies.

Table 5.17. Average pasture cover and condition score at planned start of calving for Farm C

Strategy	Period of planned start of calving (dates)	Average pasture cover (APC) (kg DM/ha)	Condition Score (units)
Actual	11-08	2,083	4.9
Current	11-08	2,231	5.0
Early	01-08	2,118	5.1
Late	21-08	2,260	5.1

5.3.3. Condition Score (CS)

Condition score (CS) for the four strategies is shown in Figure 5.13. CS tended to drop in spring. In addition, it seems that CS was similar for all the strategies with a variation of less than 0.3 units, with the exception of September and October, which showed differences of 0.6 and 0.5 units, respectively, when the "late" strategy showed the highest CSs. CS and APC at calving for each strategy are shown in Table 5.17.

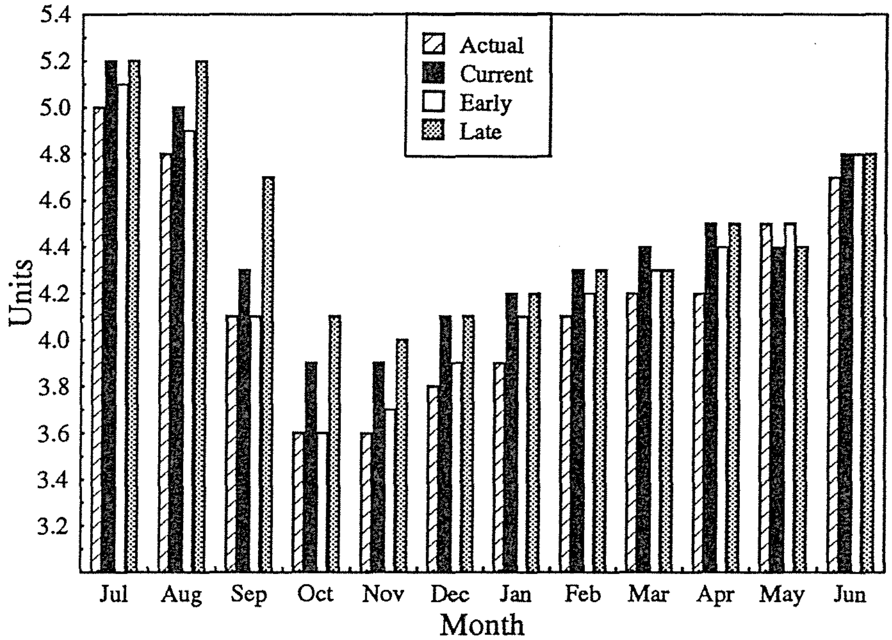

Figure 5.13. Effects of different strategies on average condition score per cow for Farm C

5.3.4. Milk Production

Average milksolids produced per cow for the four strategies are shown in Figure 5.14. The "current" and "late" strategies tended to have a higher production than the "actual" strategy (Table 5.18). Differences between strategies can be attributed to the combined effects of longer lactations, and better feed allocation.

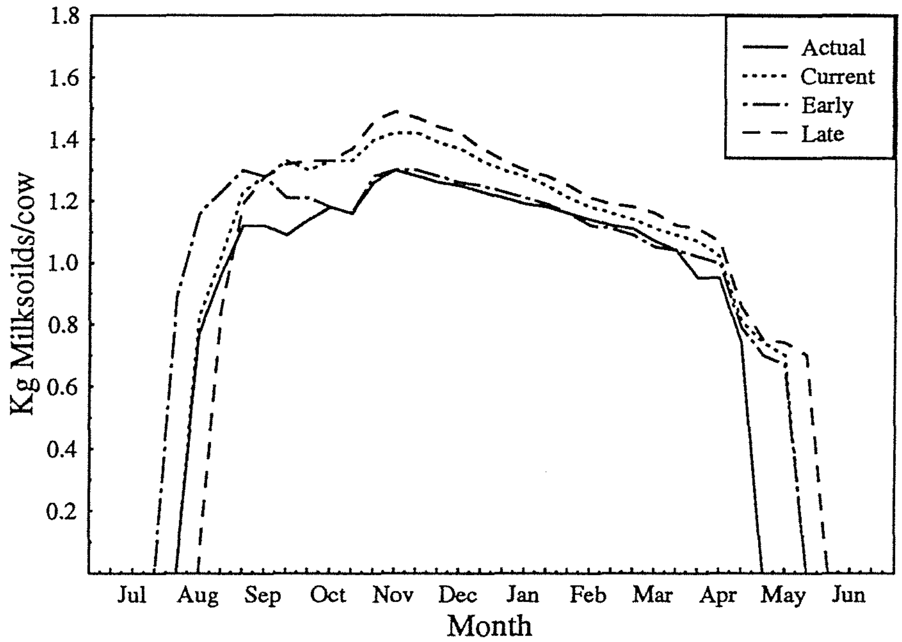

Figure 5.14. Effects of the different strategies on milk production per cow for Farm C

Table 5.18. Total milk production for the "actual", "current", "early" and "late" strategies for Farm C

	Actual	Current	Early	Late
Milksolids/farm	38,811	43,518	43,165	43,480
Milksolids/ha	554	622	619	620
Milksolids/cow	250	279	278	278
Days in milk	220	229	239	225

Milk production per farm for the four strategies is shown in Figure 5.15. Milk production was higher for the "current" strategy, followed by the "late" and "early" strategies, with the "actual" strategy having the lowest production (Table 5.18). These differences in production could be due to better feed allocation and the use of nitrogen fertiliser.

The differences in total farm production relative to the "actual" strategy were 4,707, 4,354, and 4,669 kg MS/farm for the "current", "early" and "late" strategies respectively. Total production over the peak months (October and November) varied as follows: 11,053 (28.5%), 12,498 (28.7%), 11,261 (26.0%), and 12,661 (29.1%) kg MS per farm for the "actual", "current", "early" and "late" strategies, respectively.

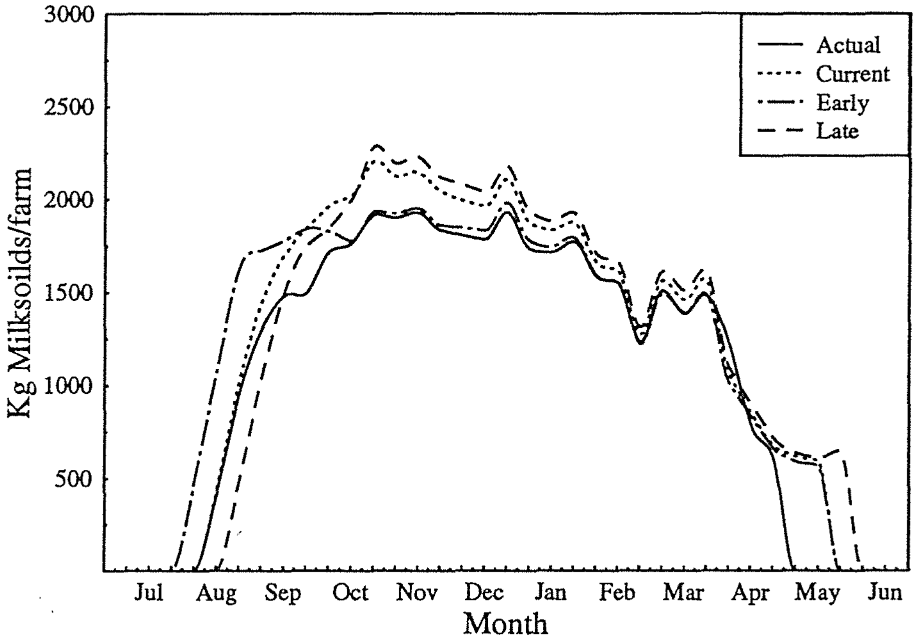

Figure 5.15. Effects of the different strategies on total milk production per farm for Farm C

5.3.5. Physical Performance

A summary of the physical performances for the four strategies is shown in Table 5.19. Animal feed and nitrogen use are also shown. Concentrates were only used in the "actual" and "current" strategies. The amount of supplements fed was similar for the "actual", "early" and "late" strategies, but lower for the "current" strategy. Supplements were fed for the "actual" strategy up to 1.5 kg DM/cow/day from August to November, while in the modified strategies supplement feeding was at 2 kg DM/cow higher during September. In the "early" and "late" strategies there were no supplements offered over the autumn. In addition, in the improved strategy, concentrates were not used during spring as in the "actual" strategy.

The increase in stocking rate (SR), which was similar on all strategies, appeared to be directly related to net pasture used. The "actual" strategy had the lowest use of nitrogen of all the strategies.

Table 5.19. Physical performance of the "actual", "current", "early" and "late" strategies for Farm C

	Actual	Current	Early	Late
Area (ha)	70	70	70	70
Cows milked	155	156	156	156
Stocking rate (cows/ha)	2.21	2.22	2.22	2.22
Net pasture used (t DM/ha)	7.1	7.7	7.7	7.7
Feed concentrate (t)	9.3	10.5	0	0
Supplements used (t)	22.3	14.1	19.4	14.0
Hay used (t)	35.6	34.0	32.7	32.9
Nitrogen used (t of N)	3.7	8.8	8.4	8.8
Dry matter cut (t)	8.0	11.9	10.6	13.3

5.3.6. Financial Performance

A summary of the financial performance for the four strategies is shown in Table 5.20. Total milk and farm income tended to be lower for the "actual" strategy, while the "late" strategy had the highest income. Concentrates, supplements, hay and nitrogen costs varied in a similar way to the physical performance of the strategies (Table 5.20). Herd costs tended to be higher for the "current", "early" and "late" strategies, as a result of the higher number of cows milked. The "late" strategy showed the highest gross margin per farm, per cow and per hectare.

Table 5.20. Financial performance of the "actual", "current", "early" and "late" strategies for Farm C

	Actual ($)	Current ($)	Early ($)	Late ($)
Milk income	142,384	159,609	158,804	159,398
Total farm income	166,434	184,059	183,254	183,848
Farm expenses:				
Concentrates	4,650	5,260	0	0
Supplements fed	11,754	8,953	10,115	8,513
Nitrogen	3,720	8,750	8,364	8,750
Herd costs	54,250	54,600	54,600	54,600
Total farm costs	74,374	77,563	73,079	71,863
Farm gross margin	92,060	106,496	110,175	111,985
Gross margin/cow	594	683	706	717
Gross margin/ha	1,315	1,521	1,573	1,599

Table 5.21 shows the difference in gross margin between the "actual" strategy and the "current", "early" and "late" strategies. The "late" strategy had the highest margin, followed by the "early" strategy, while the "current" strategy was lowest.

Table 5.21. Difference in gross margin in relation to the "actual" strategy for the "current", "early" and "late" strategies for Farm C.

	Current ($)	Early ($)	Late ($)
Net farm margin	14,346	18,115	19,925
Net margin per cow	89	112	123
Net margin per hectare	206	258	284

5.4. Farm D

5.4.1. Herbage Accumulation (HAR)

Herbage accumulation rates (HAR) for the four strategies are shown in Figure 5.16. During August, September and October, HAR for the "actual" strategy was lower than for the other three strategies. Over the rest of the season, pasture growth seemed not to be affected by different strategies or their respective spring and winter nitrogen applications. There were differences between strategies in winter nitrogen applications (Table 5.22).

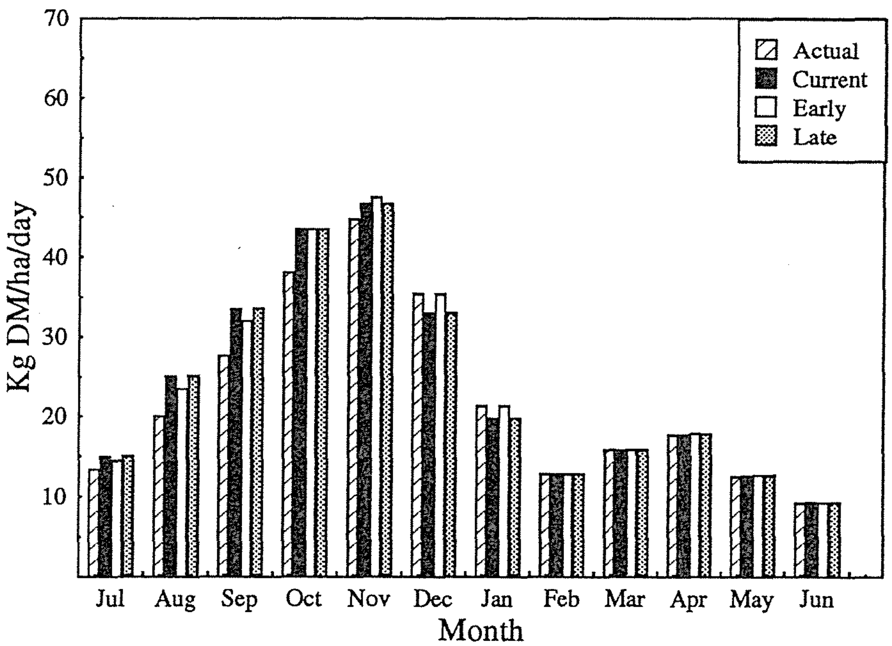

Figure 5.16. Effects of the different strategies on herbage accumulation rate for Farm D

HAR during August, September and October for the "current", "early" and "late" strategies seemed to be higher, probably as a result of different nitrogen applications (Table 5.22).

Table 5.22. Nitrogen application during spring, autumn and winter. Estimated herbage accumulation growth rates during August, September and October

	Nitrogen application (kg N/ha)			Herbage Acc. Rate (kg DM/ha/day)		
	Spring	Winter	Year	August	September	October
Actual	60	20	80	20.0	27.6	38.0
Current	90	50	140	25.0	33.4	43.5
Early	90	40	130	23.5	32.0	43.5
Late	90	50	140	25.1	33.6	43.5

Total herbage accumulation, pasture utilization rates and stocking rates are shown in Table 5.23. It can be seen that pasture utilization was higher as SR increased.

Table 5.23. Total herbage accumulation, pasture utilization and stocking rate for the "actual", "current", "early" and "late" strategies for Farm D

Strategy	Total Pasture Accumulation (t DM/ha/year)	Pasture Utilization (%)	Stocking Rate (cows/ha)
Actual	8,049	83.2	1.89
Current	8,531	84.4	1.95
Early	8,573	82.8	1.90
Late	8,541	83.1	1.93

5.4.2. Average Pasture Cover (APC)

Average pasture cover (APC) for the four strategies is shown in Figure 5.17. Major differences in pasture cover between strategies appeared during spring and summer months. During spring, the simulation values for the "early" calving strategy reached the lowest APC of any strategy at any time (1,690 kg DM/ha), while the other strategies had APC of 1,731, 1,769, and 1,782 kg DM/ha for the "actual", "current" and "late" strategies, respectively. The highest APC for each strategy was reached at the end of December. Where during spring the "late" strategy showed the highest cover. APCs were similar by the end of the lactation in all four strategies. During autumn and winter, the "actual" and "early" strategies had the highest APC. These differences could be due to the pasture growth over spring and the extra growth resulting from the nitrogen application.

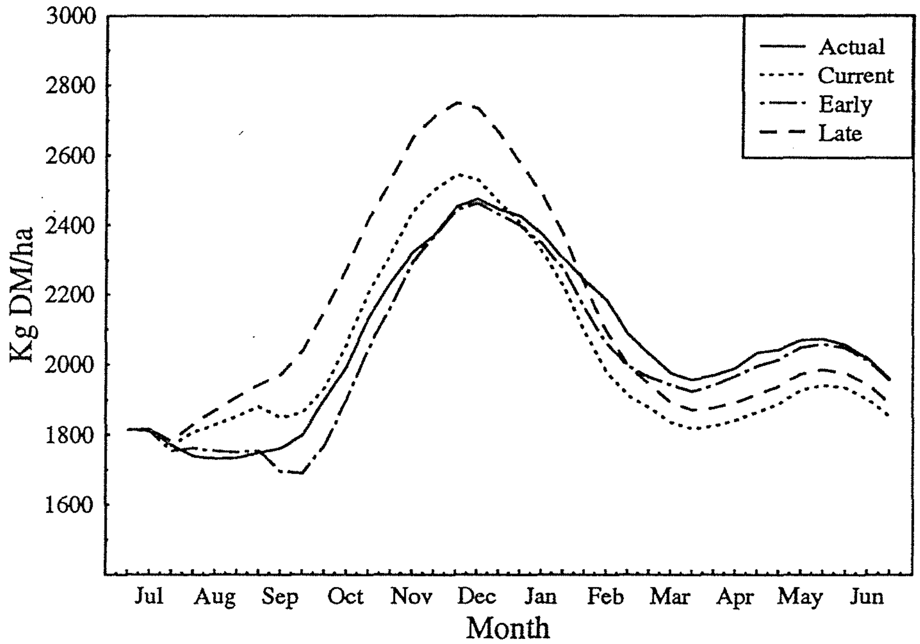

Figure 5.17. Effects of the different strategies on average pasture cover for Farm D

APC at calving date for the four strategies is shown in Table 5.24. Both CS and APC at calving were similar.

Table 5.24. Average pasture cover and condition score at planned start of calving for Farm D

Strategy	Period of planned start of calving (dates)	Average pasture cover (APC) (kg DM/ha)	Condition Score (units)
Actual	11-07	1,817	4.7
Current	11-07	1,816	4.6
Early	01-07	1,814	4.6
Late	21-07	1,782	4.8

5.4.3. Condition Score (CS)

Condition score (CS) for the four strategies is shown in Figure 5.18. There was a tendency for the CS to drop towards the end of the summer; it seems that CS was similar for all strategies, with a difference of less than 0.4 units. CS and APC at calving for each strategy are shown in Table 5.24. However, the "late" strategy tended to have a higher CS in spring.

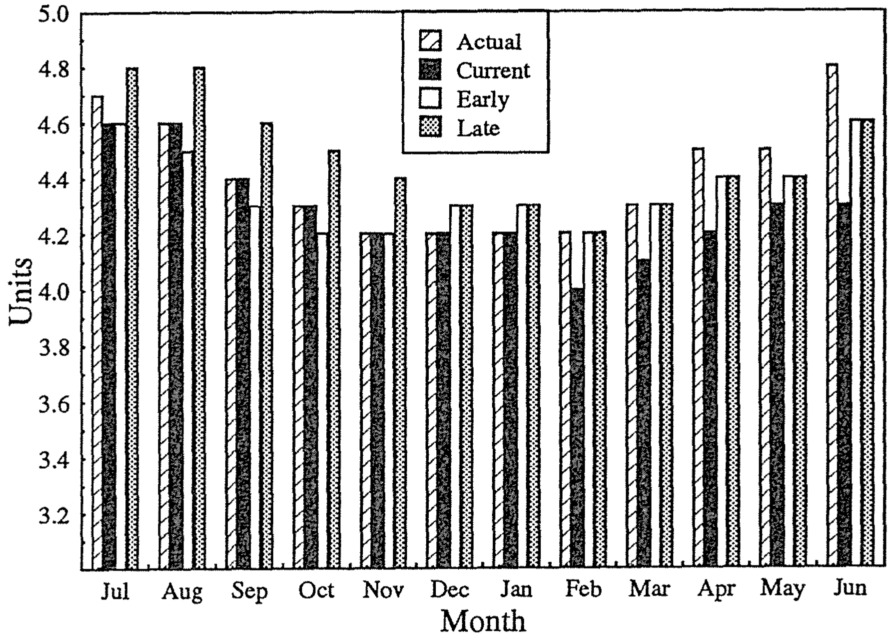

Figure 5.18. Effects of the different strategies on condition score per cow for Farm D

5.4.4. Milk Production

Average milksolids production per cow for the four strategies are shown in Figure 5.19. The "early" calving strategy tended to have a higher production as compared with the "actual" strategy (Table 5.25). The differences between strategies, can be attributed to the combination of lactation lengths and better feed allocation. It should be noted that milk production shows a fall at the peak of production, were as a result of heavy rain and cold temperatures during spring.

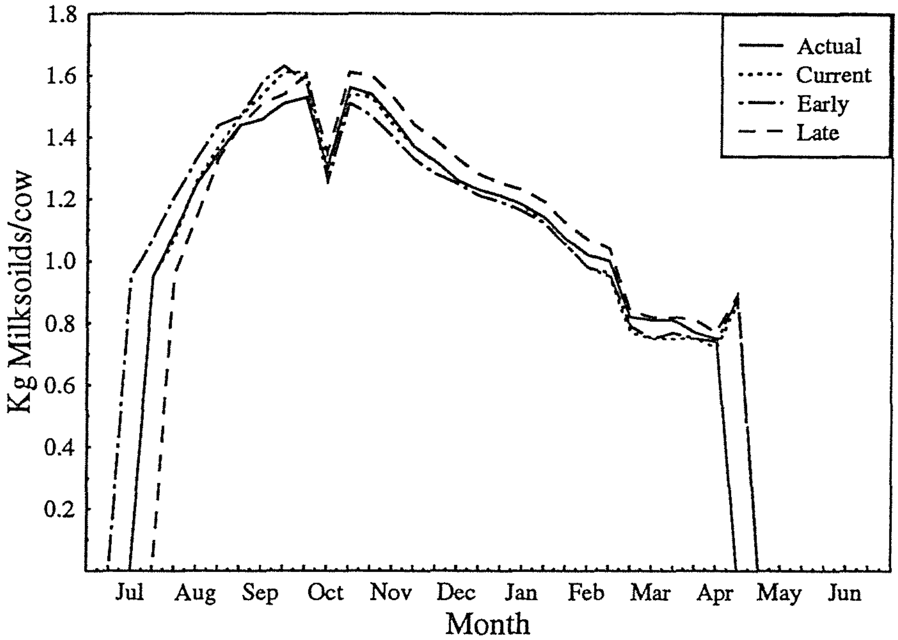

Figure 5.19. Effects of the different strategies on milk production per cow for Farm D

Table 5.25. Total milk production for the "actual", "current", "early" and "late" strategies for Farm D

Strategy	Actual	Current	Early	Late
Milksolids/farm	70,258	74,526	75,479	71,804
Milksolids/ha	502	532	539	513
Milksolids/cow	265	273	283	266
Days in milk	213	221	229	208

Milk production per farm for the four strategies is shown in Figure 5.20. Milk production per farm was highest for the "early" strategy, followed by the "current" and "late" strategies, with the "actual" strategy having the lowest production (Table 5.25). The higher production in the "current", "early" and "late" strategies could be due to a higher stocking rate, a better feed allocation and the use of nitrogen fertiliser.

The differences in total farm production relative to the "actual" strategy were 3,998, 5,221, and 1,546 kg MS/farm for the "current", "early" and "late" strategies, respectively. Total production over the peak months (October and November) varied as follows: 22,342 (31.8%), 22,961 (30.8%), 21,813 (28.9%), and 23,838 (33.2%) kg MS per farm for the "actual", "current", "early" and "late" strategies, respectively.

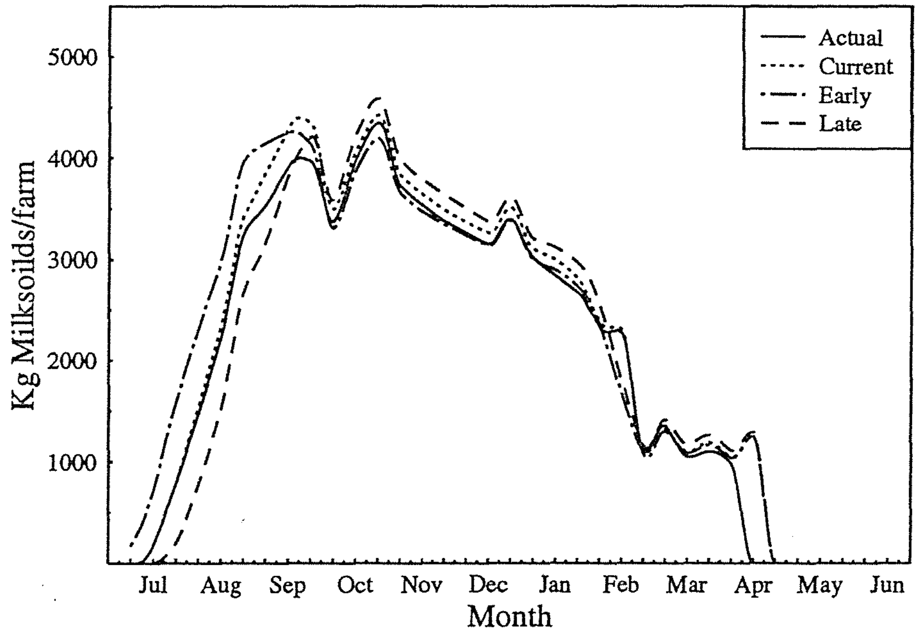

Figure 5.20. Effects of the different strategies in total milk production per farm for Farm D.

5.4.5. Physical Performance

A summary of the physical performance for the four strategies is shown in Table 5.26. Animal feed and nitrogen use are also shown. Concentrates were only used in the "actual" strategy because they did not seem to be profitable in any of the other strategies. The amount of supplements fed was lower for the "current", "early" and "late" strategies in relation to the "actual" strategy. Supplements were fed during spring and from summer to early autumn when pasture allocation was critical. Feed allocation also resulted in the strategic use of supplements, where supplements were fed during spring, from the start of calving, until October, in order to reach higher levels of milk production and keep CS. During summer to early autumn (February, March and April), supplements were fed to meet the requirements (Appendix ?).

It appeared that the increase in stocking rate (SR) was directly related to net pasture used. The "actual" strategy had the lowest use of nitrogen of all strategies.

Table 5.26. Physical performance of the "actual", "current", "early" and "late" strategies for Farm D

	Actual	Current	Early	Late
Area (ha)	140	140	140	140
Cows milked	265	273	267	270
Stocking rate (cows/ha)	1.89	1.95	1.90	1.92
Net pasture used (t DM/ha)	6.7	7.2	7.1	7.1
Feed concentrate (t DM)	13.4	0	0	0
Supplements used (t DM)	80.6	37.0	49.7	37.3
Hay used (t DM)	49.9	59.1	56.2	56.7
Nitrogen used (t of N)	11.2	18.2	18.2	18.2
Dry matter cut (t DM)	31.0	33.0	33.1	36.0

5.4.6. Financial Performance

A summary of the financial performance for the four strategies is shown in Table 5.27. Total milk and farm income tended to be lower for the "actual" strategy, while the "early" strategy had the highest income. Supplements, hay and nitrogen costs varied in a similar way to the physical performance of the strategies (Table 5.26). Herd costs tended to be higher for the "current", "early" and "late" strategies, as a result of the higher number of cows milked. The "early" strategy showed the highest gross margin per farm, per cow and per hectare.

Table 5.27. Financial performance of the "actual", "current", "early" and "late" strategies for Farm D.

	Actual ($)	Current ($)	Early ($)	Late ($)
Milk income	256,754	272,678	276,768	261,987
Total farm income	291,994	309,068	312,549	297,907
Farm expenses:				
Concentrate	6,697	0	0	0
Supplements fed	25,741	16,994	19,612	16,118
Nitrogen	11,200	18,200	18,200	18,200
Herd costs	92,750	95,550	93,450	94,500
Total farm costs	136,389	130,694	131,262	128,818
Farm gross margin	155,606	178,374	181,531	169,089
Gross margin/cow	587	653	680	626
Gross margin/ha	1,111	1,274	1,297	1,208

Table 5.28. shows the difference in gross margin between the "actual" strategy and the "current", "early" and "late" strategies. The "early" strategy had the highest margin, followed by the "current" strategy, with the "late" strategy having the lowest margin.

Table 5.28. Difference in gross margin in relation to the "actual" strategy for the "current", "early" and "late" strategies for Farm D

	Current ($)	Early ($)	Late ($)
Net farm margin	22,768	25,925	13,483
Net margin per cow	66	93	39
Net margin per hectare	163	186	97

CHAPTER 6

DISCUSSION

In this chapter, the first four sections are a discussion of the output of the improved strategy in relation to the actual strategy for each farm individually. A final section consists of a discussion summary where the outputs from all the farms are considered together.

6.1. Farm A

The results of the simulations showed that the "early" strategy had the highest gross margin and the highest levels of milk production (Tables 5.4 and 5.6). The highest gross margin per farm was a result of total farm income being $13,090 more than the "actual" strategy, while total costs increased by a net $ 811, due to higher nitrogen application and higher herd costs, although costs for supplementary feeds were lower for the "early" strategy than for the "actual" strategy (Table 5.4).

Higher milk production per cow (kg milksolids) from the "early" strategy could be because of:

- average lactation 7 days longer;
- better feeding levels and matching pasture supply with animal feed requirements; and
- higher pasture production and average pasture cover during critical periods (summer and winter) due to higher HARs resulting from nitrogen fertilizer.

In addition to increase in production per cow, the higher stocking rate (SR), resulted in an increase in production per hectare. Hence, both per cow and per hectare milk production were increased.

For the particular conditions of the region, advancing of calving dates gave a better match of pasture growth and animal demand. The pattern of milk production did not change, but there was an increase on lactation length. The longer lactation also resulted from the advance of calving and from the delay of drying-off dates. By getting a longer lactation it is expected that milk production per cow should increase. However total production per cow did not show large increments. This can, in part, be explained because gross efficiency of milk production decreases towards the end of lactation.

Further, from the manipulation of calving and drying-off dates, there was a better match between pasture allowance and animal requirements without compromising condition score (CS) or APC. It should be noted that the length of the dry period depends on the need to gain body condition and on the average pasture cover on the farm. That is, if the cover is too low it would be necessary to dry off some cows earlier in order to reduce feed demand.

Additional nitrogen applications resulted in an increase in total pasture production especially during spring and autumn (Table 5.1). This increase in pasture production, which maintained a higher APC, contributed to an increased milk production (kg MS) per cow at the higher stocking rate (SR).

CS at calving was similar for both the "early" and the "actual" strategies, while during early lactation CS was slightly lower for the "early" strategy, but from mid to late lactation, and during the dry period, the CS for "early" strategy was higher than in the "actual" strategy. This is the case for the "early" strategy where CS, before calving was 5.1, having a positive effect on the next lactation. By reaching a higher CS, the next lactation and levels of milk production and fertility can be improved.

The reduction in costs of supplementation was as a result of lower supplements fed due to a higher feed utilization and a better feed allocation from:

- a better match between pasture growth and animal requirements; and
- an increase in APC resulting from N application.

As shown in Table 5.2, feed utilization (total pasture eaten/total herbage accumulation) was improved from 88% to 91%. This was mainly achieved from the small increase in the number of animals on the farm (0.06 cows/ha), where the increase in SR resulted in an improved use of the pasture grown on the farm. However, as these figures are based on net herbage accumulation, it does not mean that there were no pasture losses such as pasture wastage, senescence, or decay, in the system.

Supplements were fed when pasture allocation was critical, in order to maintain milk production and CS. Feed allocation also resulted in the strategic use of supplements, where supplements were fed during the critical periods, attempting to meet the animal requirements throughout the year.

Expressed as a proportion of the total milk production, milk produced during the peak months (October and November) was reduced from 31% for the "actual" strategy, to 28% for the "early" strategy. Hence, there is a minimal difference between strategies in the proportion of milk which could be produced over the shoulder months. However, due to the higher production per animal and per hectare, the early strategy produced 1,636 kg MS more than the "actual" strategy during the peak months.

In summary, the increase in milk production and income for the "early" strategy resulted from a combination of:

- setting appropriate calving and drying-off dates which offer a better match between the pasture supply and feed demand and a longer lactation;

- an increase in the SR which gives the opportunity to improve feed utilization, where the animals eat more of the pasture produced;
- an increase in pasture production resulting from a strategic use of nitrogen over the spring and autumn, which is in conjunction with the increase in SR; and
- a more effective allocation of supplements through critical periods (summer and winter).

6.1. Farm B

The results of the simulations showed that the "late" strategy had the highest gross margin and the highest level of milk production (Tables 5.11 and 5.13). The highest gross margin per farm was a result of total farm income being $11,392 more than the "actual" strategy, while total costs increased by a net $206, probably due to higher nitrogen application and higher herd costs, although costs for supplementary feeds were lower for the "late" strategy than for the "actual" strategy (Table 5.13).

Higher milk production per cow (kg milksolids) from the "late" strategy could be because of:

- better feeding levels and matching pasture supply with animal feed requirements; and
- higher pasture production and average pasture cover during critical periods (summer and winter) due to higher HARs resulting from nitrogen fertilizer.

In addition to the increase in production per cow, the higher SR, resulted in an increase in production per hectare. Hence, both per cow and per hectare milk production were increased.

For the particular conditions of the region, the delay of calving dates gave a better matching of pasture growth and animal demand. The pattern of milk production was uniform, with variation in lactation length, giving a lactation 3 days shorter than the "actual" strategy. It was expected that milk production per cow would decrease because of the shorter lactation; however, when comparing the "actual" with the "late" strategy, total production per cow increased. This can, in part, be explained because of a better feeding of the animals over a shorter lactation.

From the manipulation of calving and drying-off dates, pasture allowance had a better match with animal requirements without compromising CS or APC. It should be noted that the length of the dry period depends on the need to gain body condition and on the average pasture cover on the farm. That is, if the cover is too low it would be necessary to dry-off some animals in order to reduce feed demand.

Additional nitrogen applications resulted in an increase in total pasture production especially during spring and late autumn (Table 5.8). This increase in pasture production contributed to an increased milk production (kg MS) per cow at higher stocking rate (SR).

CS at calving were similar for both the "late" and the "actual" strategies. During early lactation CS was slightly lower for the "actual" strategy, but, from mid to late lactation and during the dry period CS for "late" strategy was lower than in the "actual" strategy. This can be explained because of the different APCs for each strategy. It should also be considered that by reaching a higher CS, the next lactation and levels of milk production and fertility can be improved.

The reduction in the costs of supplementation by $4,484 were a result of lower supplements fed. This was due to a higher feed utilization and a better feed allocation from:

- a better match between pasture growth and animal requirements; and
- an increase in APC resulting from N application.

As shown in table 6.9, feed utilization (total pasture eaten/total herbage accumulation) was improved from 85.1% to 85.6%. This small variation is related to the modest increase in the number of animals on the farm (0.05 cows/ha), where the increase in SR resulted in an improved use of the pasture grown. However, as these figures are based on net herbage accumulation, it does not mean that there were no pasture losses such as pasture wastage, senescence, or decay, in the system.

Supplements were fed when pasture allocation was critical, in order to maintain milk production and CS. Feed allocation also resulted in the strategic use of supplements, where supplements were fed during the critical (February, March and April) periods, attempting to meet the animal requirements throughout late summer and early autumn.

Milk produced during the peak months (October and November), expressed as a proportion of the total milk production, increased from 28% for the "actual" strategy to 30% for the "late" strategy; with the "late" strategy producing 2.081 kg MS more than the "actual" strategy during the peak months. Hence, there is a minimal difference between strategies in the proportion of milk which could be produced over the shoulder months.

In summary, the increase in production and income from the "late" strategy resulted from a combination of:

- setting appropriate calving and drying-off dates which offer a better match between the pasture supply and feed demand;
- an increase in the SR which gives the opportunity to improve feed utilization, where the animals eat more of the pasture produced;
- an increase in pasture production resulting from the strategic use of nitrogen over the spring and autumn, in conjunction with the increase in SR; and
- a more effective allocation of supplements through the critical periods (summer and winter).

6.2. Farm C

The results of the simulations showed the "late" strategy to have the highest gross margin, whereas the current strategy showed the highest milk production. However, differences in production between these two strategies were small (Tables 5.18 and 5.20). The highest gross margin for the "late" strategy was a result of total farm income being $17,414, above the "actual" strategy, while total costs decreased by a net $2,511 due to lower use of supplements, and not using concentrates, although nitrogen application and herd costs were higher for the "late" strategy than for the "actual" strategy (Table 5.18).

Higher milk production per cow (kg milksolids) from the "late" strategy could be because of:

- a lactation 5 days longer;
- better feeding levels and matching pasture supply with animal feed requirements; and
- higher pasture production and average pasture cover during spring due to higher HARs resulting from nitrogen fertilizer.

In addition to the increase in production per cow, the manipulation of stocking rate (SR), giving a higher SR, resulted in an increase in production per hectare. Hence, both per cow and per hectare milk production were increased, even though changes were minimal.

For the particular conditions of the region, the delay of calving and drying-off dates gave a better matching of pasture growth and animal demand. The pattern of milk production was uniform, but with a longer lactation resulting from the larger delay in drying-off dates. By getting a longer lactation it is expected then, that milk production per cow should increase.

From the manipulation of calving and drying-off dates, pasture allowance had a better match with animal requirements without compromising CS or APC. It should be noted that the extent of the dry period would depend on the need to gain body condition and on the average pasture cover of the farm. That is, if the cover is too low it would be necessary to dry-off some animals in order to reduce feed demand.

Additional nitrogen applications resulted in an increase in total pasture production especially during spring and winter. This increase in pasture production contributed to an increased milk production (kg MS) per cow at higher stocking rate (SR).

CS at calving was similar for both the "late" and the "actual" strategies, while during early lactation CS was lower for the "actual" strategy, but towards the end of lactation CS for both strategies was similar. However, during the dry period, the "late" strategy showed again a higher CS; CS before calving was 5.3, helping the next lactation. By reaching a higher CS before calving, the next lactation and levels of milk production and fertility can be improved.

The reduction in the costs of supplementary feeding were as a result of not using concentrates and lower supplementary feed due to a higher feed utilization and a better feed allocation from a better match between pasture growth and animal requirements, and from the higher APC resulting from N application.

As shown in Table 5.16, feed utilization (total pasture eaten/total herbage accumulation) were similar between strategies, because of small changes in animal numbers (0.01 cows/ha). This was probably because the farm was close to its potential carrying capacity. Pasture utilization was close to 100%, showing low pasture losses in relation to total pasture accumulation. However, as these figures are based on net herbage accumulation, it does not mean that there were no pasture losses such as, pasture wastage, senescence, or decay in the system.

Supplements were fed when pasture allocation was critical, in order to maintain milk production and CS. Feed allocation also resulted in the strategic use of supplements, where supplements were fed during spring, attempting to meet the animal requirements during early and mid lactation.

Milk produced during the peak months (October and November), expressed as a proportion of the total milk production, increased from 28.5% for the "actual" strategy, to 29.1% for the "late" strategy; where the "late" strategy produced 1,608 kg MS more than the "actual" strategy during the peak months. Hence, there is a minimal difference between strategies in the proportion of milk which could be produced over the shoulder months.

In summary, the increase in production and income from the "late" strategy resulted from a combination of:

- setting appropriate calving and drying-off dates which offer a better match between pasture supply and feed demand and a longer lactation;
- an increase in pasture production resulting from a strategic use of nitrogen over the spring, autumn, and winter, in conjunction with the increase in SR; and
- a more effective allocation of supplements through the year.

6.1. Farm D

The results of the simulations showed that the "early" strategy had the highest gross margin and the highest levels of milk production (Tables 5.25 and 5.27). The highest gross margin per farm was a result of total farm income being $20,555 above the "actual" strategy, while total costs decreased by a net $5,127, due to lower use of supplements and not using concentrates, although nitrogen application and herd costs were higher for the "early" strategy than for the "actual" strategy (Table 5.27).

Higher milk production per cow (kg milksolids) from the "late" strategy could be because of:

- a lactation 16 days longer;
- better feeding levels and matching pasture supply with animal feed requirements; and
- higher pasture production and average pasture cover during critical periods (summer and winter) due to higher HARs resulting from nitrogen fertilizer.

In addition to the increase in production per cow, the manipulation of stocking rate (SR), giving a higher SR, resulted in an increase in production per hectare. Hence, both per cow and per hectare milk production were increased, even though changes were minimal.

For the particular conditions of the region, the advance of calving dates gave a better matching of pasture growth and animal demand. The pattern of milk production was uniform, but longer lactation resulted from the advance in calving dates and the delay on drying-off dates. By getting a longer lactation it is expected then, that milk production per cow should increase; however, when comparing the "late" and "actual" strategy production was about the same, but with a shorter lactation. This can, in part, be explained because gross efficiency of milk production decreases towards the end of lactation.

From the manipulation of calving and drying-off dates, there was a better match between pasture allowance and animal requirements without compromising CS or APC. It should be noted that the extent of the dry period depends on the need to gain body condition and on the average pasture cover of the farm. That is, if the cover is too low it would be necessary to dry-off some animals in order to reduce feed demand.

Additional nitrogen applications resulted in an increase in total pasture production especially during spring and autumn. This increase in pasture production contributed to an increased milk production (kg MS) per cow at higher SR.

CS at calving was similar for both the "late" and the "actual" strategies, however during early lactation CS was slightly lower for the "actual" strategy, but from mid to late lactation the "late" strategy had a CS slightly lower than in the "actual" strategy. By reaching a higher CS, the next lactation and levels of milk production and fertility can be improved.

The reduction in the costs of supplementary feeding, as a result of lower supplements fed, maybe due to a higher feed utilization and a better feed allocation from:

- a better match between pasture growth and animal requirements; and
- an increase in APC resulting from N application.

As shown in Table 5.23, feed utilization (total pasture eaten/total herbage accumulation) improved from 83.2% to 84.4%. This was mainly achieved from the small increase in the number of animals on the farm (0.03 cows/ha), improving the use of the pasture grown on the farm. However, as these figures are based on net herbage accumulation, it does not mean that there were no losses such as pasture wastage, senescence, or decay in the system.

Supplements were fed during spring, and from summer to early autumn, when pasture allocation was critical. Feed allocation also resulted in the strategic use of supplements, where supplements were fed during spring, from the start of calving until October, in order to reach higher levels of milk production and maintain CS.

Milk produced during the peak months (October and November), expressed as a proportion of the total milk production, decreased from 31.8% for the "actual" strategy to 28.9% for the "early" strategy. Hence, there is a minimal difference between strategies in the proportion of milk which could be produced over the shoulder months. However, the "early" strategy produced 1,496 kg MS more than the "actual" strategy during the peak months.

In summary, the increase in production and income from the "early" strategy resulted from a combination of:

- setting appropriate calving and drying-off dates which offer a better match between the pasture supply and feed demand and longer lactations;
- an increase in SR which gives the opportunity to improve feed utilization, where animals eat more of the pasture produced;
- an increase in pasture production resulting from a strategic use of nitrogen over the spring and autumn in conjunction with the increase in SR; and
- a more effective allocation of supplements through the critical periods (summer and winter).

6.5. Summary

For each case study farm, the simulation model UDDER was used to help to design of alternative management options with improved gross margins. The variables which were manipulated to achieve this were:

- calving and drying off dates;
- stocking rate;
- supplementary feeding; and
- nitrogen fertiliser.

The effects of changes in these variables were monitored in the system's physical and financial parameters, the variables being manipulated within a whole farm system, to give production and financial responses from the combined effect of the variable changes (Appendices 6 & 7). The effects of the changes in single variables have not been measured.

Improvements in gross margins were achieved in the model by changing calving and drying-off dates; the improvement being the result of a better match of animal requirements with pasture production. The different locations for the four farms and the effect of climate on pasture production, meant that each farm has a different improved calving and drying-off date. From the results obtained it can be seen that the calving pattern for the best strategies for Farms A and D was advanced; whereas for Farms B and C the delayed calving dates were the ones that gave better results. The reasons for these differences can be explained because of the weather's effect on pasture growth (Figure 5.1, 5.6, 5.11 and 5.16). The matching of pasture supply and demand is consistent with Holmes (1986, 1987) and Phillips (1983) who maintain that calving dates should be chosen so that the start of lactation will coincide with the start of pasture growth. That is, under the particular conditions of the region, advancing of calving date gave a better matching of pasture growth and animal demand.

Drying off dates, were delayed in all strategies and lactation was lengthened, with exception of Farm B which showed a shorter lactation (Table 6.1). Hence, by obtaining a longer lactation it is expected that milk production per cow would increase; however, variations in milk produced per cow as an effect form a longer lactation length were not marked. This can, in part, be explained because gross efficiency of milk production decreases towards the end of lactation (Wilson and Davey, 1982; and Hutton, 1963) because a greater proportion of the dietary energy is diverted to body tissues. Another cause could be because of a more restricted feed allocation towards the end of the lactation.

After manipulating calving and lactation lengths, average lactation length for the best strategies of each farm ranged between 225 and 235 days, being slightly higher than the New Zealand average of 226 days (Livestock Improvement, 1991/92).

Table 6.1. *Summary of the changes in start of calving and drying-off dates, stocking rate, concentrates fed, supplements fed, nitrogen fertiliser applied and the variation in gross margin for the "best" strategies for each farm compared with the actual strategy.*

	Farm A	Farm B	Farm C	Farm D
Start of calving (days)	- 10	+ 10	+ 10	- 10
Change in lactation length (days)	+ 7	- 3	+ 5	+ 16
Increase stocking rate (cows/ha)	0.06	0.05	0.01	0.03
Concentrates fed (t DM)	0	0	- 9.3	- 13.4
Supplements fed (t DM)	-16.2	- 14.6	- 8.3	- 30.9
Nitrogen fertiliser applied (kg N/ha/yr)	+ 13	+ 29	+ 72	+ 50
Increase in:				
Milk production/ha (%)	4.0	4.7	11.9	7.4
Milk production/cow (%)	1.4	2.4	11.2	6.8
Peak production (%)	3.0	1.8	2.7	1.0
Gross margin (%)	6.0	6.5	21.5	16.6

Stocking rate was increased in all strategies in the order by 0.01 to 0.06 cows per hectare (Table 6.1). As stocking rate increased, so too did gross margin improve, consistent with Hodgson (1990) and Holmes and Parker (1992). This effect is attributed to better feed utilization and hence lower herbage losses.

That is, when extra pasture is produced, an increased stocking rate is one way of ensuring that the extra pasture production is consumed, and when supplements are fed the pasture spared is not wasted. The effect of changing a variable such as SR has been combined with changes in other variables such as the use of supplementary feeding. Some authors have indicated that an increase in SR will result in reduced animal intake from lower herbage allowances to the animals (McMeekan, 1956; Stockdale and King, 1980; Holmes and Parker, 1992), but in this study the use of supplementary feed and nitrogen fertiliser application ensured that intake was not restricted; despite small increase in SR.

Strategic supplementary feeding is used to meet animal requirements without compromising APC or CS. Results indicate that gross margins could be improved by directing supplementary feeding along critical periods. In the present study this was mainly in summer and winter, although one farm (Farm D) used supplements profitably during early spring. Further, the use of concentrates was not profitable for most of the improved strategies, mainly because of the high cost of concentrate and the relatively low milk payout.

In additional to the better feeding of the animals, either by improving the match between pasture growth and animal requirements, or by a better feed allocation, condition score of the animals will also be improved. Hence, by achieving higher CSs next lactations and fertility levels can be improved. This is in agreement with the findings of Grainger and McGowan (1982) and McDougall, (1992) where, with higher precalving CS, milk production and fertility was increased.

Nitrogen fertiliser applications were used in the model to increase HAR and to build up pasture reserves during critical periods. This practice seems to have a place in all case study farms as additional nitrogen application resulted in an increase in total pasture production especially during spring and autumn. This increase in pasture production contributed to increased milk production (kg MS) per cow at higher SR. This is consistent with King and Stockdale (1980) who mention that the benefits of an increase in pasture production from nitrogen fertilizer use may come from an increase in production per cow and/or the carrying capacity. As well as the effects noted above, nitrogen application may well have an effect on pasture composition, encouraging high fertility species (Grant, 1981; Luscombe, 1981).

Increments in soil fertility also result in seasonal changes in pasture production. These changes could be due to higher fertility species have different seasonal production patterns. These changes are reported by Mathew (1988), who mentions that pasture production patterns vary by changing grass:clover balance or by an increased incidence of low fertility tolerant species.

Differences between strategies in terms of milk production in peak months (October and November) were between 1% and 3% of the total milk production. Hence, the potential to shift a proportion of total milk production into shoulder months is limited. Table 6.1 shows a summary of the changes in management and production for the four strategies.

As shown in Table 6.1 net margin over the "actual" strategies in the different strategies between farms vary between 6% and 21.5%, which in monetary terms are $12,297, $11,187, $19,925 and $25,768 for farms A, B, C and D, respectively. These margins are mainly as a result of an appropriate manipulation of the variables, rather than from a possible shift in milk production from peak months into shoulder months.

In the choice of any management strategy it should be considered that the price of supplements, nitrogen, and milk payout influence the profitability of the farm. In this case concentrate supplementation was not economical, but if concentrate prices were to drop and/or milk payout were to increase (Yuretich, Gray and Lynch, 1993), then the use of concentrate supplementation could become feasible.

CHAPTER 7

CONCLUSIONS

New Zealand is well-known worldwide for its on-farm efficiency, being the world's most cost-effective producer, and for its cooperative structure with a very good marketing network throughout the world. However, on-farm efficiency can be offset by lower factory efficiency. Thus, greater levels of efficiency can be achieved with improved utilization of factory capacity.

Tui Milk Products differential payment will provide a market signal to the producers about the real value of the milk at different times of the year. It is expected that through this change in payout some farmers will shift their supply patterns in order to obtain better returns than the differential payment offers. However, the opportunity to improve their management without necessarily shifting production is an option which seems to be more effective in obtaining improved returns.

The simulation model (UDDER) can be satisfactorily used in farm consultancy and research, as a decision support aid to identify and evaluate appropriate farm management practices on dairy farms. It should be considered that the relationships in the model are based on research carried out on experimental farms which are not necessarily the same as those of the farms under study; that is, the simulations give an approximation of likely performance of the farm. However, by simulating these management alternatives the possible output can be quantified before it is actually carried out. Thus, UDDER assists in the planning process in the management of a farm. So when analysing and evaluating the results it should be remarked that the actual strategy is given for a specific year, and does not necessarily mean that future seasons will show the same performance.

From the results of this study, farm management practices, such as selection of calving and drying-off dates, stocking rate, supplementary feeding, concentrate feeding and nitrogen fertiliser, offer opportunities to improve gross margins in the case study farms. However, the changes obtained were relatively small.

The collection of the information to fulfil the requirements of the model are a major constraint in situations were farm monitoring systems are not emplaced. Hence, with a better information the closer the simulations can be to reality.

Further research would be necessary to evaluate larger changes in calving dates. In addition, sensitivity analyses for the elements in the system in order to obtain higher returns; this could be by finding the breakeven prices at which concentrates can be introduced into the system, and how much the differential payment would need to change by to achieve a larger shift of milk production into the shoulder months. Finally, it is important to evaluate the effect of moving into shoulder months on the industry as a whole, looking at a level where both farm and factory efficiencies would be maximised. In addition parallel evaluations with the use of linear programming models will give optimal alternative management options.

This study confirmed that the climatic conditions of each region influence pasture production patterns, as well as the choice of appropriate calving and drying-off dates, the timing of supplementary feeding and fertiliser applications.

In addition, the successful manipulation of these variables depends on the climatic conditions of the specific farm. This study has been based on one year's data, and there has been no opportunity to test the applicability of the improved strategies in years with different pasture production patterns.

The comparison of the simulated results with the actual observations and the evaluated practices, indicates a potential improvement in some dairy farm management practices. However, these outputs need to be discussed with specific consultants and farmers before being transformed into recommendations for management practice.

An outcome that was not evaluated was possible changes in pasture composition resulting from the use of fertilisers and their influence on production. Together with climate, these may become the main criteria for selecting pasture species. Increased production from new pasture species will deplete soil resources more rapidly, so that more fertiliser input may be necessary to sustain the system.

The implementation of practices, such as concentrate feeding and nitrogen fertiliser will depend largely on the economics involved in the system, the costs of the inputs and the selling price of the milk, the willingness of the farmer to implement alternative management, as well as farmer and adviser perceptions of the likely outcomes.

APPENDICES

APPENDIX 1. Assumptions taken in the simulations run by UDDER

Concentrate and supplement details (% DM & % digestibility)

Concentrate: 80% digestibility

Supplements: 70% digestibility

Pasture response to nitrogen fertiliser:

Date of application	Pasture response (kg DM/kg N)
20-07	8
15-09	10
20-11	12
01-03	8
01-05	8

Prices in the inputs and outputs of the farm:

Feed:		Herd:	
Concentrate ($/t DM)	500	Herd costs per cow ($)	350
Cost of supplement 1 ($/t DM)	240	Calf price ($)	70
Cost of supplement 2 ($/t DM)	210	Culled cows ($)	400
Selling conserved supplements ($/t DM)	200	Milk Payout:	
Supplement conservation costs ($/t DM)	68	Peak months ($/kg MS)	10.35
Price of nitrogen ($/t)	1,000	Shoulder months ($/kg MS)	11.67

APPENDIX 2A: Farm A - "Actual" strategy

Date	No. Cows Milk	No. Cows Dry	Pasture Gr. Rate kgDM/h/d	Avg. Past. Cover kgDM/ha	Herbage Allow. <---------	Milkers Pasture Intake kg DM/cow/day	Conc. Intake	Suppl. Intake ----->	Milkfat per Cow kg MF	Total Milkfat kg MF	CS Units
01-07	0	211	11.5	1612	0.0	0	0	0.0	0.00	0	4.9
11-07	9	205	13.8	1630	21.2	11.7	0	0.0	0.56	51	4.9
21-07	54	171	17.9	1660	30.4	13.7	0	0.0	0.65	385	4.9
01-08	97	135	22.4	1701	31.6	14	0	0.0	0.77	745	4.9
11-08	145	99	26.1	1734	33.4	14.4	0	0.0	0.84	1214	4.8
21-08	197	61	28.7	1765	42.4	14.9	0	0.0	0.88	1901	4.8
01-09	225	36	31.1	1788	41.3	14.9	0	0.0	0.92	2065	4.7
11-09	262	8	33.1	1807	47.0	14.9	0	0.0	0.92	2423	4.6
21-09	268	4	40.3	1825	49.1	15	0	0.0	0.96	2583	4.6
01-10	274	0	46.1	1906	92.0	15.2	0	0.0	0.96	2618	4.5
11-10	274	0	51.6	2076	76.0	15.3	0	0.0	0.94	2579	4.4
21-10	274	0	56.3	2137	54.5	15.2	0	0.0	0.90	2702	4.4
01-11	274	0	61.1	2255	83.4	15.2	0	0.0	0.84	2304	4.4
11-11	274	0	64.5	2399	88.5	15.1	0	0.0	0.78	2144	4.3
21-11	274	0	57.9	2568	109.8	15	0	0.0	0.73	2009	4.3
01-12	274	0	51.6	2493	83.3	14.8	0	0.0	0.69	1879	4.3
11-12	274	0	45	2668	67.0	14.6	0	0.0	0.64	1755	4.3
21-12	274	0	36.5	2784	54.4	14.4	0	0.0	0.65	1961	4.3
01-01	274	0	27.2	2819	57.1	14.2	0	0.0	0.66	1822	4.3
11-01	274	0	18.8	2766	62.1	14	0	0.0	0.68	1852	4.3
21-01	268	0	14.1	2637	55.1	10.5	0	3.0	0.64	1884	4.3
01-02	268	0	9.8	2530	54.6	10.2	0	3.0	0.62	1649	4.3
11-02	248	0	6.5	2396	49.5	9.8	0	3.0	0.59	1471	4.2
21-02	248	0	6.7	2253	53.8	12.4	0	0.0	0.59	1178	4.2
01-03	248	0	7.3	2099	35.7	11.3	0	0.0	0.57	1403	4.2
11-03	125	0	8	1918	34.3	11.2	0	0.0	0.57	716	4.1
21-03	125	0	9.1	1865	34.4	10.7	0	0.0	0.47	643	4.1
01-03	125	0	10.2	1826	43.0	5.9	0	5.0	0.43	543	4.2
11-03	125	0	10.4	1854	42.0	5.7	0	5.0	0.43	532	4.2
21-03	125	0	7.4	1884	40.3	5.6	0	5.0	0.41	515	4.2
01-04	0	0	3.6	1886	0.0	0	0	0.0	0.00	0	0.0
11-04	0	0	1.9	1912	0.0	0	0	0.0	0.00	0	0.0
21-04	0	248	3.3	1921	0.0	0	0	0.0	0.00	0	4.8
01-05	0	248	5.8	1805	0.0	0	0	0.0	0.00	0	4.8
11-05	0	248	11.8	1709	0.0	0	0	0.0	0.00	0	4.8
21-05	0	248	15.3	1669	0.0	0	0	0.0	0.00	0	4.9

Milk Income	$291,986	Farm Size (ha)	132	Past. Eaten (t DM/ha)	7.7
TOTAL FARM INCOME	$321,136	Herd Size (#)	285	Conc. Used (t DM)	0
				Suppl. Used (t DM)	36.9
Concentrate Costs	$0	Kg MF/farm	45,527	Hay Used (t DM)	42.4
Supplements Costs	$9,516	Kg MF/cow	159.7	DM Cut for Suppl. (t)	62.5
Nitrogen Costs	$7,624	Kg MF/ha.	344.9	Nitrogen Used (t)	7.6
Other Variable Costs	$99,750			Nitrogen Applications (kg N)	
TOTAL FARM COSTS	$116,890			20-09	1,440
				25-03	640
FARM GROSS MARGIN	$204,246			10-05	1,200
GROSS MARGIN / COW	$717			10-06	3,000
GROSS MARGIN / HA.	$1,547			15-06	1,344

APPENDIX 2B: Farm A - "Current" strategy

Date	No. Cows Milk	No. Cows Dry	Pasture Gr. Rate kgDM/h/d	Avg. Past. Cover kgDM/ha	Herbage Allow. (kg DM/cow/day)	Pasture Intake (kg DM/cow/day)	Conc. Intake (kg DM/cow/day)	Suppl. Intake (kg DM/cow/day)	Milkfat per Cow kg MF	Total Milkfat kg MF	CS Units
01-07	0	222	11.5	1612	0.0	0	0	0.5	0.00	0	4.9
11-07	9	215	13.8	1625	20.1	11	0	0.5	0.56	50	4.9
21-07	57	180	17.8	1650	28.8	13.1	0	0.5	0.64	403	4.9
01-08	102	142	22.3	1684	30.0	13.9	0	0.0	0.77	780	4.8
11-08	153	104	25.9	1710	31.6	14.3	0	0.0	0.83	1276	4.8
21-08	207	64	28.3	1729	39.9	14.8	0	0.0	0.87	1989	4.7
01-09	237	38	30.8	1734	38.5	14.8	0	0.0	0.91	2163	4.7
11-09	276	9	32.7	1738	43.4	14.8	0	0.0	0.92	2534	4.6
21-09	282	4	37.9	1737	44.8	14.8	0	0.0	0.95	2693	4.5
01-10	288	0	44.2	1782	82.0	15	0	0.0	0.95	2724	4.5
11-10	288	0	49.7	1920	67.0	15.1	0	0.0	0.93	2681	4.4
21-10	288	0	54.4	1946	47.5	14.9	0	0.0	0.88	2800	4.3
01-11	288	0	59.3	2028	71.9	15	0	0.0	0.83	2393	4.3
11-11	288	0	62.7	2145	75.8	15	0	0.0	0.78	2239	4.3
21-11	288	0	57.9	2285	95.0	14.9	0	0.0	0.73	2102	4.3
01-12	288	0	51.6	2420	77.1	14.7	0	0.0	0.68	1959	4.2
11-12	288	0	45	2580	61.9	14.6	0	0.0	0.64	1830	4.2
21-12	288	0	36.5	2681	50.1	14.4	0	0.0	0.64	2042	4.2
01-01	288	0	27.2	2700	52.4	14.2	0	0.0	0.66	1897	4.2
11-01	288	0	18.8	2632	56.6	13.9	0	0.0	0.67	1929	4.2
21-01	282	0	14.1	2490	49.7	10.1	0	3.0	0.63	1954	4.2
01-02	282	0	9.8	2377	49.0	9.2	0	3.5	0.60	1695	4.2
11-02	261	0	6.5	2253	44.2	9.1	0	3.5	0.58	1519	4.2
21-02	261	0	6.7	2112	48.1	11.4	0	0.5	0.57	1198	4.2
01-03	261	0	7.3	1964	31.9	10.4	0	0.0	0.54	1400	4.1
11-03	111	0	7.9	1790	30.5	10.2	0	0.0	0.54	596	3.9
21-03	111	0	12.4	1761	31.3	10.2	0	0.0	0.45	543	4.0
01-03	111	0	16.9	1779	40.4	10.8	0	0.0	0.45	501	4.0
11-03	111	0	17.1	1832	42.4	10.9	0	0.0	0.45	502	4.1
21-03	111	0	14.1	1885	40.1	10.7	0	0.0	0.44	489	4.1
01-04	111	0	9.5	1909	11.8	7.5	0	0.0	0.37	411	4.0
11-04	0	0	6.5	1930	0.0	0	0	0.0	0.00	0	0.0
21-04	0	261	5	1984	0.0	0	0	0.0	0.00	0	4.7
01-05	0	261	4.5	1864	0.0	0	0	0.0	0.00	0	4.7
11-05	0	261	8	1741	0.0	0	0	0.0	0.00	0	4.7
21-05	0	261	10.9	1649	0.0	0	0	0.0	0.00	0	4.8

Milk Income	$303,282	Farm Size (ha)	132	Past. Eaten (t DM/ha)	8.2
TOTAL FARM INCOME	$334,002	Herd Size (#)	300	Conc. Used (t DM)	0
				Suppl. Used (t DM)	23.2
Concentrate Costs	$0	Kg MF/farm	47,291	Hay Used (t DM)	44.6
Supplements Costs	$7,491	Kg MF/cow	157.6	DM Cut for Suppl. (t)	56.4
Nitrogen Costs	$6,468	Kg MF/ha.	358.3	Nitrogen Used (t)	6.5
Other Variable Costs	$105,000			Nitrogen Applications (kg N)	
TOTAL FARM COSTS	$118,959			20-09	1,440
				25-03	640
FARM GROSS MARGIN	$215,043			10-05	1,200
GROSS MARGIN / COW	$717			10-06	3,000
GROSS MARGIN / HA.	$1,629			15-06	1,344

APPENDIX 2C: Farm A - "Early" strategy

	Milk	Dry	Gr. Rate	Cover	Allow.	Intake	Intake	Intake	per Cow	Milkfat	
			kgDM/h/d	kgDM/ha	<---------	kg DM/cow/day		----->	kg MF	kg MF	Units
01-07	9	210	11.5	1612	10.8	6.5	0	0.0	0.44	40	4.8
11-07	55	175	13.7	1621	20.6	11.5	0	0.0	0.60	330	4.8
21-07	105	139	17.4	1614	29.3	13.6	0	0.0	0.76	873	4.8
01-08	149	102	21.7	1601	30.2	13.9	0	0.0	0.82	1216	4.8
11-08	201	64	25.6	1598	31.4	14.2	0	0.0	0.85	1714	4.7
21-08	237	38	27.6	1592	36.9	14.5	0	0.0	0.90	2347	4.6
01-09	269	10	29.7	1579	35.1	14.2	0	0.0	0.90	2417	4.6
11-09	272	8	31.2	1565	41.8	14.6	0	0.0	0.95	2571	4.5
21-09	274	6	38.3	1557	41.0	14.2	0	0.0	0.93	2539	4.4
01-10	274	6	45.3	1625	78.0	14.7	0	0.0	0.92	2513	4.3
11-10	274	6	51.4	1792	65.1	14.9	0	0.0	0.89	2441	4.3
21-10	274	6	56.2	1854	47.0	14.7	0	0.0	0.84	2538	4.3
01-11	274	6	61	1976	72.5	14.9	0	0.0	0.79	2166	4.2
11-11	274	6	64.3	2126	77.7	14.8	0	0.0	0.74	2033	4.2
21-11	274	6	57.9	2311	98.7	14.7	0	0.0	0.70	1912	4.2
01-12	274	6	51.6	2456	80.3	14.6	0	0.0	0.65	1790	4.2
11-12	274	6	45	2624	64.6	14.4	0	0.0	0.61	1679	4.2
21-12	274	6	36.5	2739	52.4	14.2	0	0.0	0.62	1881	4.2
01-01	274	6	27.3	2775	55.2	14	0	0.0	0.64	1752	4.2
11-01	274	6	18.8	2722	59.6	13.7	0	0.0	0.65	1781	4.3
21-01	269	6	14.1	2595	53.3	10.2	0	3.0	0.61	1816	4.3
01-02	269	6	9.8	2487	52.5	9.8	0	3.0	0.59	1587	4.3
11-02	248	6	6.5	2357	47.5	9.4	0	3.0	0.57	1403	4.2
21-02	248	6	6.7	2219	51.8	12	0	0.0	0.57	1123	4.2
01-03	248	6	7.3	2067	34.4	10.5	0	0.5	0.54	1329	4.2
11-03	131	0	8	1899	32.9	10.3	0	0.5	0.54	708	4.1
21-03	131	0	13.3	1850	33.1	9.8	0	0.5	0.44	634	4.1
01-03	131	0	18.8	1865	43.2	10.2	0	0.5	0.44	581	4.1
11-03	131	0	19	1926	43.2	10.1	0	0.5	0.44	575	4.2
21-03	131	0	16	1988	43.9	10	0	0.5	0.43	561	4.2
01-04	131	0	11.2	2021	12.6	8	0	0.0	0.37	491	4.1
11-04	0	0	8.2	2042	0.0	0	0	0.0	0.00	0	0.0
21-04	0	254	5.8	2113	0.0	0	0	0.0	0.00	0	4.8
01-05	0	254	4.5	1998	0.0	0	0	0.0	0.00	0	4.9
11-05	0	254	8.3	1860	0.0	0	0	0.0	0.00	0	4.9
21-05	0	254	11.1	1757	0.0	0	0	0.0	0.00	0	5.1

Milk Income	$304,606	Farm Size (ha)	132	Past. Eaten (t DM/ha)	8.2
TOTAL FARM INCOME	$334,226	Herd Size (#)	292	Conc. Used (t DM)	0
				Suppl. Used (t DM)	20.7
Concentrate Costs	$0	Kg MF/farm	47,339	Hay Used (t DM)	40.5
Supplements Costs	$6,261	Kg MF/cow	162.1	DM Cut for Suppl. (t)	54.7
Nitrogen Costs	$9,240	Kg MF/ha.	358.6	Nitrogen Used (t)	9.2
Other Variable Costs	$102,200			Nitrogen Applications (kg N)	
TOTAL FARM COSTS	$117,701			20-09	1,440
				25-03	640
FARM GROSS MARGIN	$216,525			10-05	1,200
GROSS MARGIN / COW	$742			10-06	3,000
GROSS MARGIN / HA.	$1,640			15-06	1,344

APPENDIX 2D: Farm A - "Late" strategy

Date	No. Cows Milk	Dry	Pasture Gr. Rate kgDM/h/d	Avg. Past. Cover kgDM/ha	Herbage Allow. <----------	Pasture Intake kg DM/cow/day	Conc. Intake	Suppl. Intake ----->	Milkfat per Cow kg MF	Total Milkfat kg MF	CS Units
01-07	0	225	11.5	1612	0.0	0	0	0.0	0.00	0	4.9
11-07	0	225	13.8	1626	0.0	0	0	0.0	0.00	0	4.9
21-07	9	218	18	1659	28.6	13.5	0	0.0	0.60	59	5.0
01-08	52	182	22.6	1734	30.1	13.9	0	0.0	0.63	326	5.0
11-08	103	144	26.2	1790	32.2	14.4	0	0.0	0.78	804	4.9
21-08	155	106	28.4	1836	40.9	14.8	0	0.0	0.85	1453	4.9
01-09	204	65	31.2	1873	43.0	15	0	0.0	0.88	1803	4.9
11-09	240	38	33.3	1893	45.9	14.9	0	0.0	0.93	2225	4.8
21-09	280	9	39.3	1915	48.0	15	0	0.0	0.93	2611	4.7
01-10	286	4	45	1970	89.1	15.2	0	0.0	0.97	2774	4.6
11-10	292	0	50.5	2116	72.4	15.3	0	0.0	0.96	2793	4.6
21-10	292	0	55.3	2142	51.1	15.2	0	0.0	0.92	2965	4.5
01-11	292	0	60.1	2219	77.0	15.3	0	0.0	0.87	2542	4.4
11-11	292	0	63.5	2326	80.5	15.2	0	0.0	0.81	2377	4.4
21-11	292	0	57.9	2457	99.3	15.1	0	0.0	0.76	2224	4.4
01-12	292	0	51.6	2535	79.2	15	0	0.0	0.71	2070	4.3
11-12	292	0	45	2684	63.6	14.8	0	0.0	0.66	1929	4.3
21-12	292	0	36.5	2775	51.0	14.6	0	0.0	0.67	2147	4.3
01-01	292	0	27.2	2784	53.3	14.4	0	0.0	0.68	1991	4.3
11-01	292	0	18.8	2706	57.4	14.1	0	0.0	0.69	2021	4.3
21-01	286	0	14.1	2555	50.3	10.5	0	3.0	0.65	2053	4.3
01-02	286	0	9.8	2431	49.5	10.1	0	3.0	0.63	1792	4.2
11-02	264	0	6.5	2284	44.5	9.8	0	3.0	0.60	1595	4.2
21-02	264	0	6.7	2128	48.1	12.2	0	0.0	0.60	1265	4.2
01-03	264	0	7.3	1966	31.7	10.6	0	0.0	0.56	1470	4.1
11-03	112	0	7.9	1785	30.2	10.3	0	0.0	0.56	624	4.0
21-03	112	0	12.4	1753	31.0	8.8	0	2.0	0.46	563	4.0
01-03	112	0	16.9	1787	39.7	9	0	2.0	0.46	513	4.0
11-03	112	0	17.1	1856	41.7	9.2	0	2.0	0.46	511	4.1
21-03	112	0	14.1	1925	39.6	8.9	0	2.0	0.44	497	4.1
01-04	112	0	9.5	1967	11.7	7.4	0	0.0	0.38	424	4.0
11-04	112	0	6.5	1987	10.7	7	0	0.0	0.40	453	3.8
21-04	0	264	5	1982	0.0	0	0	0.0	0.00	0	4.5
01-05	0	264	4.4	1862	0.0	0	0	0.0	0.00	0	4.6
11-05	0	264	8	1733	0.0	0	0	0.0	0.00	0	4.7
21-05	0	264	11.1	1637	0.0	0	0	0.0	0.00	0	4.8

Milk Income	$299,944	Farm Size (ha)	132	Past. Eaten (t DM/ha)	8.2
TOTAL FARM INCOME	$331,274	Herd Size (#)	304	Conc. Used (t DM)	0
				Suppl. Used (t DM)	29.9
Concentrate Costs	$0	Kg MF/farm	46,872	Hay Used (t DM)	46.6
Supplements Costs	$8,742	Kg MF/cow	154.2	DM Cut for Suppl. (t)	62.3
Nitrogen Costs	$7,260	Kg MF/ha.	355.1	Nitrogen Used (t)	7.3
Other Variable Costs	$106,400			Nitrogen Applications (kg N)	
TOTAL FARM COSTS	$122,402			20-09	1,440
				25-03	640
FARM GROSS MARGIN	$208,872			10-05	1,200
GROSS MARGIN / COW	$687			10-06	3,000
GROSS MARGIN / HA.	$1,582			15-06	1,344

APPENDIX 3A: Farm B - "Actual" strategy

Date	No. Cows Milk	Dry	Pasture Gr. Rate kgDM/h/d	Avg. Past. Cover kgDM/ha	Herbage Allow. <----------	Pasture Intake kg DM/cow/day	Conc. Intake	Suppl. Intake ----->	Milkfat per Cow kg MF	Total Milkfat kg MF	CS Units
01-07	0	169	11.2	1864	0.0	0	0	0.0	0.00	0	4.6
11-07	9	162	10.7	1882	10.1	6.7	0	0.0	0.46	41	4.5
21-07	56	127	11.3	1852	30.5	14.4	0	0.0	0.65	403	4.5
01-08	117	74	12.3	1756	36.1	14.6	0	0.0	0.75	872	4.5
11-08	146	52	13.8	1609	37.6	14.1	0	0.0	0.87	1277	4.5
21-08	173	32	16.8	1464	30.5	9.8	0	0.0	0.78	1482	4.2
01-09	185	24	20.1	1417	29.2	9.2	0	0.0	0.75	1383	3.9
11-09	207	7	24.1	1410	28.8	9.2	0	0.0	0.69	1438	3.6
21-09	216	0	36.2	1435	31.7	10.7	0	0.0	0.72	1555	3.5
01-10	216	0	48.3	1534	37.9	12.8	0	0.0	0.76	1645	3.5
11-10	216	0	59.9	1697	41.2	14.2	0	0.0	0.79	1696	3.5
21-10	216	0	64.6	2043	47.8	15.1	0	0.0	0.80	1905	3.6
01-11	216	0	67	2190	51.7	15.2	0	0.0	0.80	1734	3.7
11-11	216	0	72.4	2342	78.3	15.2	0	0.0	0.79	1709	3.8
21-11	216	0	59.9	2545	82.6	15	0	0.0	0.77	1653	3.9
01-12	216	0	48.1	2625	74.8	14.8	0	0.0	0.74	1588	3.9
11-12	216	0	38.1	2538	87.2	14.6	0	0.0	0.71	1536	4.0
21-12	216	0	44.3	2271	61.0	14.4	0	0.0	0.71	1693	4.0
01-01	203	0	54	2313	59.5	14.3	0	0.0	0.72	1454	4.1
11-01	203	0	54.3	2444	63.3	14.1	0	0.0	0.71	1445	4.1
21-01	203	0	35.8	2579	64.3	13.9	0	0.0	0.68	1520	4.2
01-02	203	0	12.3	2525	46.0	9.6	0	4.0	0.63	1279	4.2
11-02	191	11	-5.6	2366	46.6	9.2	0	4.0	0.61	1156	4.2
21-02	191	11	-1.6	2073	32.0	8.3	0	4.0	0.58	887	4.2
01-03	191	11	4.5	1889	29.8	7.2	0	5.0	0.56	1077	4.2
11-03	191	11	11.3	1743	26.0	6.8	0	5.0	0.55	1044	4.2
21-03	170	32	15.2	1682	24.9	6.5	0	5.0	0.53	997	4.2
01-03	170	32	18.8	1666	21.7	6.3	0	5.0	0.51	874	4.2
11-03	163	32	24.5	1689	20.4	6.2	0	5.0	0.50	815	4.3
21-03	163	32	23.6	1773	21.1	4.9	0	5.0	0.39	639	4.3
01-04	0	169	21.4	1869	0.0	0	0	0.0	0.00	0	4.4
11-04	0	169	19.9	1933	0.0	0	0	0.0	0.00	0	4.5
21-04	0	169	18.1	2012	0.0	0	0	0.0	0.00	0	4.6
01-05	0	169	16.4	2067	0.0	0	0	0.0	0.00	0	4.6
11-05	0	169	14.5	2130	0.0	0	0	0.0	0.00	0	4.7
21-05	0	169	13.8	2176	0.0	0	0	0.0	0.00	0	4.7

Milk Income	$236,941	Farm Size (ha)	90	Past. Eaten (t DM/ha)	8.6
TOTAL FARM INCOME	$269,981	Herd Size (#)	225	Conc. Used (t DM)	0
				Suppl. Used (t DM)	75.1
Concentrate Costs	$0	Kg MF/farm	36,797	Hay Used (t DM)	10.1
Supplements Costs	$13,076	Kg MF/cow	163.5	DM Cut for Suppl. (t)	53.7
Nitrogen Costs	$6,460	Kg MF/ha.	408.9	Nitrogen Used (t)	6.5
Other Variable Costs	$78,750			Nitrogen Applications (kg N)	
TOTAL FARM COSTS	$98,286			20-09	1,440
				25-03	640
FARM GROSS MARGIN	$171,695			10-05	1,200
GROSS MARGIN / COW	$763			10-06	3,000
GROSS MARGIN / HA.	$1,908			15-06	1,344

APPENDIX 3B: Farm B - "Current" strategy

Date	No. Cows Milk	Dry	Pasture Gr. Rate kgDM/h/d	Avg. Past. Cover kgDM/ha	Herbage Allow.	Pasture Intake	Conc. Intake	Suppl. Intake	Milkfat per Cow kg MF	Total Milkfat kg MF	CS Units
					<----------	kg DM/cow/day		----->			
01-07	0	173	11.2	1864	0.0	0	0	0.0	0.00	0	4.6
11-07	9	166	10.7	1882	9.9	6.5	0	0.0	0.45	41	4.5
21-07	58	129	11.3	1851	29.8	14.3	0	0.0	0.65	415	4.4
01-08	120	76	12.2	1751	35.3	14.6	0	0.0	0.74	890	4.5
11-08	150	53	13.6	1597	36.8	14.1	0	0.0	0.87	1304	4.5
21-08	177	33	16.7	1445	29.5	9.4	0	0.0	0.76	1483	4.1
01-09	189	24	20	1400	28.2	8.8	0	0.0	0.73	1373	3.8
11-09	212	7	24	1397	27.8	8.8	0	0.0	0.67	1424	3.6
21-09	221	0	41.9	1424	31.2	10.8	0	0.0	0.71	1563	3.5
01-10	221	0	54.3	1572	38.4	13.3	0	0.0	0.76	1684	3.5
11-10	221	0	66.2	1777	42.6	14.6	0	0.0	0.79	1745	3.5
21-10	221	0	70.2	2169	49.7	15.3	0	0.0	0.80	1955	3.6
01-11	221	0	72.6	2358	54.5	15.3	0	0.0	0.80	1774	3.7
11-11	221	0	73.1	2551	82.7	15.2	0	0.0	0.79	1744	3.8
21-11	221	0	55.1	2745	85.9	15	0	0.0	0.76	1685	3.9
01-12	221	0	42.8	2765	76.1	14.9	0	0.0	0.73	1620	3.9
11-12	221	0	32.7	2611	86.4	14.6	0	0.0	0.71	1571	4.0
21-12	221	0	39	2264	59.1	14.4	0	0.0	0.71	1733	4.0
01-01	207	0	48.5	2237	55.6	11.7	0	2.5	0.70	1449	4.1
11-01	207	0	54.3	2377	59.8	11.6	0	2.5	0.69	1437	4.1
21-01	207	0	35.8	2573	62.6	11.4	0	2.5	0.67	1515	4.2
01-02	196	12	12.3	2585	45.6	10.6	0	3.0	0.63	1244	4.2
11-02	196	12	-5.7	2395	47.2	10.3	0	3.0	0.61	1189	4.2
21-02	196	12	-1.6	2071	31.6	9.3	0	3.0	0.58	916	4.2
01-03	196	12	4.4	1862	28.4	8	0	4.0	0.56	1105	4.2
11-03	196	12	11.1	1693	25.6	7.6	0	4.0	0.55	1073	4.2
21-03	196	12	15	1608	23.8	7.1	0	4.0	0.52	1130	4.2
01-03	150	58	18.4	1570	20.1	6.1	0	5.0	0.51	762	4.2
11-03	143	58	26.4	1591	18.9	6	0	5.0	0.49	706	4.2
21-03	143	58	25.7	1688	20.4	5	0	5.0	0.39	560	4.3
01-04	143	30	23.7	1790	19.1	9.8	0	0.0	0.41	586	4.2
11-04	143	30	21.3	1843	18.1	10.4	0	0.0	0.48	690	4.3
21-04	0	173	19.6	1870	0.0	0	0	0.0	0.00	0	4.3
01-05	0	173	18	1944	0.0	0	0	0.0	0.00	0	4.4
11-05	0	173	11.7	2026	0.0	0	0	0.0	0.00	0	4.5
21-05	0	173	11.2	2048	0.0	0	0	0.0	0.00	0	4.5

Milk Income	$247,207	Farm Size (ha)	90	Past. Eaten (t DM/ha)	8.8
TOTAL FARM INCOME	$280,857	Herd Size (#)	230	Conc. Used (t DM)	0
				Suppl. Used (t DM)	78.6
Concentrate Costs	$0	Kg MF/farm	38,368	Hay Used (t DM)	10.4
Supplements Costs	$13,660	Kg MF/cow	166.8	DM Cut for Suppl. (t)	56
Nitrogen Costs	$6,300	Kg MF/ha.	426.3	Nitrogen Used (t)	6.3
Other Variable Costs	$80,500			Nitrogen Applications (kg N)	
TOTAL FARM COSTS	$100,460			20-09	1,440
				25-03	640
FARM GROSS MARGIN	$180,397			10-05	1,200
GROSS MARGIN / COW	$784			10-06	3,000
GROSS MARGIN / HA.	$2,004			15-06	1,344

APPENDIX 3C: Farm B - "Early" strategy

Date	No. Cows Milk	No. Cows Dry	Pasture Gr. Rate kgDM/h/d	Avg. Past. Cover kgDM/ha	Herbage Allow. <----------	Milkers Pasture Intake kg DM/cow/day	Conc. Intake	Suppl. Intake ----->	Milkfat per Cow kg MF	Total Milkfat kg MF	CS Units
01-07	9	166	11.2	1864	8.8	5.8	0	0.0	0.44	40	4.5
11-07	58	129	10.7	1880	9.9	6.6	0	0.0	0.48	281	4.3
21-07	129	76	11.1	1842	29.3	14.3	0	0.0	0.73	1030	4.3
01-08	150	53	12	1668	34.2	14.6	0	0.0	0.86	1292	4.4
11-08	177	33	13.2	1488	34.4	13.6	0	0.0	0.87	1531	4.3
21-08	189	24	16.1	1321	25.4	6.3	0	0.0	0.65	1349	3.8
01-09	212	7	19.5	1340	26.8	7.7	0	0.0	0.63	1326	3.5
11-09	221	0	23.6	1348	26.4	7.7	0	0.0	0.59	1293	3.3
21-09	221	0	41.4	1391	30.4	10.2	0	0.0	0.63	1392	3.2
01-10	221	0	54	1542	37.7	13	0	0.0	0.68	1509	3.2
11-10	221	0	66	1750	42.1	14.5	0	0.0	0.72	1588	3.3
21-10	221	0	70.2	2140	49.1	15.1	0	0.0	0.74	1803	3.5
01-11	221	0	72.6	2332	53.9	15.2	0	0.0	0.75	1653	3.6
11-11	221	0	73.1	2528	82.0	15	0	0.0	0.74	1643	3.7
21-11	221	0	55.1	2726	85.3	14.9	0	0.0	0.72	1597	3.8
01-12	221	0	42.8	2752	75.8	14.7	0	0.0	0.70	1546	3.9
11-12	221	0	32.7	2603	86.2	14.4	0	0.0	0.68	1508	3.9
21-12	221	0	39	2262	59.1	14.2	0	0.0	0.69	1666	4.0
01-01	207	0	48.5	2240	55.7	14	0	0.0	0.69	1429	4.0
11-01	207	0	54.3	2317	59.1	13.8	0	0.0	0.69	1426	4.1
21-01	207	0	35.8	2450	60.0	13.6	0	0.0	0.66	1498	4.1
01-02	196	12	12.3	2396	43.0	10.7	0	2.5	0.62	1207	4.2
11-02	196	12	-4.8	2202	43.3	10.3	0	2.5	0.58	1141	4.2
21-02	196	12	-1.1	1886	28.9	9.3	0	2.5	0.56	875	4.2
01-03	196	12	4.3	1682	26.2	7.3	0	4.0	0.53	1040	4.2
11-03	150	58	19	1528	23.6	7	0	4.0	0.52	783	4.1
21-03	150	58	23.1	1540	23.7	7	0	4.0	0.51	836	4.2
01-03	150	58	26.8	1598	20.9	6.8	0	4.0	0.49	735	4.2
11-03	143	58	30	1686	20.5	7	0	4.0	0.48	689	4.2
21-03	143	58	29.3	1798	21.8	6	0	4.0	0.38	547	4.3
01-04	143	30	27.1	1916	20.7	10	0	0.0	0.40	569	4.3
11-04	143	30	16.7	1998	19.5	10.7	0	0.0	0.47	672	4.3
21-04	0	173	14.9	1971	0.0	0	0	0.0	0.00	0	4.4
01-05	0	173	13.1	1987	0.0	0	0	0.0	0.00	0	4.4
11-05	0	173	11.7	2018	0.0	0	0	0.0	0.00	0	4.5
21-05	0	173	11.2	2040	0.0	0	0	0.0	0.00	0	4.5

Milk Income	$242,015	Farm Size (ha)	90	Past. Eaten (t DM/ha)	9
TOTAL FARM INCOME	$275,665	Herd Size (#)	230	Conc. Used (t DM)	0
				Suppl. Used (t DM)	51.6
Concentrate Costs	$0	Kg MF/farm	37,498	Hay Used (t DM)	10.4
Supplements Costs	$7,230	Kg MF/cow	163.0	DM Cut for Suppl. (t)	55.6
Nitrogen Costs	$8,100	Kg MF/ha.	416.6	Nitrogen Used (t)	8.1
Other Variable Costs	$80,500			Nitrogen Applications (kg N)	
TOTAL FARM COSTS	$95,830			20-09	1,440
				25-03	640
FARM GROSS MARGIN	$179,835			10-05	1,200
GROSS MARGIN / COW	$782			10-06	3,000
GROSS MARGIN / HA.	$1,998			15-06	1,344

APPENDIX 4A: Farm C - "Actual" strategy

Date	No. Cows Milk	Dry	Pasture Gr. Rate kgDM/h/d	Avg. Past. Cover kgDM/ha	Herbage Allow. <----------	Pasture Intake kg DM/cow/day	Conc. Intake	Suppl. Intake ----->	Milkfat per Cow kg MF	Total Milkfat kg MF	CS Units
01-07	0	0	5.1	1973	0.0	0	0	0.0	0.00	0	0.0
11-07	0	0	8.1	1997	0.0	0	0	0.0	0.00	0	0.0
21-07	0	115	9.2	2049	0.0	0	0	0.0	0.00	0	5.0
01-08	0	115	9.5	2061	0.0	0	0	1.5	0.00	0	5.0
11-08	53	76	9.9	2083	9.2	5.2	0	1.5	0.44	235	4.9
21-08	90	47	10.7	2078	9.2	5.1	0	1.5	0.55	540	4.5
01-09	116	25	14	2055	14.0	7.4	0	1.5	0.64	740	4.3
11-09	132	14	14.8	2018	14.2	7.3	0	1.5	0.64	845	4.1
21-09	138	9	15	1973	14.3	7.2	0	1.5	0.62	853	3.8
01-10	150	0	15.6	1925	14.3	7.4	2	1.5	0.65	979	3.7
11-10	150	0	16.8	1885	14.5	8.1	2	1.5	0.67	1005	3.5
21-10	150	0	21.4	1850	13.8	8.2	2	1.5	0.66	1091	3.5
01-11	150	0	24.3	1857	37.1	13.6	0	1.5	0.72	1083	3.5
11-11	149	0	29.2	1801	41.1	14.9	0	0.0	0.74	1098	3.6
21-11	143	0	31.8	1702	39.2	14.5	0	0.0	0.73	1044	3.7
01-12	143	0	34.1	1651	38.7	14.2	0	0.0	0.72	1028	3.7
11-12	143	0	36.7	1627	41.0	14	0	0.0	0.71	1016	3.8
21-12	143	0	39.4	1656	44.1	14	0	0.0	0.70	1100	3.8
01-01	143	0	42.3	1743	44.7	14	0	0.0	0.69	987	3.9
11-01	143	0	44.3	1841	47.4	14.1	0	0.0	0.68	977	3.9
21-01	136	0	41.7	1956	49.7	14	0	0.0	0.67	1009	4.0
01-02	136	0	38.2	2070	52.0	13.9	0	0.0	0.66	903	4.0
11-02	136	0	34.4	2139	53.0	13.7	0	0.0	0.65	884	4.1
21-02	136	0	29.2	2175	43.1	13.4	0	0.0	0.64	701	4.1
01-03	136	0	24.1	2166	36.1	13.1	0	0.0	0.63	861	4.2
11-03	130	0	18.4	2112	22.0	12	0	0.0	0.61	789	4.2
21-03	130	0	14.9	2028	22.1	11.8	0	0.0	0.59	845	4.2
01-03	130	0	12.4	1901	18.0	6.8	0	5.0	0.54	702	4.2
11-03	84	31	12.8	1861	18.0	6.7	0	5.0	0.54	452	4.2
21-03	84	31	14.1	1835	17.6	5.4	0	5.0	0.42	352	4.3
01-04	0	115	12.4	1838	0.0	0	0	5.0	0.00	0	4.4
11-04	0	115	10.7	1814	0.0	0	0	0.0	0.00	0	4.5
21-04	0	115	9.1	1797	0.0	0	0	0.0	0.00	0	4.6
01-05	0	0	7.4	1782	0.0	0	0	0.0	0.00	0	0.0
11-05	0	0	3.4	1830	0.0	0	0	0.0	0.00	0	0.0
21-05	0	0	2.8	1837	0.0	0	0	0.0	0.00	0	0.0

Milk Income	$142,384	Farm Size (ha)	70	Past. Eaten (t DM/ha)	7.1
TOTAL FARM INCOME	$166,434	Herd Size (#)	155	Conc. Used (t DM)	9.3
				Suppl. Used (t DM)	22.3
Concentrate Costs	$4,650	Kg MF/farm	22,122	Hay Used (t DM)	35.6
Supplements Costs	$11,754	Kg MF/cow	142.7	DM Cut for Suppl. (t)	8
Nitrogen Costs	$3,720	Kg MF/ha.	316.0	Nitrogen Used (t)	3.7
Other Variable Costs	$54,250			Nitrogen Applications (kg N)	
TOTAL FARM COSTS	$74,374			20-09	1,440
				25-03	640
FARM GROSS MARGIN	$92,060			10-05	1,200
GROSS MARGIN / COW	$594			10-06	3,000
GROSS MARGIN / HA.	$1,315			15-06	1,344

APPENDIX 4B: Farm C - "Current" strategy

Date	No. Cows Milk	Dry	Pasture Gr. Rate kgDM/h/d	Avg. Past. Cover kgDM/ha	Herbage Allow. <----------	Pasture Intake kg DM/cow/day	Conc. Intake	Suppl. Intake ----->	Milkfat per Cow kg MF	Total Milkfat kg MF	CS Units
01-07	0	0	5.1	1973	0.0	0	0	0.0	0.00	0	0.0
11-07	0	0	11.1	1997	0.0	0	0	0.0	0.00	0	0.0
21-07	0	115	15	2078	0.0	0	0	0.0	0.00	0	5.2
01-08	0	115	15.3	2152	0.0	0	0	1.5	0.00	0	5.2
11-08	53	76	15.7	2231	9.8	5.7	0	1.5	0.47	246	5.0
21-08	90	47	16.5	2279	10.1	5.8	0	1.5	0.58	578	4.7
01-09	117	25	25.8	2307	15.8	8.9	0	1.5	0.70	821	4.5
11-09	133	14	24.2	2366	16.6	9.4	0	1.5	0.73	969	4.3
21-09	139	9	21.6	2378	17.1	9.3	1	1.5	0.76	1051	4.1
01-10	151	0	22.3	2370	17.4	9.8	1	1.5	0.74	1119	4.0
11-10	151	0	23.4	2353	17.8	10.8	1	1.5	0.76	1152	3.9
21-10	151	0	28	2327	17.1	10.9	1	1.5	0.76	1257	3.8
01-11	151	0	24.5	2339	46.1	13.3	1	1.5	0.80	1209	3.9
11-11	150	0	29.5	2278	50.1	14.6	1	0.0	0.81	1222	3.9
21-11	144	0	32.6	2187	48.3	14.5	1	0.0	0.81	1164	4.0
01-12	144	0	35.2	2143	48.1	15	0	0.0	0.79	1136	4.0
11-12	144	0	37.9	2111	51.2	14.8	0	0.0	0.78	1118	4.1
21-12	144	0	40.2	2075	53.4	14.6	0	0.0	0.76	1201	4.1
01-01	144	0	42.6	2155	53.3	14.5	0	0.0	0.74	1069	4.1
11-01	144	0	44.3	2243	55.9	14.4	0	0.0	0.73	1045	4.2
21-01	137	0	41.7	2350	57.9	14.2	0	0.0	0.71	1068	4.2
01-02	137	0	38.2	2456	60.0	14.1	0	0.0	0.69	946	4.3
11-02	137	0	34.4	2521	60.9	13.8	0	0.0	0.67	919	4.3
21-02	137	0	29.2	2552	49.4	13.6	0	0.0	0.66	726	4.3
01-03	137	0	24.1	2539	41.3	13.3	0	0.0	0.65	891	4.3
11-03	131	0	18.6	2478	25.0	12.7	0	0.0	0.63	831	4.4
21-03	131	0	15.5	2383	25.1	12.5	0	0.0	0.62	890	4.4
01-03	100	31	12.6	2249	20.6	12.1	0	0.0	0.61	609	4.4
11-03	84	31	12.5	2122	20.6	9.9	0	2.0	0.58	488	4.5
21-03	84	31	13.4	2051	20.2	8.8	0	2.0	0.46	388	4.5
01-04	84	31	11.8	2003	12.3	7.3	0	2.0	0.42	353	4.5
11-04	84	31	10.1	1963	12.4	7.3	0	2.0	0.40	339	4.6
21-04	0	115	8.5	1915	0.0	0	0	2.0	0.00	0	4.7
01-05	0	0	6.9	1877	0.0	0	0	0.0	0.00	0	0.0
11-05	0	0	3.1	1920	0.0	0	0	0.0	0.00	0	0.0
21-05	0	0	2.8	1924	0.0	0	0	0.0	0.00	0	0.0

Milk Income	$159,609	Farm Size (ha)	70	Past. Eaten (t DM/ha)	7.7
TOTAL FARM INCOME	$184,059	Herd Size (#)	156	Conc. Used (t DM)	10.5
				Suppl. Used (t DM)	14.1
Concentrate Costs	$5,261	Kg MF/farm	24,805	Hay Used (t DM)	34
Supplements Costs	$8,953	Kg MF/cow	159.0	DM Cut for Suppl. (t)	11.9
Nitrogen Costs	$8,750	Kg MF/ha.	354.4	Nitrogen Used (t)	8.8
Other Variable Costs	$54,600			Nitrogen Applications (kg N)	
TOTAL FARM COSTS	$77,563			20-09	1,440
				25-03	640
FARM GROSS MARGIN	$106,496			10-05	1,200
GROSS MARGIN / COW	$683			10-06	3,000
GROSS MARGIN / HA.	$1,521			15-06	1,344

APPENDIX 4C: Farm C - "Early" strategy

Date	No. Cows Milk	Dry	Pasture Gr. Rate kgDM/h/d	Avg. Past. Cover kgDM/ha	Herbage Allow. <----------	Pasture Intake kg DM/cow/day	Conc. Intake	Suppl. Intake ----->	Milkfat per Cow kg MF	Total Milkfat kg MF	CS Units
01-07	0	0	5.1	1973	0.0	0	0	0.0	0.00	0	0.0
11-07	0	0	10	1997	0.0	0	0	0.0	0.00	0	0.0
21-07	0	115	13	2067	0.0	0	0	0.0	0.00	0	5.2
01-08	53	76	13.3	2118	9.4	4.8	0	6.5	0.51	272	5.1
11-08	92	47	13.7	2160	9.6	4.8	0	6.5	0.66	611	4.9
21-08	120	25	14.6	2189	9.8	4.9	0	6.5	0.70	930	4.7
01-09	133	14	22.9	2217	15.2	8.4	0	1.5	0.74	983	4.4
11-09	139	9	22.1	2243	15.8	8.7	0	1.5	0.73	1014	4.1
21-09	151	0	20.6	2238	16.3	9	0	1.5	0.69	1049	3.9
01-10	151	0	21.3	2235	16.5	9.4	0	1.5	0.69	1041	3.7
11-10	151	0	22.4	2226	16.4	10.1	0	1.5	0.67	1011	3.6
21-10	151	0	26.9	2190	16.4	10.8	0	1.5	0.66	1101	3.5
01-11	151	0	24.5	2183	43.4	13.9	0	1.5	0.73	1096	3.6
11-11	150	0	29.5	2111	47.1	15.2	0	0.0	0.74	1111	3.7
21-11	144	0	32.6	2006	44.7	14.9	0	0.0	0.74	1060	3.8
01-12	144	0	35.2	1951	44.5	14.7	0	0.0	0.73	1052	3.8
11-12	144	0	37.9	1927	47.0	14.5	0	0.0	0.72	1043	3.9
21-12	144	0	40.2	1920	49.5	14.3	0	0.0	0.71	1129	4.0
01-01	144	0	42.6	2006	50.3	14.2	0	0.0	0.70	1013	4.0
11-01	144	0	44.3	2100	52.5	14.1	0	0.0	0.69	995	4.1
21-01	137	0	41.7	2212	55.0	14	0	0.0	0.68	1022	4.1
01-02	137	0	38.2	2323	57.0	13.8	0	0.0	0.66	906	4.2
11-02	137	0	34.4	2392	58.1	13.6	0	0.0	0.64	881	4.2
21-02	137	0	29.2	2428	47.1	13.2	0	0.0	0.63	696	4.2
01-03	137	0	24.1	2420	39.5	12.9	0	0.0	0.62	851	4.3
11-03	131	0	18.6	2365	24.0	12.3	0	0.0	0.60	792	4.3
21-03	131	0	15.4	2277	24.1	12.1	0	0.0	0.59	849	4.3
01-03	100	31	12.6	2149	19.8	11.6	0	0.0	0.58	580	4.4
11-03	84	31	13.2	2026	19.8	11.5	0	0.0	0.57	477	4.4
21-03	84	31	14.9	1941	19.6	10.5	0	0.0	0.45	380	4.5
01-04	84	31	13.3	1884	11.9	8.4	0	0.0	0.40	338	4.5
11-04	84	31	11.7	1848	12.2	8.6	0	0.0	0.38	323	4.5
21-04	0	115	10.2	1802	0.0	0	0	0.0	0.00	0	4.6
01-05	0	0	8.5	1784	0.0	0	0	0.0	0.00	0	0.0
11-05	0	0	3.9	1843	0.0	0	0	0.0	0.00	0	0.0
21-05	0	0	2.8	1855	0.0	0	0	0.0	0.00	0	0.0

Milk Income	$158,805	Farm Size (ha)	70	Past. Eaten (t DM/ha)	7.7
TOTAL FARM INCOME	$183,255	Herd Size (#)	156	Conc. Used (t DM)	0
				Suppl. Used (t DM)	19.4
Concentrate Costs	$0	Kg MF/farm	24,604	Hay Used (t DM)	32.7
Supplements Costs	$10,115	Kg MF/cow	157.7	DM Cut for Suppl. (t)	10.6
Nitrogen Costs	$8,364	Kg MF/ha.	351.5	Nitrogen Used (t)	8.4
Other Variable Costs	$54,600			Nitrogen Applications (kg N)	
TOTAL FARM COSTS	$73,079			20-09	1,440
				25-03	640
FARM GROSS MARGIN	$110,176			10-05	1,200
GROSS MARGIN / COW	$706			10-06	3,000
GROSS MARGIN / HA.	$1,574			15-06	1,344

APPENDIX 4D: Farm C - "Late" strategy

Date	No. Cows Milk	Dry	Pasture Gr. Rate kgDM/h/d	Avg. Past. Cover kgDM/ha	Herbage Allow. <----------	Pasture Intake kg DM/cow/day	Conc. Intake	Suppl. Intake ----->	Milkfat per Cow kg MF	Total Milkfat kg MF	CS Units
01-07	0	0	5.1	1973	0.0	0	0	0.0	0.00	0	0.0
11-07	0	0	10.4	1998	0.0	0	0	0.0	0.00	0	0.0
21-07	0	115	13.6	2074	0.0	0	0	0.0	0.00	0	5.2
01-08	0	115	14	2135	0.0	0	0	1.5	0.00	0	5.3
11-08	0	115	14.4	2202	0.0	0	0	1.5	0.00	0	5.3
21-08	51	76	15.3	2260	9.8	5.3	0	3.5	0.48	270	5.1
01-09	87	47	25.4	2298	15.4	7.6	0	3.5	0.68	588	4.9
11-09	117	25	24.5	2392	16.1	8	0	3.5	0.73	851	4.7
21-09	133	14	22.6	2455	16.7	9.3	0	1.5	0.75	995	4.5
01-10	139	9	23.3	2451	17.0	9.9	0	1.5	0.76	1053	4.3
11-10	151	0	24.4	2439	17.7	11.1	0	1.5	0.76	1140	4.1
21-10	151	0	29	2413	17.7	11.7	0	1.5	0.78	1302	4.0
01-11	151	0	24.5	2413	50.2	14.1	0	1.5	0.83	1249	4.0
11-11	150	0	29.5	2316	50.3	15.5	0	0.0	0.85	1268	4.0
21-11	144	0	32.6	2206	49.5	15.4	0	0.0	0.84	1206	4.1
01-12	144	0	35.2	2141	47.7	15.2	0	0.0	0.82	1184	4.1
11-12	144	0	37.9	2107	51.5	15	0	0.0	0.81	1160	4.1
21-12	144	0	40.2	2068	53.0	14.8	0	0.0	0.78	1241	4.1
01-01	144	0	42.6	2144	53.3	14.7	0	0.0	0.76	1101	4.2
11-01	144	0	44.3	2229	55.5	14.5	0	0.0	0.74	1073	4.2
21-01	137	0	41.7	2333	57.7	14.4	0	0.0	0.73	1098	4.2
01-02	137	0	38.2	2436	59.6	14.3	0	0.0	0.71	972	4.3
11-02	137	0	34.4	2497	60.5	14.1	0	0.0	0.69	946	4.3
21-02	137	0	29.2	2524	48.9	13.8	0	0.0	0.68	748	4.3
01-03	137	0	24.1	2507	40.9	13.5	0	0.0	0.67	920	4.3
11-03	131	0	18.6	2442	24.8	12.9	0	0.0	0.66	860	4.3
21-03	131	0	15.5	2343	24.9	12.7	0	0.0	0.64	921	4.4
01-03	100	31	12.6	2204	20.3	12.2	0	0.0	0.63	628	4.4
11-03	84	31	12.8	2074	20.4	12	0	0.0	0.61	516	4.5
21-03	84	31	14	1978	20.0	11	0	0.0	0.49	412	4.5
01-04	84	31	12.5	1908	12.1	8.7	0	0.0	0.43	364	4.5
11-04	84	31	10.9	1862	12.3	8.8	0	0.0	0.42	349	4.5
21-04	84	31	9.3	1806	8.3	5.9	0	0.0	0.40	370	4.3
01-05	0	0	7.7	1769	0.0	0	0	0.0	0.00	0	0.0
11-05	0	0	3.5	1820	0.0	0	0	0.0	0.00	0	0.0
21-05	0	0	2.8	1829	0.0	0	0	0.0	0.00	0	0.0

Milk Income	$159,398	Farm Size (ha)	70	Past. Eaten (t DM/ha)	7.8
TOTAL FARM INCOME	$183,848	Herd Size (#)	156	Conc. Used (t DM)	0
				Suppl. Used (t DM)	14
Concentrate Costs	$0	Kg MF/farm	24,784	Hay Used (t DM)	32.9
Supplements Costs	$8,513	Kg MF/cow	158.9	DM Cut for Suppl. (t)	13.3
Nitrogen Costs	$8,750	Kg MF/ha.	354.1	Nitrogen Used (t)	8.8
Other Variable Costs	$54,600			Nitrogen Applications (kg N)	
TOTAL FARM COSTS	$71,863			20-09	1,440
				25-03	640
FARM GROSS MARGIN	$111,985			10-05	1,200
GROSS MARGIN / COW	$718			10-06	3,000
GROSS MARGIN / HA.	$1,600			15-06	1,344

APPENDIX 5A: Farm D - "Actual" strategy

Date	No. Cows Milk	Dry	Pasture Gr. Rate kgDM/h/d	Avg. Past. Cover kgDM/ha	Herbage Allow.	Pasture Intake	Conc. Intake	Suppl. Intake	Milkfat per Cow kg MF	Total Milkfat kg MF	CS Units
					<----------	kg DM/cow/day		----->			
01-07	0	207	11.4	1814	0.0	0	0	0.0	0.00	0	4.7
11-07	19	192	12.3	1817	16.7	10.6	0	0.0	0.54	103	4.7
21-07	66	155	16.4	1771	16.9	10.8	0	0.0	0.62	453	4.7
01-08	119	113	17.9	1739	20.9	8.7	0	4.5	0.71	844	4.7
11-08	167	72	20	1731	26.7	9.1	0	4.5	0.77	1281	4.6
21-08	207	41	22.2	1733	30.1	9.2	0	4.5	0.82	1856	4.6
01-09	244	12	24.3	1748	35.9	9.7	0	3.5	0.83	2023	4.5
11-09	260	0	27.9	1762	37.0	10	0	3.5	0.86	2238	4.4
21-09	260	0	30.7	1799	42.4	8.4	0	5.5	0.87	2261	4.3
01-10	260	0	34.6	1899	44.3	9.2	1	3.0	0.74	1925	4.3
11-10	257	0	38.4	1993	46.8	8.8	2	3.5	0.89	2278	4.3
21-10	257	0	41.1	2132	52.7	12.6	2	0.0	0.88	2482	4.3
01-11	257	0	43.8	2235	51.1	14	0	0.0	0.83	2120	4.2
11-11	257	0	43.9	2321	48.0	13.9	0	0.0	0.78	2012	4.2
21-11	257	0	46.5	2372	39.4	13.6	0	0.0	0.75	1924	4.2
01-12	257	0	40.5	2453	40.7	13.6	0	0.0	0.72	1857	4.2
11-12	257	0	34.8	2475	40.5	13.3	0	0.0	0.70	1797	4.2
21-12	257	0	30.8	2446	47.3	13.1	0	0.0	0.69	1937	4.2
01-01	257	0	27	2426	47.1	12.8	0	0.0	0.67	1716	4.2
11-01	249	8	23.5	2376	45.6	12.4	0	0.0	0.65	1615	4.2
21-01	228	8	13.3	2303	38.0	7.3	0	5.0	0.61	1522	4.2
01-02	228	8	12.6	2241	35.9	7	0	5.0	0.58	1324	4.2
11-02	228	8	12.3	2184	35.1	8.8	0	2.5	0.57	1294	4.1
21-02	167	69	13.4	2087	35.5	8.2	0	2.5	0.47	631	4.2
01-03	167	69	14.6	2030	34.2	7.9	0	2.5	0.46	771	4.2
11-03	130	77	15.9	1976	33.5	7.8	0	2.5	0.46	598	4.3
21-03	130	77	16.9	1957	33.8	5.8	0	4.2	0.44	630	4.4
01-03	130	77	18	1970	29.3	5.8	0	4.2	0.43	556	4.4
11-03	0	207	18.5	1990	0.0	0	0	4.2	0.00	0	4.5
21-03	0	207	16.5	2034	0.0	0	0	0.0	0.00	0	4.5
01-04	0	207	14.2	2043	0.0	0	0	0.0	0.00	0	4.6
11-04	0	207	12.3	2069	0.0	0	0	0.0	0.00	0	4.6
21-04	0	207	10.9	2072	0.0	0	0	0.0	0.00	0	4.6
01-05	0	207	9.5	2056	0.0	0	0	0.0	0.00	0	4.7
11-05	0	207	8.4	2018	0.0	0	0	0.0	0.00	0	4.8
21-05	0	207	9.6	1960	0.0	0	0	0.0	0.00	0	4.9

Milk Income	$256,754	Farm Size (ha)	140	Past. Eaten (t DM/ha)	6.7
TOTAL FARM INCOME	$291,994	Herd Size (#)	265	Conc. Used (t DM)	13.4
				Suppl. Used (t DM)	80.6
Concentrate Costs	$6,697	Kg MF/farm	40,047	Hay Used (t DM)	49.9
Supplements Costs	$25,742	Kg MF/cow	151.1	DM Cut for Suppl. (t)	31
Nitrogen Costs	$11,200	Kg MF/ha.	286.0	Nitrogen Used (t)	11.2
Other Variable Costs	$92,750			Nitrogen Applications (kg N)	
TOTAL FARM COSTS	$136,389			20-09	1,440
				25-03	640
FARM GROSS MARGIN	$155,606			10-05	1,200
GROSS MARGIN / COW	$587			10-06	3,000
GROSS MARGIN / HA.	$1,111			15-06	1,344

APPENDIX 5B: Farm D - "Current" strategy

Date	No. Cows Milk	No. Cows Dry	Pasture Gr. Rate kgDM/h/d	Avg. Past. Cover kgDM/ha	Herbage Allow. <----------	Pasture Intake kg DM/cow/day	Conc. Intake	Suppl. Intake ----->	Milkfat per Cow kg MF	Total Milkfat kg MF	CS Units
01-07	0	213	11.4	1814	0.0	0	0	0.0	0.00	0	4.7
11-07	19	198	12.3	1816	16.2	10.3	0	0.0	0.54	102	4.6
21-07	68	160	21.1	1769	16.6	8.7	0	3.0	0.61	456	4.6
01-08	123	117	22.9	1808	20.9	10.1	0	3.0	0.72	886	4.6
11-08	172	74	25.1	1829	27.2	10.8	0	3.0	0.78	1349	4.6
21-08	213	42	27.2	1852	31.1	10.9	0	3.0	0.84	1958	4.6
01-09	251	12	28.8	1880	37.2	13.6	0	0.0	0.88	2205	4.5
11-09	268	0	35	1850	39.4	14	0	0.0	0.92	2457	4.4
21-09	268	0	36.5	1862	43.7	12.1	0	2.0	0.92	2475	4.4
01-10	268	0	40.1	1932	44.7	10	0	3.0	0.74	1993	4.4
11-10	265	0	44	2057	47.1	10.3	0	3.5	0.88	2329	4.3
21-10	265	0	46.3	2207	53.8	14.2	0	0.0	0.87	2524	4.3
01-11	265	0	49	2317	51.8	14.2	0	0.0	0.82	2183	4.2
11-11	265	0	46.8	2440	49.1	14.1	0	0.0	0.78	2073	4.2
21-11	265	0	44.2	2503	40.0	13.8	0	0.0	0.75	1986	4.2
01-12	265	0	38.2	2545	40.7	13.7	0	0.0	0.72	1918	4.2
11-12	265	0	32.4	2530	39.9	13.4	0	0.0	0.70	1857	4.2
21-12	265	0	28.4	2465	46.1	13.1	0	0.0	0.69	2001	4.2
01-01	265	0	24.7	2406	45.2	12.7	0	0.0	0.67	1769	4.2
11-01	265	0	21.3	2326	43.4	12.1	0	0.0	0.64	1706	4.2
21-01	243	0	13.3	2223	35.7	10	0	1.2	0.60	1601	4.1
01-02	243	0	12.6	2094	33.6	9.4	0	1.2	0.56	1356	4.0
11-02	243	0	12.3	1980	31.8	6.9	0	4.0	0.54	1310	4.0
21-02	175	68	13.4	1913	31.0	6.2	0	4.0	0.44	621	4.0
01-03	175	68	14.5	1878	29.8	6.9	0	2.5	0.43	751	4.0
11-03	145	68	15.9	1836	30.6	7.3	0	2.5	0.43	626	4.1
21-03	145	68	16.9	1818	31.4	6.1	0	4.2	0.43	679	4.1
01-03	145	68	17.9	1825	26.5	5.9	0	4.2	0.41	600	4.2
11-03	145	68	18.5	1842	24.1	6.5	0	4.2	0.49	708	4.2
21-03	0	213	16.7	1864	0.0	0	0	0.0	0.00	0	4.3
01-04	0	213	14.4	1888	0.0	0	0	0.0	0.00	0	4.2
11-04	0	213	12.4	1927	0.0	0	0	0.0	0.00	0	4.2
21-04	0	213	10.9	1941	0.0	0	0	0.0	0.00	0	4.2
01-05	0	213	9.5	1934	0.0	0	0	0.0	0.00	0	4.3
11-05	0	213	8.3	1904	0.0	0	0	0.0	0.00	0	4.3
21-05	0	213	9.9	1852	0.0	0	0	0.0	0.00	0	4.4

Milk Income	$272,678	Farm Size (ha)	140	Past. Eaten (t DM/ha)	7.2
TOTAL FARM INCOME	$309,068	Herd Size (#)	273	Conc. Used (t DM)	0
				Suppl. Used (t DM)	37
Concentrate Costs	$0	Kg MF/farm	42,480	Hay Used (t DM)	59.1
Supplements Costs	$16,944	Kg MF/cow	155.6	DM Cut for Suppl. (t)	33
Nitrogen Costs	$18,200	Kg MF/ha.	303.4	Nitrogen Used (t)	18.2
Other Variable Costs	$95,550			Nitrogen Applications (kg N)	
TOTAL FARM COSTS	$130,694			20-09	1,440
				25-03	640
FARM GROSS MARGIN	$178,374			10-05	1,200
GROSS MARGIN / COW	$653			10-06	3,000
GROSS MARGIN / HA.	$1,274			15-06	1,344

APPENDIX 5C: Farm D - "Early" strategy

Date	No. Cows Milk	No. Cows Dry	Pasture Gr. Rate kgDM/h/d	Avg. Past. Cover kgDM/ha	Herbage Allow.	Pasture Intake	Conc. Intake	Suppl. Intake	Milkfat per Cow kg MF	Total Milkfat kg MF	CS Units
					<----------	kg DM/cow/day		----->			
01-07	19	194	11.4	1814	16.3	8.4	0	3.0	0.54	102	4.6
11-07	67	156	12.4	1811	16.5	8.6	0	3.0	0.61	410	4.6
21-07	120	114	19.6	1754	16.8	8.8	0	3.0	0.69	914	4.6
01-08	174	72	21.3	1763	21.0	10.1	0	3.0	0.76	1329	4.5
11-08	208	41	23.5	1753	26.9	10.8	0	3.0	0.82	1708	4.5
21-08	246	12	25.6	1750	28.4	10.7	0	3.0	0.84	2268	4.4
01-09	262	0	26.9	1755	36.0	13.8	0	0.0	0.90	2369	4.4
11-09	262	0	32.9	1696	37.4	14.1	0	0.0	0.93	2430	4.3
21-09	262	0	36.3	1690	40.8	11.8	0	2.0	0.90	2354	4.2
01-10	262	0	40.1	1769	42.4	9.9	0	3.0	0.72	1885	4.2
11-10	259	0	44	1899	44.8	10.6	0	3.5	0.86	2215	4.2
21-10	259	0	46.3	2047	51.6	14.2	0	0.0	0.84	2392	4.2
01-11	259	0	49	2162	49.8	14.1	0	0.0	0.80	2077	4.2
11-11	259	0	46.8	2294	47.6	14	0	0.0	0.76	1977	4.2
21-11	259	0	46.5	2368	39.1	13.7	0	0.0	0.73	1903	4.2
01-12	259	0	40.5	2444	40.3	13.6	0	0.0	0.71	1843	4.2
11-12	259	0	34.8	2463	40.0	13.3	0	0.0	0.69	1790	4.3
21-12	259	0	30.8	2431	46.7	13.1	0	0.0	0.68	1929	4.3
01-01	259	0	27	2398	46.1	12.7	0	0.0	0.66	1706	4.3
11-01	259	0	23.5	2348	45.0	12.2	0	0.0	0.64	1649	4.2
21-01	238	0	13.3	2273	37.2	9.5	0	2.0	0.60	1558	4.2
01-02	238	0	12.6	2161	35.2	9	0	2.0	0.56	1331	4.1
11-02	171	67	12.3	2060	33.5	6.8	0	4.5	0.55	944	4.2
21-02	171	67	13.4	1996	33.0	6	0	4.5	0.45	610	4.2
01-03	171	67	14.6	1965	31.8	5.7	0	4.5	0.43	742	4.2
11-03	142	67	15.9	1942	32.5	7.4	0	2.5	0.44	621	4.3
21-03	142	67	16.9	1924	33.3	5.6	0	4.2	0.43	665	4.3
01-03	142	67	18	1940	28.4	5.5	0	4.2	0.42	593	4.4
11-03	142	67	18.6	1968	26.5	6.2	0	4.2	0.50	710	4.4
21-03	0	208	16.9	1996	0.0	0	0	0.0	0.00	0	4.5
01-04	0	208	14.5	2014	0.0	0	0	0.0	0.00	0	4.5
11-04	0	208	12.5	2049	0.0	0	0	0.0	0.00	0	4.5
21-04	0	208	11	2058	0.0	0	0	0.0	0.00	0	4.5
01-05	0	208	9.5	2047	0.0	0	0	0.0	0.00	0	4.6
11-05	0	208	8.4	2012	0.0	0	0	0.0	0.00	0	4.6
21-05	0	208	9.7	1956	0.0	0	0	0.0	0.00	0	4.7

Milk Income	$276,769	Farm Size (ha)	140	Past. Eaten (t DM/ha)	7.1
TOTAL FARM INCOME	$312,549	Herd Size (#)	267	Conc. Used (t DM)	0
				Suppl. Used (t DM)	49.7
Concentrate Costs	$0	Kg MF/farm	43,023	Hay Used (t DM)	56.2
Supplements Costs	$19,367	Kg MF/cow	161.1	DM Cut for Suppl. (t)	33.1
Nitrogen Costs	$18,200	Kg MF/ha.	307.3	Nitrogen Used (t)	18.2
Other Variable Costs	$93,450			Nitrogen Applications (kg N)	
TOTAL FARM COSTS	$131,017			20-09	1,440
				25-03	640
FARM GROSS MARGIN	$181,532			10-05	1,200
GROSS MARGIN / COW	$680			10-06	3,000
GROSS MARGIN / HA.	$1,297			15-06	1,344

APPENDIX 5D: Farm D - "Late" strategy

Date	No. Cows Milk	No. Cows Dry	Pasture Gr. Rate kgDM/h/d	Avg. Past. Cover kgDM/ha	Herbage Allow. <----------	Pasture Intake kg DM/cow/day	Conc. Intake	Suppl. Intake ----->	Milkfat per Cow kg MF	Total Milkfat kg MF	CS Units
01-07	0	211	11.4	1814	0.0	0	0	0.0	0.00	0	4.7
11-07	0	211	12.4	1817	0.0	0	0	0.0	0.00	0	4.8
21-07	19	196	21.2	1782	16.9	10.9	0	0.0	0.55	115	4.8
01-08	68	158	22.9	1831	21.2	11	0	2.0	0.65	445	4.8
11-08	116	116	25.1	1868	27.9	11.8	0	2.0	0.76	879	4.8
21-08	170	73	27.3	1908	33.0	12	0	2.0	0.82	1532	4.8
01-09	211	42	29	1942	39.2	11.8	0	2.0	0.86	1817	4.7
11-09	248	12	35.2	1972	40.8	12	0	2.0	0.88	2188	4.6
21-09	265	0	36.5	2040	48.1	10.3	0	4.0	0.91	2403	4.5
01-10	265	0	40.1	2150	49.2	10.2	0	3.0	0.77	2046	4.5
11-10	262	0	44	2276	52.5	10.8	0	3.5	0.92	2423	4.5
21-10	262	0	46.3	2420	58.9	14.5	0	0.0	0.91	2617	4.4
01-11	262	0	49	2529	56.8	14.5	0	0.0	0.87	2267	4.4
11-11	262	0	46.8	2652	53.4	14.4	0	0.0	0.82	2155	4.4
21-11	262	0	44.2	2713	43.5	14.2	0	0.0	0.79	2070	4.3
01-12	262	0	38.2	2751	44.1	14	0	0.0	0.76	1994	4.3
11-12	262	0	32.3	2733	43.3	13.8	0	0.0	0.73	1923	4.3
21-12	262	0	28.4	2663	50.0	13.6	0	0.0	0.71	2059	4.3
01-01	262	0	24.7	2575	48.2	13.2	0	0.0	0.70	1827	4.3
11-01	262	0	21.3	2489	47.1	12.8	0	0.0	0.68	1776	4.3
21-01	240	0	13.3	2375	38.3	11	0	1.0	0.64	1690	4.2
01-02	240	0	12.6	2228	36.3	10.5	0	1.0	0.61	1455	4.2
11-02	173	68	12.3	2095	34.2	8.9	0	2.5	0.59	1024	4.2
21-02	173	68	13.4	1999	32.9	7.9	0	2.5	0.48	661	4.2
01-03	173	68	14.6	1944	31.7	7.6	0	2.5	0.47	806	4.2
11-03	143	68	15.9	1893	32.1	7.8	0	2.5	0.47	668	4.3
21-03	143	68	16.9	1871	32.5	6.4	0	4.2	0.46	720	4.4
01-03	143	68	17.9	1876	27.1	6.1	0	4.2	0.44	633	4.4
11-03	143	68	18.6	1892	25.2	6.4	0	4.2	0.51	735	4.4
21-03	0	211	16.8	1916	0.0	0	0	0.0	0.00	0	4.5
01-04	0	211	14.5	1938	0.0	0	0	0.0	0.00	0	4.5
11-04	0	211	12.4	1974	0.0	0	0	0.0	0.00	0	4.5
21-04	0	211	10.9	1986	0.0	0	0	0.0	0.00	0	4.5
01-05	0	211	9.5	1977	0.0	0	0	0.0	0.00	0	4.6
11-05	0	211	8.4	1945	0.0	0	0	0.0	0.00	0	4.6
21-05	0	211	9.8	1891	0.0	0	0	0.0	0.00	0	4.7

Milk Income	$261,987	Farm Size (ha)	140	Past. Eaten (t DM/ha)	7.1
TOTAL FARM INCOME	$297,907	Herd Size (#)	270	Conc. Used (t DM)	0
				Suppl. Used (t DM)	37.3
Concentrate Costs	$0	Kg MF/farm	40,928	Hay Used (t DM)	56.7
Supplements Costs	$16,118	Kg MF/cow	151.6	DM Cut for Suppl. (t)	36
Nitrogen Costs	$18,200	Kg MF/ha.	292.3	Nitrogen Used (t)	18.2
Other Variable Costs	$94,500			Nitrogen Applications (kg N)	
TOTAL FARM COSTS	$128,818			20-09	1,440
				25-03	640
FARM GROSS MARGIN	$169,089			10-05	1,200
GROSS MARGIN / COW	$626			10-06	3,000
GROSS MARGIN / HA.	$1,208			15-06	1,344

APPENDIX 6. Summary of the physical performance of the actual strategies vs the "improved" strategy for each particular farm.

	Farm A		Farm B		Farm C		Farm D	
Strategy	Actual	Early	Actual	Late	Actual	Late	Actual	Early
Physical performance:								
- Area (ha)	132	132	90	90	70	70	140	140
- Total pasture accumulation (t DM/ha)	8.7	9.0	10.1	10.5	7.1	7.9	8.0	8.6
- Net pasture used (t DM/ha)	7.7	8.2	8.3	9.0	7.2	7.7	6.7	7.1
- Pasture utilization (%)	88.2	91.0	85.1	85.6	98.0	97.9	83.2	82.8
- Stocking rate (cows/ha)	2.15	2.27	2.50	2.55	2.21	2.22	1.89	1.90
- Concentrate used (t DM)	0	0	0	0	9.3	0	13.4	0
- Supplements used (t DM)	36.9	23.2	75.1	60.5	22.3	14.0	80.6	49.7
- Hay used (t DM)	42.4	44.6	10.1	10.4	35.6	32.7	49.9	56.2
- Nitrogen used (kg N/ha/year)	57	70	71	100	53	125	80	130
Milk production:								
- Milksolids/farm	79,872	83,051	64,556	67,631	38,811	43,480	70,258	75,479
- Milksolids/ha	605	629	717	751	554	620	502	539
- Milksolids/cow	280	284	287	294	250	278	265	283

APPENDIX 7. Summary of the financial performance of the actual strategies vs the "improved" strategy for each particular farm.

	Farm A		Farm B		Farm C		Farm D	
Strategy	Actual	Early	Actual	Late	Actual	Late	Actual	Early
Financial performance:								
- Milk income	291,986	304,606	236,941	247,723	142,384	159,393	256,751	276,768
Total farm income	321,136	334,226	269,981	281,373	161,434	183,848	291,994	291,994
Farm expenses:								
- Concentrates fed ($)	0	0	0	0	4,650	0	6,697	0
- Supplements fed ($)	9,516	6,261	13,076	8,992	11,754	8,513	25,741	19,612
- Nitrogen ($)	7,64	9,240	6,460	9,000	3,720	8,750	11,200	18,200
- Herd costs ($)	99,890	102,200	78,750	80,500	54,250	54,600	92,750	93,450
Total farm costs ($)	116,890	117,701	98,286	98,492	74,374	71,863	136,389	131,262
Gross margin/farm ($)	204,246	216,525	171,695	182,882	92,060	111,985	155,606	181,531
Gross margin/cow ($)	717	742	763	795	594	717	587	680
Gross margin/ha ($)	1,547	1,640	1,908	2,032	1,315	1,599	1,111	1,297

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