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**PHYSICAL AND FINANCIAL EVALUATION
OF A GROUP OF HIGH PRODUCING
DAIRY FARMS IN NEW ZEALAND**

A thesis presented in partial fulfilment
of the requirements for the degree of

Master of Applied Science (MApplSc)

in
Pastoral Science



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This thesis is dedicated to my parents

José Eduardo Salles and Teresinha V. Regasso Salles

ABSTRACT

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Traditionally, New Zealand dairy production has been based on high pasture utilisation at high stocking rates, which resulted in low animal performance. Recently, a group of farmers (AGMARDT – Dairy Farm Monitoring Programme) gradually changed their production policy to a high production per hectare system achieved through high animal performance. The system is based on pre and post grazing herbage mass targets, strategic use of supplements to overcome pasture deficit and moderate stocking rates (2.7 cows/ha). This project evaluated the physical and financial characteristics of nine case study farms in the Southern North Island of New Zealand, involved in these changes. A one-year system study was conducted (2000/2001) in which physical and financial data were obtained to identify factors affecting farm production, efficiency and profitability. The results showed that the systems were effective and profitable, under the conditions in the 2000/2001 year. Average annual milksolids production per cow (411 kg MS/cow/year) and per hectare (1,100 kg MS/ha/year) for the case study farms were 33% higher than the national average. Average annual total intake for all farms was 5,257 kg DM/cow, 14,035 kg DM/ha, 59,656 MJ ME/cow and 159,232 MJ ME/ha. Mean economic farm surplus per ha for all case study farms (NZ\$ 3,077/ha) was higher than regional averages (by 62% to 84%) and comparable to the industry's top 10% farms. Milksolids production per cow ($R^2 = 0.71$) and per hectare ($R^2 = 0.74$) were closely correlated with pasture intake. Supplements (24% of total annual ME intake) were used to overcome pasture deficits, so their effects were related to long term influences on maintaining both pasture and animal potentials. Differences between pasture intakes from farmer's visual assessment and plate meter readings (adjusted data) in summer, suggested that farmers were underestimating intake and/or the adjusted data, relying on standardised national equations, were overestimated. The measured ME intakes were higher than the theoretical requirements for all farms, suggesting measured intake overestimation and/or feed waste. Feed conversion efficiencies (6.0 to 7.4 g MS/MJ ME intake) increased with decreases in intakes, not with increases in milk yields. On-farm techniques used to measure feed intake, particularly from pasture, should be improved; and farmers' skill in increasing feed efficiency should be optimised, mainly in the systems achieving higher animal performance. Since the milk payment of NZ\$5.00/kg MS will probably not remain in the future, control of production costs should receive more emphasis, particularly supplement costs.

Keywords: dairy system, pasture management, feed quality, pasture intake, supplement intake, animal performance, stocking rate, feed conversion efficiency, cost of milksolids production, profitability.

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Vision without action is just a dream.

Action without vision is just activity.

Vision and action together can change the world.

Joel Barker

President

Infinity, Ltd.

CHAPTER 1

GENERAL INTRODUCTION

The primary objective of dairy production systems is to produce high quality dairy products for human consumption by utilising the ability of the grazing ruminant animal to consume and transform feeds that are not suitable for human nutrition into milk. Milk should be produced at competitive prices for the consumer, as well as being profitable for the producers. This implies that the inputs and outputs of the system should be precisely adjusted.

Low milk production costs in New Zealand grazing systems are based on growing and utilising large amounts of grazed pasture. Effective feeding of the herd in a grazing system must ensure that feed demand is matched by the supply of pasture throughout the year (Holmes *et al.*, 1987). The success of New Zealand dairy production over the past years has been based on the increased amount of pasture harvested as a consequence of better pasture utilisation resulting from high stocking rates (Holmes, 1998; Matthews, 1995), combined with genetic improvement, which increased milk production and feed conversion efficiency per animal (Holmes & Matthews, 2001). Traditionally, dairy systems have adjusted herbage intakes to overcome feed deficits, and pasture limitations have resulted in low animal performance (Matthews, 1994). When the objective is to increase production per cow, high pasture allowances are required in order to achieve high animal intakes. However, greater herbage allowance could increase herbage wastage, leading to a conflict between pasture utilisation and forage intake (Hodgson, 1990; Matthews, 1995).

When aiming at high intakes per animal, supplementary feed may replace the cow's function as the buffer of the system. The input of supplements reduces variation in farm production levels, but supplementary feed inputs and farm profitability vary between seasons (Matthews, 1995), depending on the amount of supplement required and the relative price of supplements and milk.

After identifying that high pasture utilisation leads to a certain degree of animal underfeeding, a group of farmers have gradually changed their production policy from a focus on high production per hectare through high stocking rate to a strategy based on high production per hectare through improved animal performance. They concluded that this objective could be obtained by decreasing stocking rate and utilising supplements strategically, while still maintaining efficient pasture utilisation.

Accordingly, a three-year Dairy Farm Monitoring Programme was established (see Chapter 3) on twelve farms in the Southern North Island of New Zealand. All farms were attempting to improve per cow nutrition in order to improve farm productivity and profitability. This study shows an analysis of the results of the third year of the project, and focuses on the physical and financial components influencing the performance of these dairy systems. The specific objectives of this study are:

- to understand and identify factors affecting productivity, efficiency and profitability of the case study farms;
- to compare the physical and financial performance among the case study farms and with industry data;

- to identify opportunities for further improvement in the efficiency of both physical and financial management of the case study farms;

These objectives were accomplished through a series of biological and financial analyses. This thesis is presented in seven chapters. Chapter 2 is a review of literature reporting relevant physical and financial information. It covers the topics of New Zealand dairy production, feed conversion efficiency, supplementary feed utilisation and tools for the analysis of financial data.

The Dairy Farm Monitoring Programme is described in Chapter 3. It contains information regarding the background of the project, objectives, project benefits and outcomes for the 1999/2000 season. Chapter 4 describes the methodology used to monitor the case study farms. It covers the biological measurements and calculations, as well as the statistical and financial analyses.

Chapter 5 provides a general description of the farms followed by information on feed consumption, feed conversion efficiency, factors influencing milksolids production and financial results for individual farms. The main findings and their implications are considered in a general discussion (Chapter 6) and conclusions (Chapter 7).

CHAPTER 2

LITERATURE REVIEW

2.1. INTRODUCTION

Milk production in New Zealand is mainly based on grazed pasture. Grazing production systems are characterised by relatively short lactations determined by the seasonal nature of pasture growth. Consequently milk production is mainly restrained by the availability of feed throughout the year. The possibility of extending lactation through the use of supplementary feed has been widely demonstrated throughout New Zealand. However, the biological and economic efficiency of this approach has shown great variation when supplements are included in the system, due to numerous variables affected by their utilisation. Herd, pasture, reproduction and nutrition management and costs of production play an important role in the efficiency and profitability of a dairy farm. All these factors must be adjusted to take full advantage of the system's potential. This literature review aims to outline the key points of New Zealand dairy production; the main factors related to feed conversion efficiency and supplementary feed utilisation and the importance of production function and financial key performance indicators.

2.2. NEW ZEALAND DAIRY PRODUCTION

Less than 10% of the total milk produced in the world originates from grazing systems (Steinfeld & Maki-Hokkonen, 1995), including most dairy farms in New Zealand. The reason for the low proportion of milk production from grazing systems is the difficulty

of maintaining pasture growth and grazing throughout the year. Temperate countries like New Zealand, South Ireland, Argentina and parts of southern Australia have unique environmental characteristics allowing the production of good quality forages, required by the high yielding dairy cow.

Although the combination of temperature, rainfall, soil fertility and other environmental factors will largely determine the production potential of pastoral systems, productivity of a dairy system is also significantly influenced by feed demand, pasture utilisation and animal performance. These factors are discussed in the following sections.

2.2.1. Environment and seasonal production

The environment is the main determinant of the productivity on grassland systems. The main environmental components influencing the system are temperature, solar radiation, precipitation and soil fertility. The combination of these factors will define the predominant grass species in an ecosystem, pasture annual yield, seasonal growth and pasture quality. As an example, particular climatic and soil combinations results in annual dry matter (DM) production between 2.5 and 25 t per hectare in temperate conditions and over 50 tonnes per hectare in the wet tropics (Holmes *et al.*, 1987). Although maximum herbage accumulation rates of 26.6 t DM/ha/year for temperate forage grasses was recorded at Te Awa, New Zealand (Suckling, 1960), Hodgson (1989) considered 14 t DM/ha/year as the normal maximum in New Zealand, and Penno *et al.* (1996) recorded a little over 20 t DM/ha/year in some recent dairy trials. In the wet tropics, high dry matter production is expected, as the 85.2 t DM/ha/year for Napier grass in El Salvador (Cooper, 1970). However, the quality of the forage is inferior than that obtained in temperate regions.

The pattern of pasture production in New Zealand is affected by the low winter temperatures and by the moisture stress levels in summer and early autumn (Matthews, 1994) when the highest temperatures of the year are achieved (Clark *et al.*, 2001). Soil fertility also influences the potential of pasture production (Korte *et al.*, 1987). Seasonal patterns of pasture production influenced by climatic and soil characteristics in New Zealand can be divided into four major categories: warm humid, summer dry, cold humid and cold dry (Figure 2.1) (Korte *et al.*, 1987).

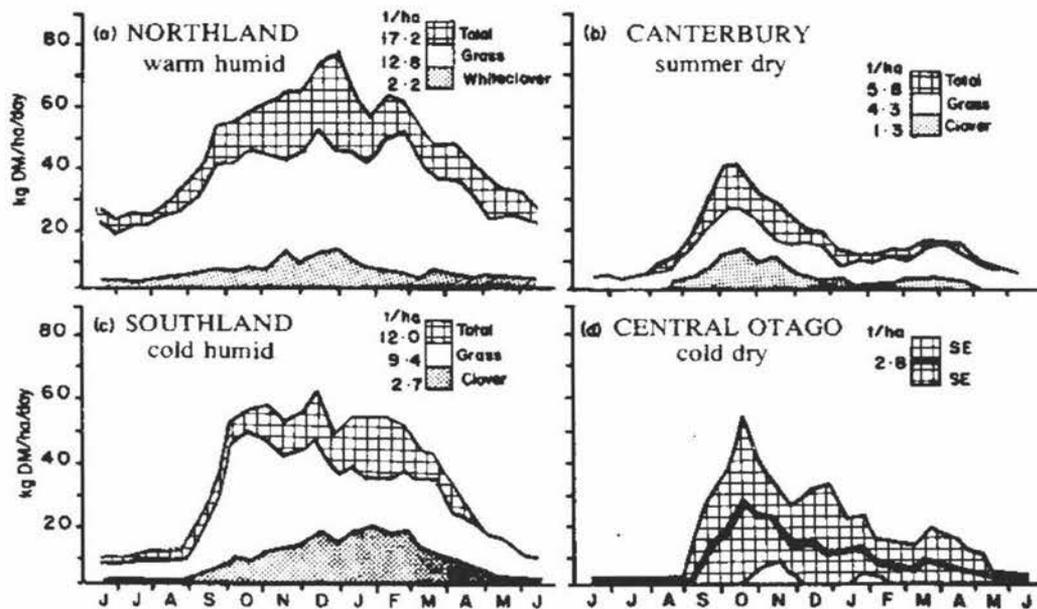


Figure 2.1 Typical seasonal patterns of pasture production in New Zealand, showing the daily accumulation rates (kg DM/ha/day) for clover, grass and total pasture. Mean annual production is also given (t DM/ha) (Korte *et al.*, 1987).

Despite the great proportion of New Zealand dairy pastures already operating at high levels of phosphate and potassium fertility (Hodgson, 1989), soil analyses revealed that 38% of Olsen P test values on dairy farms were below optimum levels (Butler & Johnston, 1997). Furthermore, around 60% of dairy farms in North Island do not have adequate soil fertility levels to sustain maximum production (Roberts *et al.*, 1992).

Phosphorus, potassium, sulphur, lime or other nutrients in deficit are normally applied in order to provide better conditions for grass and legumes development (Roberts *et al.*, 1992). Use of nitrogen (N) fertiliser is increasing steadily in dairying (Clark *et al.*, 2001) to overcome short term feed deficits. Although more milksolids were produced with 400 kg N/ha/year than with 200 kg N/ha/year (Ledgard *et al.*, 1997), most of the increase was obtained by applying only 200 kg N/ha/year, this being also the most profitable option (Penno *et al.*, 1996) with less risk of ground water contamination (Clark, 1997).

The environmental effects on the pattern of pasture growth in a specific region, will not only determine the production potential but also the management strategies to overcome periods of deficit (Matthews, 1994). Strategic use of supplements, adequate stocking rates, calving dates and drying off dates have been utilised in order to adjust the system to seasonal pasture distribution patterns (Figure 2.2a) and to pasture production variation between years within the same region (Figure 2.2b) (Matthews, 1994).

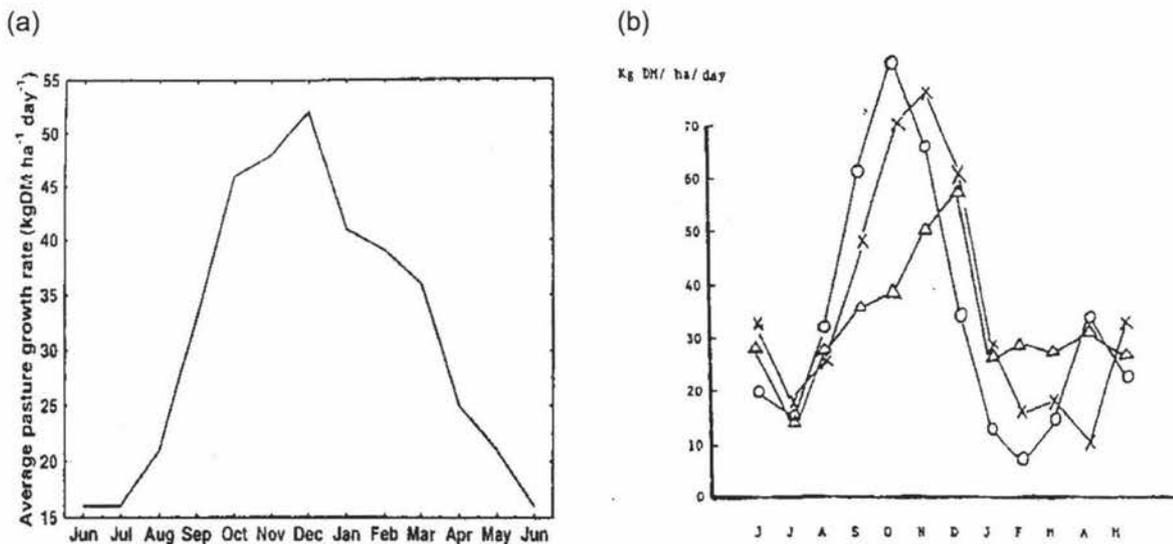


Figure 2.2 Monthly pasture growth rates in the Manawatu region, mean of 11 years data (a) and monthly pasture growth rates from Massey No. 3 Dairy for three years (b) (Matthews, 1994).

Calving and drying off dates play an important role in the management policy of a seasonal pasture based dairy systems in New Zealand. Dry matter consumption varies throughout lactation and it is usually highest 70 to 90 days after calving, a period that also coincides with the initiation of mating. Therefore, in order to match the maximum animal demand with maximum pasture production, about 95% of the cows in New Zealand calve in late winter-early spring, as shown in Figure 2.3 (Bryant, 1989; Garcia & Holmes, 1999; Holmes & Matthews, 2001).

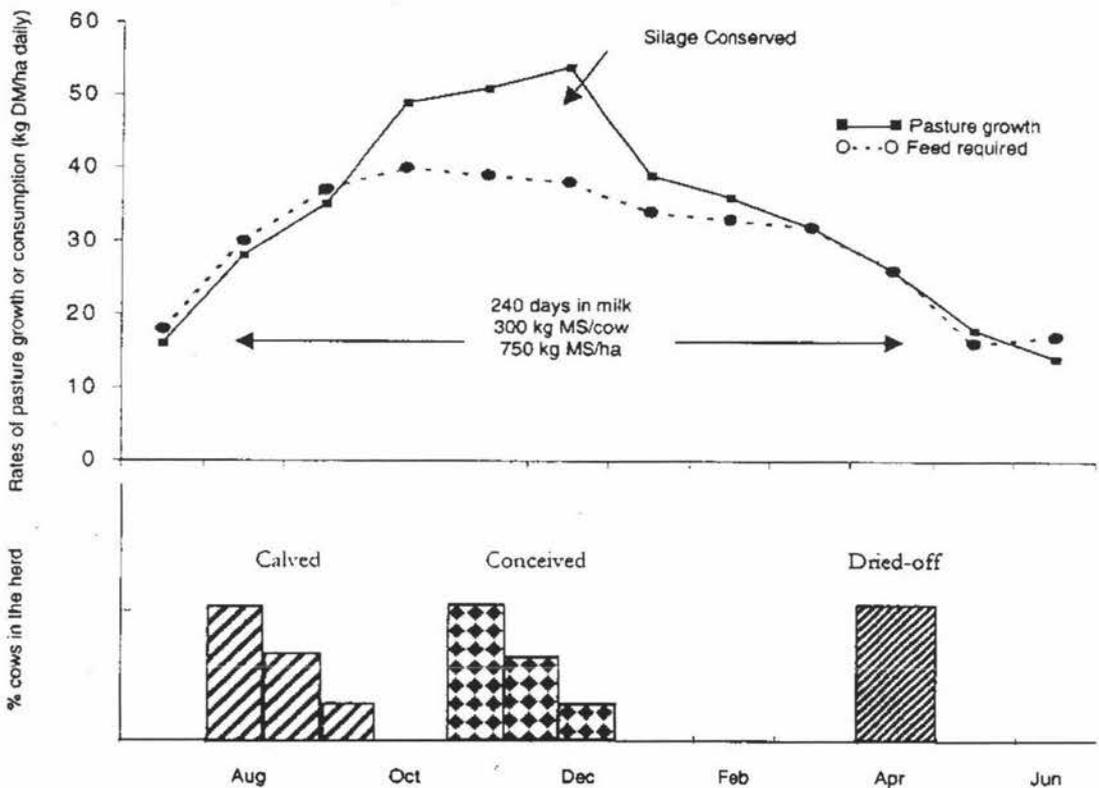


Figure 2.3 The relationship between feed demand and supply in a pastoral system, in a moist summer and cool winter region, with 2.5 cows/ha and no supplements (Holmes & Matthews, 2001).

Selecting the appropriate calving date will influence the level of feeding in early lactation as well as lactation length (Holmes *et al.*, 1987). After a relatively short lactation period of 220-240 days, cows are usually dried-off in late autumn to reduce

feed demand during winter, which is characterised by slow pasture growth rates (Garcia & Holmes, 1999). This early dry-off prevents an excessive decrease in body condition and farm pasture cover (Pinares & Holmes, 1996).

Supplementary feed has a significant influence in calving and drying off dates, in both spring and autumn calving systems in New Zealand. In spring calving systems, supplementary feed can extend lactation when used in early spring or late autumn. Autumn calving systems combined with supplement utilisation could also be an alternative for farms with low pasture growth rates during summer (Holmes, 2001). Farmers owning large herds may split the herd into spring and autumn calving cows in order to have a more even distribution of work, while others may be stimulated by the premium prices paid for milk during winter. Autumn calving may be an attractive idea and it has proved to be a profitable system if efficient management and supplementation is applied (Holmes, 2001).

2.2.2. Feed demand versus pasture utilisation and animal performance

Stocking rate is one of the most powerful management tools to regulate the amount of herbage available to the animals over the year (White, 1987). It can be defined as the number of animals per hectare of land (White, 1987), as the number of livestock grazed per tonne of feed grown (Holmes *et al.*, 1987) or as the ratio of total herd liveweight to total feed supply (Penno, 2000). All these concepts reflect the relationship between feed demand and feed supply and any of the above definitions is appropriate if the components, such as cow size and pasture production, are taken into consideration when it comes to the interpretation of the values.

A direct effect of stocking rate is the regulation of the amount of pasture consumed per animal. Herbage intake per animal and consumption per unit area are inversely related

(Hodgson, 1990). The conversion efficiency of ingested herbage into animal products increases progressively as intake per animal increases (Hodgson, 1990; Ungar, 1996). However, the efficiency of herbage utilisation increases as herbage consumption per unit area increases (Hodgson, 1990) due to a reduction in pasture wasted through death and decay of uneaten herbage (Holmes *et al.*, 1987). The waste of pasture throughout the year can be reduced by ensuring that there are sufficient stock on the farm to eat all the available pasture (Holmes *et al.*, 1987). However, this generally results in reduced intake per animal.

In general, the main factors limiting intake of grazing cows are the sward condition and pasture availability. Figure 2.4 shows that high pasture intake per animal is obtained by offering high pasture mass and allowances while preventing low levels of post grazing herbage mass (Poppi *et al.*, 1987). However, if the major objective is to attain high pasture utilisation, post grazing herbage mass will be low and intake per animal will be limited (Poppi *et al.*, 1987).

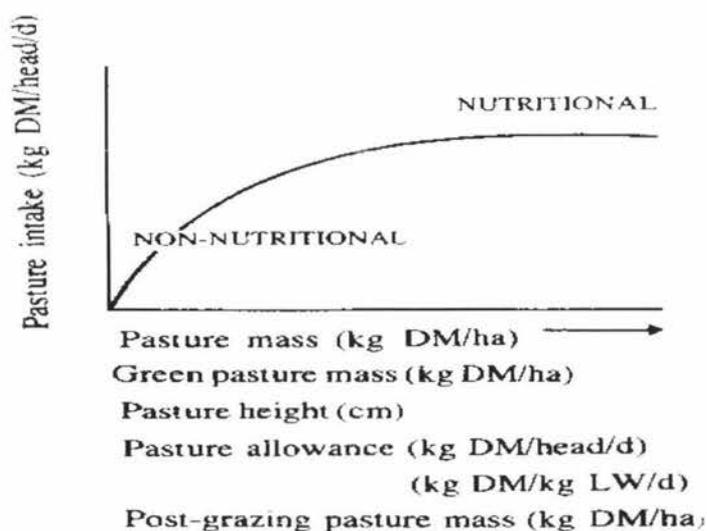


Figure 2.4 The relationship of pasture intake per animal to various pasture characteristics and methods of pasture allocation (Poppi *et al.*, 1987).

In the ascending part of the curve (Figure 2.4), intake is limited by sward structure and by the ability of the animal to harvest pasture (grazing behaviour). At this point, intake is very sensitive to changes in the amount of pasture available, which means that any mistake in pasture allocation will have a significant effect on animal performance (Poppi *et al.*, 1987). At the plateau of the curve, intake is controlled by nutritional factors, such as digestive capacity, rate of digestion in the rumen, concentration of metabolic products (Poppi *et al.*, 1987) and animal characteristics, such as genotype, size and physiological stage (Holmes, 1989; Poppi *et al.*, 1987).

Trials conducted over the last 50 years in New Zealand and Australia showed that in 34 of the 35 experiments, milksolids production per cow decreased when stocking rate was increased by 1 cow/ha (Figure 2.5b) (Penno, 1999). Production per hectare has always increased with increases in stocking rate up to 1980; since then only 3 out of 15 trials resulted in higher production per hectare (Figure 2.5a) (Penno, 1999).

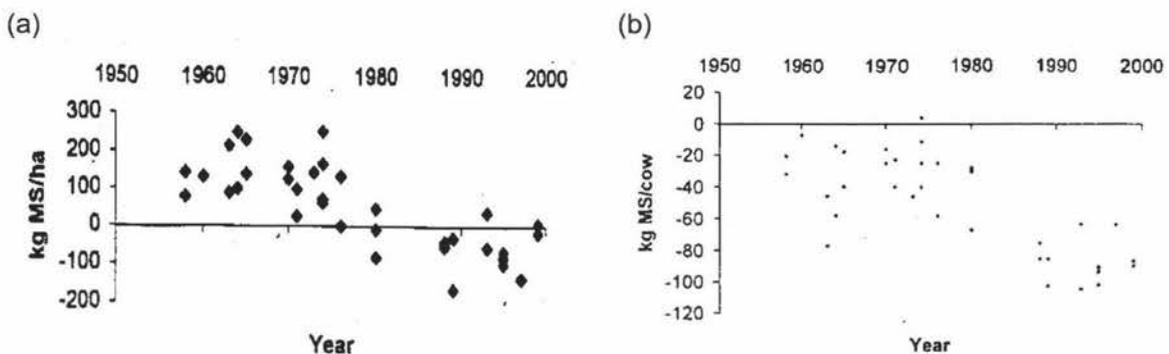


Figure 2.5 A summary of the effects of increasing stocking rate by 1 cow/ha on milksolids production per hectare (a) and milksolids production per cow (b) in trials comparing different stocking rates between 1958 and 2000 (Penno, 1999).

Over 50 years, from 1948 to 1998, the amount of pasture consumed per hectare on New Zealand dairy farms has more than doubled as a result of increased stocking rates (Holmes, 1998). Part of the increase in milk yield per hectare may also be a

consequence of the higher annual net pasture production, due to the better pasture utilisation caused by the increased stocking rate (Penno, 1999).

Research and farmers attitudes in New Zealand has traditionally focused on maximising productivity per hectare through increases of stocking rate. It was assumed that efficiency of feed utilisation was more important than performance per animal (Penno, 1999). As the genetic merit of New Zealand dairy cows improved (Holmes & Hughes, 1993), there was a possibility to increase both production per animal and per hectare. This philosophy relies on good nutrition standards which results in lower pasture utilisation efficiency. However, the higher levels of production stimulated by an increase in herbage intake per animal offsets the lower pasture utilisation (Penno, 1999).

Some farmers in New Zealand have been adopting this system and an on-farm observation in the Manawatu showed that a 23% reduction in stocking rate and 35% increase in supplementary feed extended the lactation length from 205 to 278 days and increased milksolids production per cow and per hectare by 55% and 20%, respectively (Cassells & Matthews, 1995).

The main challenge in a grazing system is to achieve a reasonable compromise between the efficiencies of the three main stages of production: herbage growth, herbage consumption and animal production (Hodgson, 1990). In this situation, the decision should be based on the most suitable feed demand for the system considering all the factors involved, such as pasture production, composition and utilisation, animal performance and efficiency, soil structure and fertility, as well as financial and other management parameters.

2.3. FEED CONVERSION EFFICIENCY

There are three important areas between animal input and output relationships in a dairy system, which can be listed as milk production, efficiency of energy use in different physiological states and the energy value of each feed (Moe & Tyrrell, 1975). Milk production is determined by the current physiological state of the animal and its ability to produce milk (genetic ability, nutritional history and stage of lactation); and by the nutrients offered to the animal (level of nutrition and type of diet) (Moe & Tyrrell, 1975).

Nutrition is an important determinant of milk output and it also has a considerable impact on animal health. Feed is the largest single cost of milk production in most systems (Korver, 1988). Therefore, gross feed conversion efficiency (milk output/total feed input) is an important factor in determining the cost of milk production. Feed conversion efficiency is one of the factors that affects the functional components of output, which is influenced by the cow's ability to digest, absorb and metabolise nutrients from feed (Holmes, 1988).

The intake of nutrients and the efficiency of conversion of those nutrients into body tissue or milk dictate the rate of growth and milk production of growing and lactating animals, respectively. Nutrient intake is the result of feed intake multiplied by its nutrient concentration, which is influenced by the capacity of the animal to digest and absorb the nutrients in the alimentary tract (Hodgson, 1990). In general, the major determinant of animal performance is likely to be the intake of metabolisable energy (Figure 2.6).

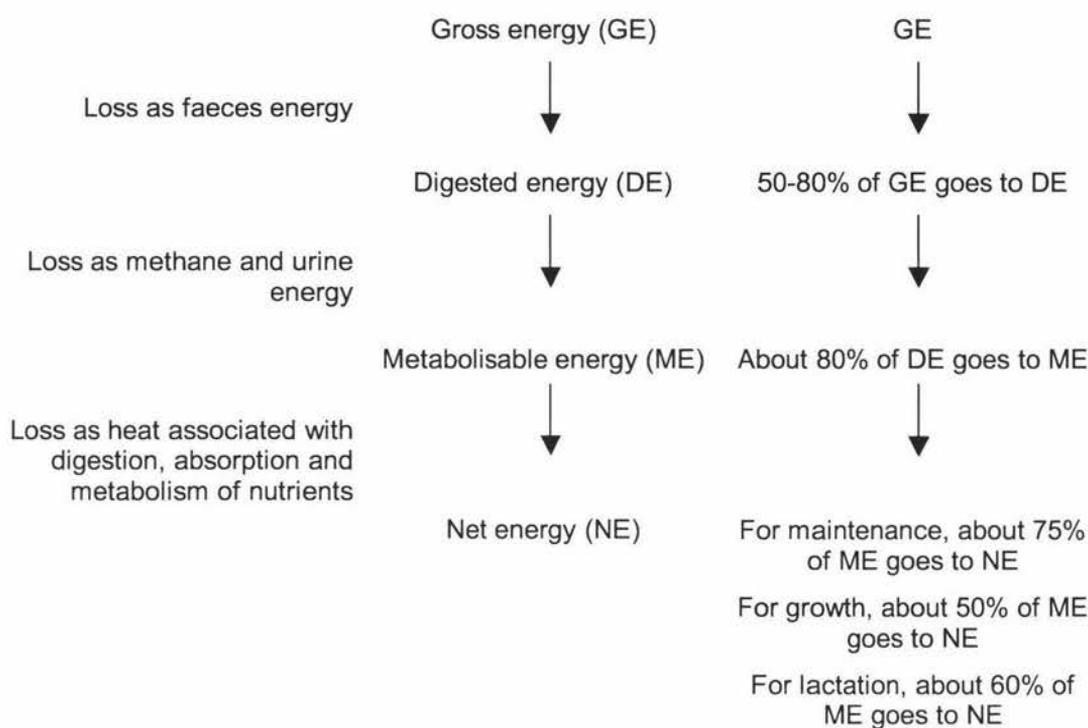


Figure 2.6 The digestion and metabolism of dietary energy in ruminant animals. Adapted from Hodgson (1990).

2.3.1. Definition

The efficiency of milk production is commonly defined as the ratio of milk output to feed inputs, or vice-versa (Wang *et al.*, 1992). The links between inputs, outputs and functional components of outputs of a dairy system are illustrated in simplified form in Table 2.1. A definition of feed conversion efficiency is “the rate of converting dietary nutrients to milk after adjustment for nutrients supplied by catabolism (e.g., negative energy balance) or nutrients diverted to replenish tissue reserves” (Blake & Custodio, 1984). The term efficiency of milk production could be explained in more practical terms, using the expressions gross efficiency and net efficiency. “The proportion of total dietary energy ingested that is recovered as milk energy is termed gross efficiency” and “the efficiency with which energy consumed in excess of maintenance needs is used for production” is termed net efficiency (Moe & Tyrrell, 1975).

Gross feed conversion efficiency of dairy cattle is usually defined as energy in milk divided by energy intake (Blake & Custodio, 1984). Gross efficiency of milk yield was also defined as kilograms of milk produced per kilogram of total digestible nutrients (TDN) consumed (Wang *et al.*, 1992). Some other measures of feed efficiency that have been used in different experiments are: milk energy divided by Mcal of digestible energy intake (Dickinson *et al.*, 1969; Lamb *et al.*, 1975); yield of fat corrected milk divided by therms of estimated energy (Hooven *et al.*, 1971; Miller *et al.*, 1971); yield of solids-corrected milk divided by dry matter (DM) intake (Grieve *et al.*, 1976) and kilograms of milksolids divided by kilograms of metabolic liveweight (Kolver, 2001).

Table 2.1 Simplified outline of the main components of dairy productivity (Holmes, 1988).

Inputs
Feed (including land and fertilizer)
Capital
Labour
Management
Functional components of output
Age at the first calving
Number of lactations per lifetime
Milk yield per lactation
Composition of milk
Live weight of cattle sold
Factors that affect the functional components:
Feed intake and feed conversion efficiency
Capacity for milk production and growth
Fertility, health and longevity
Outputs
Milk solids
Meat and cattle

2.3.2. Factors affecting feed conversion efficiency

The input of foodstuffs and other environment factors, and of course the ability of the cow to utilise these inputs to produce milk, affect the feed conversion efficiency for milk production (Blake & Custodio, 1984).

2.3.2.1. Nutrient partitioning

The nutrients ingested, digested and absorbed by the cow can follow different paths within the animal. This is called partition of nutrients and is represented in Figure 2.7. Out of the four possible directions of nutrient flow, nutrients for lactation and nutrients for pregnancy are not of direct benefit to the animal itself. However, evolution has given a high priority to these physiological processes, allowing them to proceed even at the expense of other metabolic activities (Bauman & Currie, 1980), because they are beneficial to the unborn and new born calves.

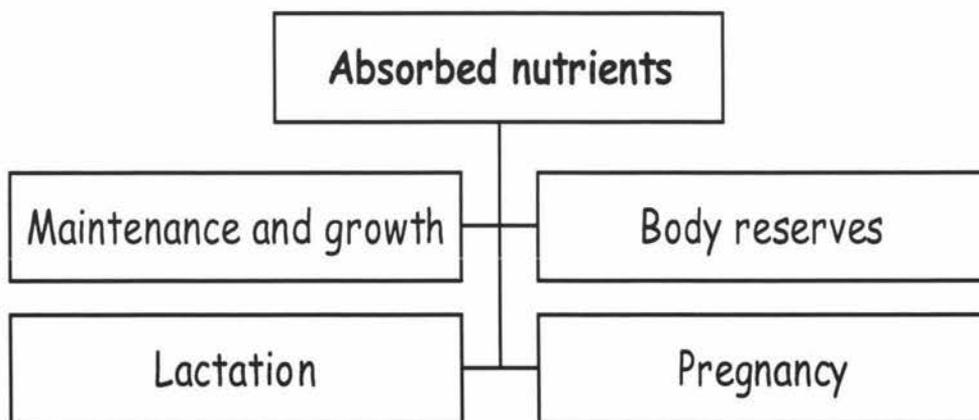


Figure 2.7 Partitioning of nutrients (Bauman & Currie, 1980).

Lactation and late pregnancy are highly demanding physiological activities to such an extent that the total metabolism of the animal must be altered in order to accommodate these needs. The metabolic changes to provide energy at this stage include the mobilisation of energy stored as lipids, glycogen and labile protein (Bauman & Currie,

1980). Pregnancy includes not only foetus development, but also growth of the foetal membranes, the gravid uterus and the mammary gland (Bauman & Currie, 1980). Only 40 % of foetal birth weight is acquired in the first 7 months of gestation (Bauman & Currie, 1980), with the other 60% occurring during the last 2 months of pregnancy.

Because of the high nutrient demand during the last stage of pregnancy, it is important to dry-off the cows at least 60 days before the planned date of calving in order to avoid competition for nutrients between the foetus and milk production requirements (Bauman & Currie, 1980) and also to provide time for the regeneration and repair of the mammary gland for the next lactation. The daily nutrient requirements of the foetus during the last 60 days of pregnancy are equivalent to the nutrients required to produce about 3 to 6 kg milk/day (Bauman & Currie, 1980). Similarly, mammary gland development reaches its peak at the end of lactation, coinciding with the high energy demand of the growing foetus (Bauman & Currie, 1980).

With the onset of lactation a number of metabolic adaptations occur and it is during this period that the genetic ability of the animal to partition nutrients towards milk production becomes active (Bauman & Currie, 1980). Therefore, from a metabolic point of view, milk production will be determined by the animals' genetic capacity to alter and coordinate the partitioning of nutrients towards milk production, and modifying not only their metabolism but also the rate at which the metabolism is changed and adapted to the new situation.

➤ Lipid and glucose metabolism during lactation

When lactation commences in the high yielding dairy cow, adipose tissue is mobilized and the synthesis of new storage lipids decreases. As a consequence the concentration of blood serum triglycerides and free fatty acids increases. Gluconeogenesis in the liver

is triggered and up to 80 % of formed glucose is used by the mammary gland at peak lactation (Bauman & Currie, 1980).

Glucose and insulin are homeostatic regulators of lipid metabolism in adipose tissue. In other words, when certain levels of either compound are attained, lipid turnover stops. This is true for non-pregnant animals. In lactating cows, however, probably as a consequence of the energetic demands of early lactation, the adipose tissue becomes insensitive to these regulators and lipolysis rates remain high and unaffected (Bauman & Currie, 1980).

The partitioning of oxidizable nutrients towards metabolic activities other than lactation is reduced. For example, at day 30 pre-partum, 34 % of the total glucose turnover is oxidized to CO₂, while at day 7 post-partum this value amounts to only 8-9 % (Bauman & Currie, 1980).

➤ Energetic balance

In general, dairy cattle experience a period of a negative energy balance during early lactation because the energy output as milk production is so high that the lower dry matter intake characteristic of this period can not support the energy required for milk yield and maintenance (NRC, 1988; Vries & Veerkamp, 2000).

This imbalance between dry matter intake and energy requirements is represented in Figure 2.8. It can be seen that the cow is in negative energy balance until 8 weeks post-partum, while mean dry matter intake peaks only at around 11 weeks post-partum. It was estimated that dry matter intake is depressed on average by 15 % during the first 3 weeks of lactation (NRC, 1988).

The extent of this negative balance varies widely between animals and depends on the diet (i.e. digestibility, feeding value, energy content, etc.), genetics and previous nutritional status. Figure 2.8 shows the magnitude and duration of the energy imbalance calculated by different authors, which express the return to a positive energy balance at an average of 41.5 days (Vries & Veerkamp, 2000), 56 days (NRC, 1988) and 112 days (Bauman & Currie, 1980) post-partum.

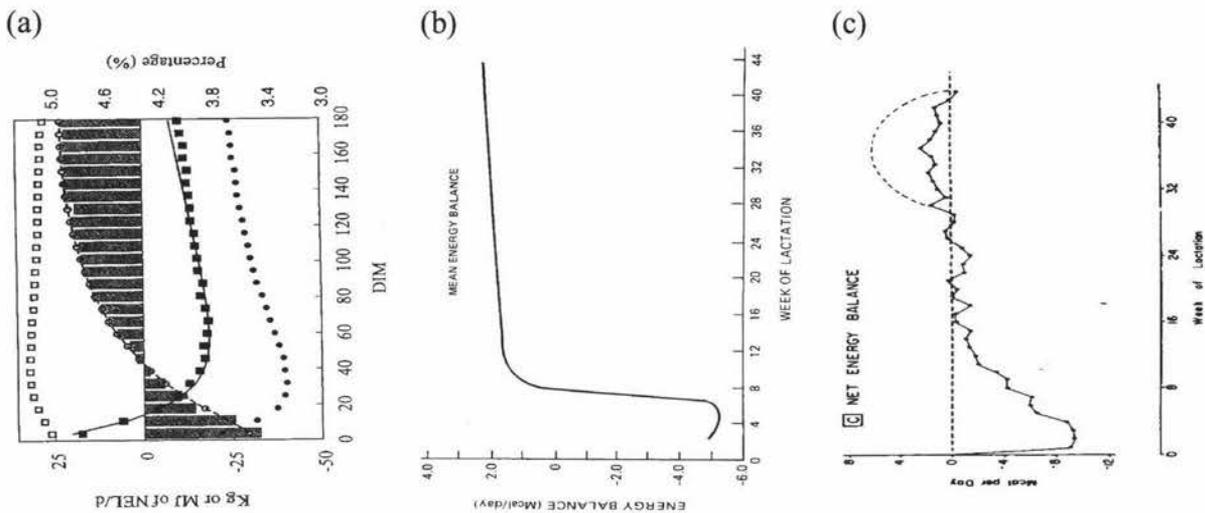


Figure 2.8 Energy balance for lactating dairy cattle: energy balance, milk yield, milk composition and dry matter intake (a); energy balance and dry matter intake (b) (NRC, 1988); energy balance, milk yield and energy intake (c); the dashed line indicates recommended overfeeding during the last one-third of lactation to recover body energy stores needed to support the next lactation (Bauman & Currie, 1980).

2.3.2.2. Diet quality

Diet quality will have a significant effect on the efficiency with which digested nutrients are used for maintenance or production. The feed conversion efficiency will increase as digestibility or metabolisable nutrient concentration in the diet increases (Hodgson, 1990).

2.3.2.3. Genetic merit

Animals with high genetic potential for production are likely to have a higher feed intake and greater feed conversion efficiency when compared with animals with low genetic potential for production (Hodgson, 1990). The reason is that as a proportion of total intake, the requirement for body maintenance decreases progressively as intake increases (Hodgson, 1990; Veerkamp *et al.*, 1994).

Studies indicated that better energy efficiency obtained by high genetic merit cows is partially due to a higher degree of body tissue catabolism (Veerkamp *et al.*, 1994). These authors argued that animals reduce their feed intake (or increase production) when more lipids are available for mobilization, rather than mobilising lipids because they produce more milk than they can support from intake alone (Veerkamp *et al.*, 1994). Dairy cows of high genetic merit have higher voluntary intakes, produce more milk (Veerkamp *et al.*, 1994) and mobilize a higher proportion of body tissue in early lactation when compared with cows of low genetic merit (Bryant & Trigg, 1981; Kolver, 2001). However, the use of tissue reserves in high genetic merit dairy cows might hide the effects of unfavourable nutrition in the short term, the negative consequence being evident in the subsequent lactations (Veerkamp *et al.*, 1994). This was confirmed by the results obtained in an experiment where the mean condition score was significantly lower in high genetic merit cows than in low genetic merit cows, fed on the same ration (Veerkamp *et al.*, 1994).

The results of experiments in New Zealand, USA and England showed that gross feed conversion efficiencies were on average 10% higher in high genetic merit cows than in low genetic merit cows (Holmes, 1998). This was a result of a greater proportion of total intake of high genetic merit cows being used for milk production instead of maintenance or body growth (Holmes, 1998).

2.3.2.4. *Age*

Older cows are more efficient than young cows because young animals produce lower milk yields and are still growing (Holmes, 1988; Hutton, 1966).

2.3.2.5. *Liveweight*

A study with dairy cows showed no significant relationship between gross conversion efficiency of feed energy to milk energy and liveweight (Hutton, 1966). Therefore, large and small cows are likely to be equally efficient, presumably because the heavier cows also produce more milk. However, the results of two experiments carried out at Massey University in New Zealand, showed that higher liveweights are associated with higher feed intake, resulting in a decrease in feed conversion efficiency at a common milk yield (Holmes *et al.*, 1993).

If the relative effects of liveweight and milk yield are considered, feed conversion efficiency is increased by approximately the same amount by either an increase in milk yield of 10% or a decrease in liveweight of 10% (Holmes *et al.*, 1993). Considering the financial analysis of the two different options, the increase in efficiency caused by a decrease in liveweight is due to the reduced energy cost of maintenance per unit of milk produced, but this would probably reduce income from meat. On the other hand, an increase in milk yield would increase income and decrease the energy cost of maintenance per unit of milk produced (by “dilution of maintenance”) as well as decrease animal cost per unit of milk produced (Holmes *et al.*, 1993).

2.3.2.6. *Stage of lactation*

An experiment conducted at the Ruakura Agricultural Research Centre in New Zealand over four dairying seasons, showed that the highest conversion efficiency indexes were achieved in the 2-3 weeks immediately after calving (Hutton, 1966). The reasons for

this higher conversion efficiency at the beginning of lactation is a combination of an initially high rate of milk secretion, a relatively low initial energy intake and liveweight loss at the beginning of lactation due to the use of body reserves.

2.4. SUPPLEMENTARY FEED

The strength of pastoral dairy systems around the world is based on the efficient use of pasture and animal management to balance seasonal variations in pasture supply and feed requirement as far as possible (White *et al.*, 1999). Even if pasture remains the predominant source of feed in grazing systems, conservation is necessary to balance feed supply and demand in much of the world where grass stops growing for part of the year due to coldness or drought (Forbes, 1995).

In recent years, research and individual farmer contributions have led to a much wider acceptance of the use of supplementary feed, or at least have created a considerable debate about the effects of supplements in the low cost New Zealand dairy systems (Thomson, 2000; White *et al.*, 1999). However, any grazing system which incorporates supplementary feed must still be based on the efficient use of pasture on the farm (Matthews, 1997). Response to supplementary feed is known to be profitable if cost of supplements and price of milk are adequate (Holmes *et al.*, 1987). However, supplement use may increase the cost of milksolids production and pasture wastage through substitution, which could reduce farm profitability. A case study in New Zealand showed a different scenario, where farmers with the highest profitability in 1996/1997 were those who had relatively high expenditure on extra feed combined with high stocking rates (Howse & Leslie, 1997).

In the late 1980s New Zealand dairy farmers started to spend increasing proportions of the total cash expenses on feed, grazing costs (Figure 2.9a) and fertiliser (Figure 2.9b)

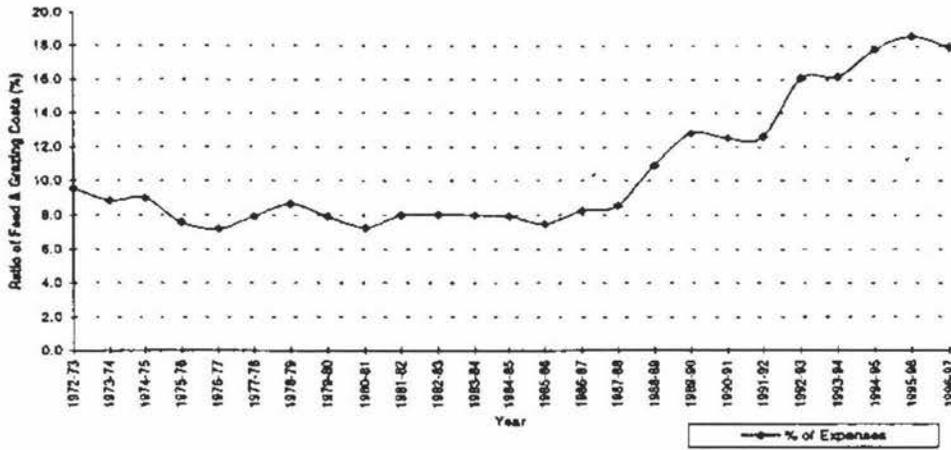
(Deane, 1999). Nevertheless, total cash expenses expressed as a proportion of income, were lower in the 1988-1997 period than in the 1978-1987 period (Figure 2.9c). A contribution for this was also the higher milk price paid in the second period when compared to 1978-1987 (LIC, 2001). Therefore, a combination of additional expenditure on feed and fertiliser with higher milk prices provided opportunity for maintenance and improvement of low cost dairy systems.

2.4.1. The effects of supplementary feed in the system

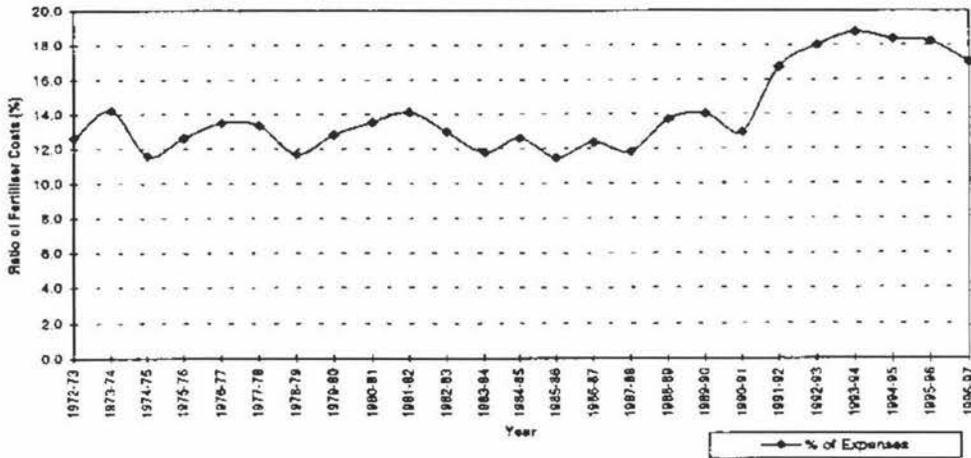
The effects of supplementary feed are complex since all the other factors involved in the system are influenced at the same time, in one way or another. In all feeding systems, the cow's response to supplementary feed is determined by the effects of substitution rate, the net increase in total nutrient intake and the partitioning of extra nutrients into extra milk (Holmes & Matthews, 2001). Therefore, careful adjustments must be done in order to maintain an efficient system.

The effects of extra feed can be classified under three concepts: immediate effects, long-term effects and total effects (Figure 2.10). Immediate effects are those events which occur during the time of supplement feeding, as milk yield, body condition score and pasture spared as a result of substitution effects. On the other hand, long-term effects occur in the future, not at the time of supplementation. Some common long term effects are longer lactations and increases in condition score and average pasture cover. Under total effects, higher milk yield, improved reproduction, higher incomes and higher overall efficiency of the system can be included.

(a)



(b)



(c)

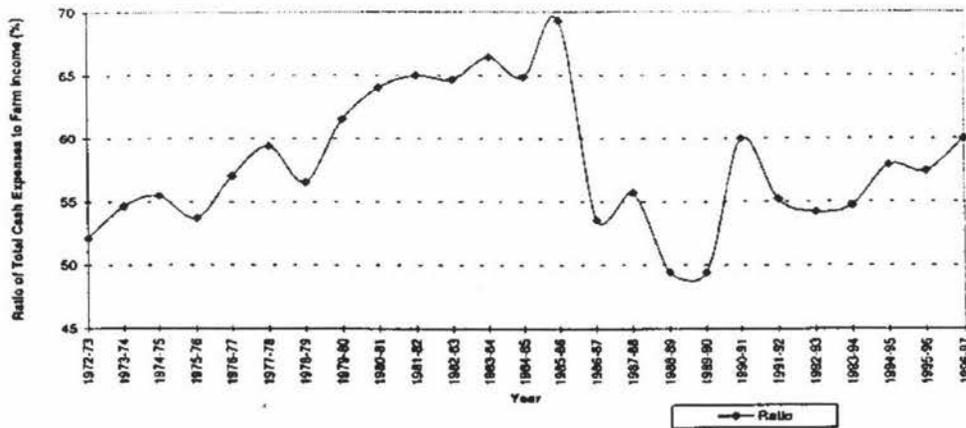


Figure 2.9 Trends in the ratio of feed and grazing costs (a) and ratio of fertiliser (b) as a proportion of total expenses (Deane, 1999). Trends in ratio of total cash expenses to farm income (c) (Deane, 1999).

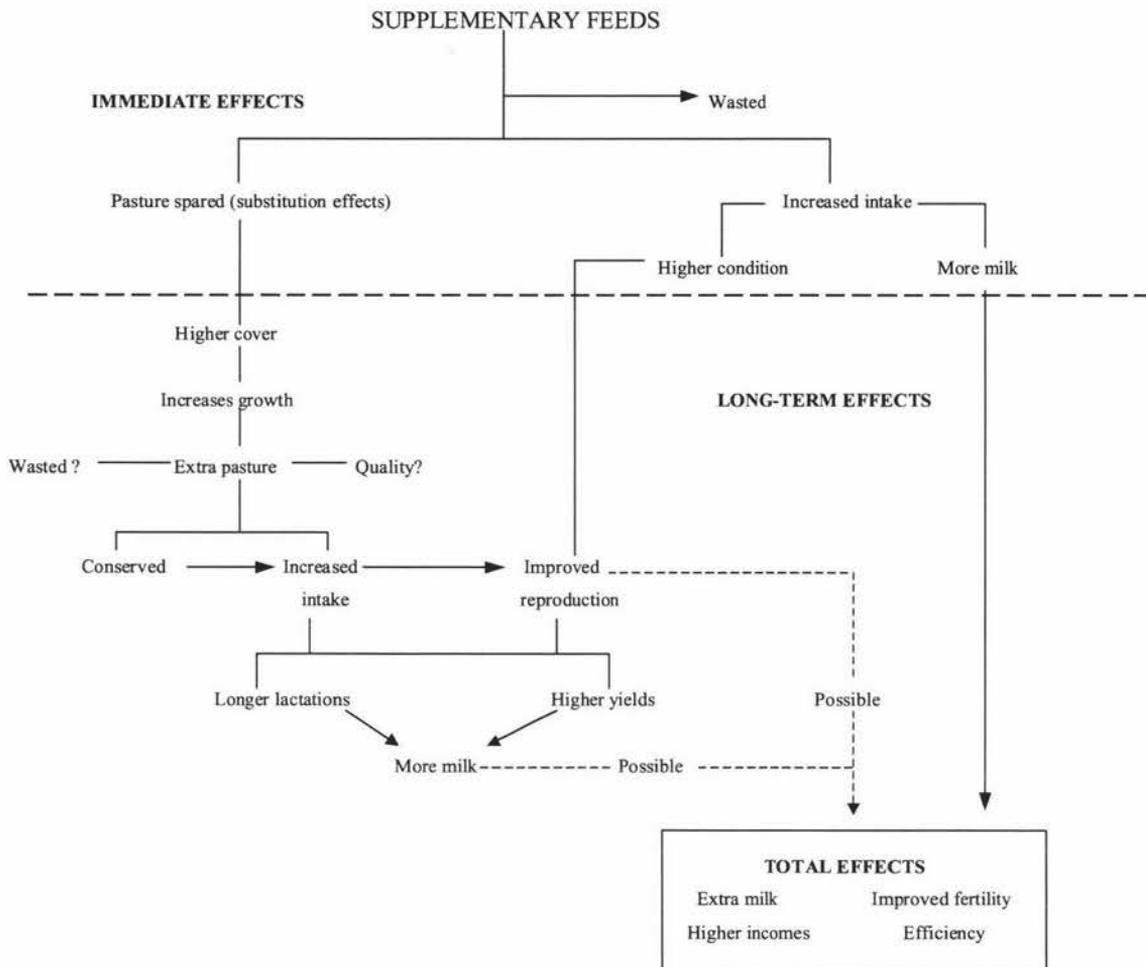


Figure 2.10 Immediate and carry-over effects of supplementary feeds in dairy systems. (Brookes, 1996; Holmes & Matthews, 2001) (adapted).

When the immediate and long term effects of extra feeds are added together, the total response is always smaller than the theoretically possible response (Holmes & Matthews, 2001; Penno, 2001). The reason for this is that energy is inevitably lost to some extent, such as in form of pasture wasted (decay, quality loss) or double conversion, e.g. from feed into liveweight and then into milk (Holmes & Matthews, 2001; Penno, 2001). However, under normal situations, the provision of extra energy can produce extra milk (Holmes & Matthews, 2001). Cows can respond to supplements at any period of the year if they had not reached their production potential due to feed

restrictions (Figure 2.4). Therefore, the decision to add supplements should be based on the cow's potential to produce milk, on the actual level of feeding, on supplements cost and on pasture cover targets.

2.4.2. Pasture substitution

As supplementary feeds are introduced to pasture-based systems, the amount of herbage eaten generally declines (Penno, 2001). The reduction in pasture intake per unit of supplementary feed offered is named substitution rate (Holmes *et al.*, 2000b; Penno, 2001). Feed substitution usually results in two main effects: an immediate improvement in the nutrient intake of animals, and a long-term effect on pasture production resulting from a short-term reduction in pasture consumption (Holmes *et al.*, 2000b; Penno, 2001).

Substitution rate is affected by several factors, including pre grazing herbage mass and quality of herbage and supplementary feed (Stockdale *et al.*, 1997). However, Grainger & Matthews (1989) stated that the main factors influencing substitution rate are the quantities of pasture and supplements offered. "Substitution rate generally increases as the level of feeding relative to the nutrient requirement of the cow increases, or as the need for extra feed decreases" (Penno, 2001). Cows will generally substitute pasture by supplements because of the relatively faster rates of ingestion, which would result in less time spent per day in feed consumption, particularly if the supplementary feed contains a higher concentration of ME/kg DM than the pasture offered (Holmes & Matthews, 2001; Penno, 2001).

The substitution rate will be low (0 – 0.2) for hungry cows which are on a very low level of feeding, but it can be high (0.6 – 1.0) for cows on high levels of feeding which are close to their maximum feed intake capacity (Holmes *et al.*, 2000a). A review of

fifteen experiments by Penno (2001), which provided 32 estimates of substitution for grazing dairy cows offered supplements, showed a high variability in substitution rate, ranging from -0.3 to 0.94. Holmes & Matthews (2001) reported substitution rates ranging from 0.3 to 0.7 in most cases measured.

A positive effect of substitution is named “managed substitution”, which is widely used on grazing systems in order to meet target levels of pasture cover and post grazing herbage mass (Holmes & Matthews, 2001). The substitution rate may have negative effects on the system, which could be reflected as lower immediate response from supplements and also higher pasture wastage in the long-term if the spared pasture resulting from substitution is not eaten later (Holmes & Matthews, 2001).

2.4.3. Use of extra feed in early lactation

As previously stated, lactation could be extended by calving earlier. However, a herd that calves too early will probably be underfed unless supplements are added, because peak pasture production will not coincide with peak animal demand (Holmes *et al.*, 1987). Figure 2.11 shows that early calving creates a feed deficit that could be covered by supplements.

An experiment to measure the immediate and carry-over effects of late-winter early-spring supplementation on milk yield, pasture cover, condition score and animal liveweight showed that 26 g MS/kg DM of pasture silage (70% dry matter digestibility) was obtained (Clark, 1993). However, there were no significant carry-over effects on liveweight, condition score or average pasture cover in this trial. The results were similar to another experiment reporting 36 g MS/kg DM of pasture silage (76% dry matter digestibility) and 23 g MS/kg DM of pasture silage (60% dry matter digestibility) fed in early lactation (Rogers, 1985). It seems that even though cows in the

supplemented treatments were eating more, milk yields, liveweight and condition score were not improved at the expected levels because the supplement was not good enough in terms of quality. This means that in order to obtain immediate and carry-over responses to supplements in early lactation, the quality of the extra feed offered, must be similar to that of grass in early spring (Ulyatt, 1981).

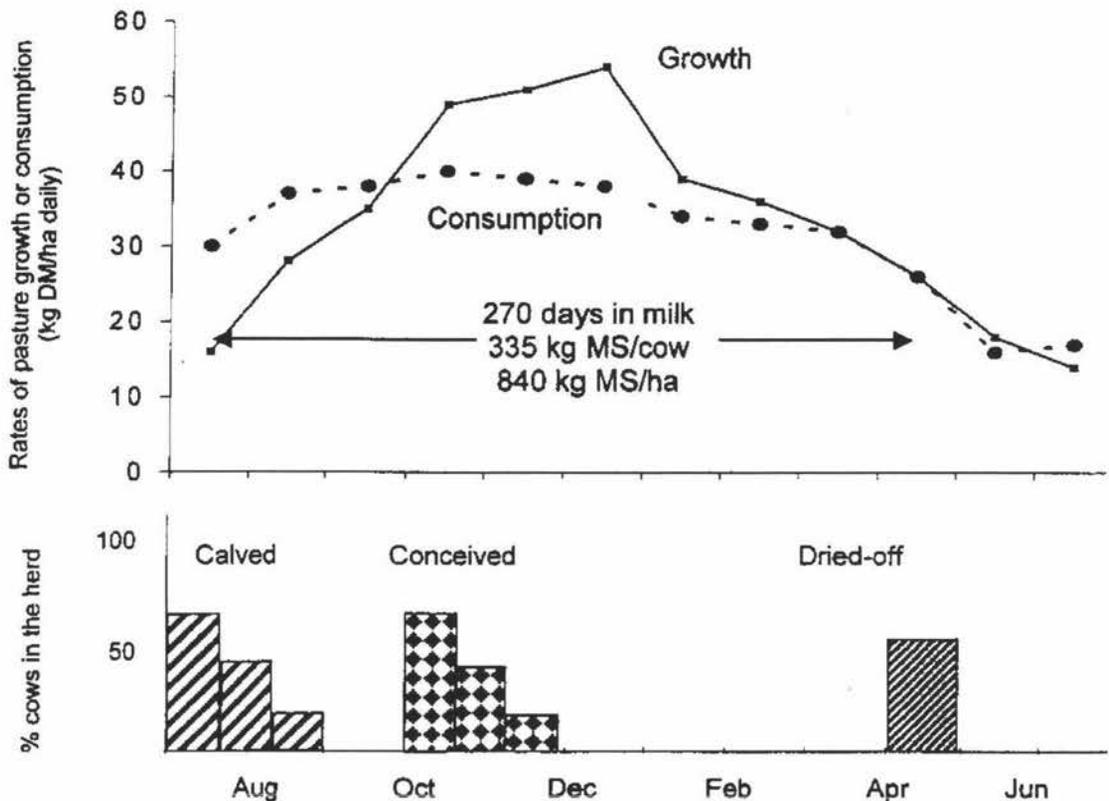


Figure 2.11 The relationship between feed demand and supply in a pastoral system, in a moist summer and cool winter, with 2.5 cows/ha, early calving and supplements feed in early lactation (Holmes *et al.*, 2000c).

Better results were obtained in an experiment during 1996/97 (calving on 20th June) and 1997/98 (calving on 5th of July) seasons to investigate the effects of maize silage on milksolids production, which showed a response of 76 and 157 g MS/kg DM of maize silage and extra 32 and 40 lactation days, for the first and second years, respectively (Thomson *et al.*, 1998). Pasture production and grazing characteristics were similar in the two years, which do not explain the difference in milksolids response between

seasons. One possible reason for the difference could be the different amount of maize silage fed each year (500 kg DM/cow in year one and 300 kg DM/cow in year two).

Another experiment using maize silage in early lactation (calving date 1st July) to increase economic farm surplus showed a milksolids response of 63 and 83 g MS/kg DM of extra feed, for optimum stocked (3.8 cows/ha) and high stocked systems (4.7 cows/ha), respectively. The economic farm surplus was greater for the high stocked system (\$2,351/ha) than for the optimum stocked system (\$2,022/ha) (Cooper, 2000). There is an opportunity to extend lactation by calving earlier in the season, and benefits of supplements will be observed whenever the amount and quality of the feed offered are adequate and the cows require the extra feed provided.

2.4.4. Use of extra feed in late lactation

One of the reasons for the low production per animal in New Zealand dairy systems is the relatively short lactation (Pinares & Holmes, 1996). There is an opportunity to extend lactations by using extra feed in the system, as shown by a trial where two separate herds were formed to measure the effects of extra feed and extended lactations on condition score and pasture cover (Pinares & Holmes, 1996). The management target for both herds was a condition score of 5 and a pasture cover of 2000 kg DM/ha on 29th May. The first herd was dried-off on 4th April with an average of 219 days in milk (D treatment) and received no supplements. The second herd (M treatment), which received supplements, was dried-off 54 days later on 29th May, with an average of 274 days in milk. The cows in the M treatment produced 57.7 kg MS/cow during the extra 54 days of lactation and consumed a total of 295 kg DM/cow of pasture silage. The short term marginal response of silage feeding was 196 g MS/kg DM of pasture silage intake (Pinares & Holmes, 1996). However, condition score and pasture cover targets were not achieved in the M treatments. Thus, in order to measure the possible

carry-over effects on milk production for the next season, the amount of extra feed which would have been required to attain the condition score target of 5 and pasture cover target of 2000 was included in the calculations, giving a reduced total marginal response of 116 g MS/kg equivalent pasture DM (Pinares & Holmes, 1996). This response to supplements was higher than the 92 g MS/kg DM of supplement reported in a similar experiment, already accounting for the carry-over effects of condition score and pasture cover, but using a 50:50 mixture of pasture silage and apple pomace (Holmes *et al.*, 1994). However, both trials had greater responses than the 66 g MS/kg DM of pasture silage fed in late lactation for 36 days with 7 extra days in milk (Holmes *et al.*, 1994). Carry-over effects could not be estimated in this latter trial.

These results demonstrate that it is possible to extend lactations in autumn, but extra feed and the dry-off date must be carefully balanced to ensure that the extra days in milk do not cause decreases in pasture cover and condition score at the beginning of the next season.

2.4.5. Use of extra feed in winter

The majority of the cows in New Zealand herds calve in early spring in order to synchronise their feed demands with the pasture growth curve (Holmes *et al.*, 1987). As stated before, changes in calving date include calving earlier or later within the spring season and more extreme changes of the calving season, such as autumn calving. Since grass growth rate in New Zealand is at a minimum during winter, these herds are heavily dependent on supplementary feeds (Holmes & Matthews, 2001).

A summary of four studies suggested that 100% autumn-calving systems can produce similar quantities of milksolids per hectare to those produced by 100% spring-calving systems (Garcia & Holmes, 1999). Three of the studies showed that autumn-calved

cows produced between 9% and 17% more milkfat per cow than spring-calved cows (Garcia & Holmes, 1999).

A survey conducted in the area of Palmerston North in order to analyse the feeds and feeding methods used during winter showed that the top ten winter-milking farms had a moderate daily milksolids production of 1.46 kg/cow in June and July. This production could be increased by feeding high amounts of high quality supplements (O'Reilly & Holmes, 1995).

Extra feeding in winter is also important in order to increase production potential in the subsequent lactation. In other words, to maintain targets of pasture cover and condition score at the beginning of the next season. Therefore, the combination of immediate and long-term effects from supplementary feed in winter has potential to improve the efficiency of the system.

2.4.6. Use of extra feed in summer

With the onset of the summer season, milk production in North Island, New Zealand progressively declines at rates as high as 19 % per month (Clark *et al.*, 1996), and by the end of summer or early autumn, the cows must be dried-off. This dramatic decline in milksolids production is a direct consequence of the decline in the amount and quality of pastures. The provision of extra feed in summer could reduce the decline in milk production to around 7 % per month, allowing for extra milking days in summer-autumn (Thomson *et al.*, 1997).

One option to increase lactation length is by using high yielding turnip cultivars of high feeding value (Clark *et al.*, 1996). In recent years, turnips have become popular as a summer fodder crop for dryland dairying regions in Australia and New Zealand. Turnip cropping is used as an adjunct to pasture renovation program and can often provide high

yields of good quality feed to overcome the summer feed gap. Turnip has shown yields of around 10 t DM/ha, ranging from 9 to 16 t DM/ha (Clark *et al.*, 1996; Harris *et al.*, 1998; Stockdale *et al.*, 1997; Thomson *et al.*, 1997).

In terms of nutritional characteristics, data from two trials in New Zealand showed that turnip had high dry matter (DM) digestibility (765 to 860 g/kg DM) and low crude protein (106 to 138 g/kgDM) and fibre (256 to 308 g/kg DM of neutral detergent fibre and 211 g/kg DM of acid detergent fibre) (Clark *et al.*, 1996; Harris *et al.*, 1998). The estimated ME of turnips is 12.5 MJ ME/kg DM (Thomson *et al.*, 1997), ranging from 11 to 13 MJ ME/kg DM (Clark *et al.*, 1996; Harris *et al.*, 1998), while summer pasture has ME values ranging from 9 to 10 MJ ME/kg DM (Thomson *et al.*, 1997). Turnips also have a growth rate of approximately 110 kg DM/ha/day over the November-January period when pasture production averages between 40 and 50 kg DM/ha/day (Thomson *et al.*, 1997).

Different methods were compared (component trials, systems modelling and whole farm trials) to evaluate dairy farm inputs using the alternative of turnips grown on-farm as summer forage (Thomson *et al.*, 1997). The trial showed responses of 36 and 66 g MS/kg DM of turnips for two component studies at Taranaki Agricultural Research Station and at Dairying Research Corporation, in New Zealand, respectively.

As a general conclusion, turnips can be a profitable alternative for supplementary feed in summer when the economic break-even point (8-10 t DM/ha) is achieved (Clark *et al.*, 1996) and the crop is carefully integrated into the feed system. However, turnip yields are very variable and highly dependent on weather conditions. If pasture renovation is necessary, turnips can absorb some of the costs which is an additional advantage.

2.4.7. Effects from supplement use in the grazing systems

Many advantages can be achieved from supplement utilisation in grazing systems for dairy cattle, such as:

- reduce risk in pastoral systems;
- fill a period of pasture shortage, such as low temperature in winter and early spring or drought in summer and autumn;
- improve the nutritive value of the total diet when pasture quality is low;
- improve milk production per cow (i.e. extend lactation);
- improve milk production per hectare (i.e. increase stocking rate);
- improve animal reproductive performance, by ensuring good condition at calving and after calving;
- control grazing residual and rotation length;
- achieve target condition score;
- increase farm pasture cover.

However, supplementary feed could increase costs of production and also pasture wastage through substitution effects, affecting pasture quality. Therefore, it is important to evaluate carefully the physical and financial response of each particular supplementary feed. Even if supplementary feed could increase productivity of the farm, there is no reason to utilise supplements if this is not profitable.

2.5. FINANCIAL

2.5.1. Production function

Optimisation of profitability is the economic objective of many businesses; this is achieved by a set of rules that ensures that the appropriate choice or decision will be made (Kay & Edwards, 1994). Much of economics is related to the concept of marginality, which can be summarised as “the incremental changes, increases or decreases, that occur at the edge or margin” (Kay & Edwards, 1994). For practical use in the present study, this could be simplified to the change in output resulting from change of a given input.

The amount of output that would be produced by different amounts of input is named production function in economics (Kay & Edwards, 1994). This is equivalent to the response curve in agriculture. The amount of production expected from using each input level is named total physical product (TPP) in economics, which is equivalent to the denomination of yield in agriculture (Kay & Edwards, 1994). The following definitions are additional information about the relationship between input and output that can be estimated from the basic data provided by the production function (Kay & Edwards, 1994).

- average physical product (APP): “the average amount of output produced by each unit of input at each input level”:

$$APP = \frac{\text{Total physical product}}{\text{Input level}} \quad \text{Equation 2.1}$$

- marginal physical product (MPP): “the additional total physical product produced by using an additional unit of input”:

$$\text{MPP} = \frac{\Delta \text{ total physical product}}{\Delta \text{ input level}} \quad \text{Equation 2.2}$$

The relationship between total physical product, average physical product and marginal physical product usually divides the production function into three stages (Figure 2.12). Stage I begins at zero input level and continues until the maximum value of APP, which is equal to MPP. Stage II ends where TPP is maximum and MPP is zero, which means that change in input causes no change in total physical product. Finally, Stage III is related to input levels where MPP is negative and TPP is declining absolutely. In the practical case of this study, stage III is not really applicable because, in biological terms, the output annual milksolids production could be relatively insensitive to increases in the input feed intake (end of stage II), but it is unlikely to decrease.

Figure 2.12 also illustrates an important law utilised in economics, named law of diminishing returns. This states that “as additional units of a variable input are used in combination with one or more fixed inputs, marginal physical product will eventually begin to decline” (Kay & Edwards, 1994). Numerous examples of diminishing returns can be observed in agriculture. Utilising one head of livestock as an example, the MPP gets smaller as the dairy cow approaches its biological capacity to utilise the input (Kay & Edwards, 1994). The production function will determine the appropriate amount of the variable input to be used. When choosing any input from the stages described in Figure 2.12, the objective is to use the input level corresponding to the greatest average physical product. However, most of the time profit can still be increased by utilising higher inputs, despite the declining value of average physical product (Kay & Edwards, 1994).

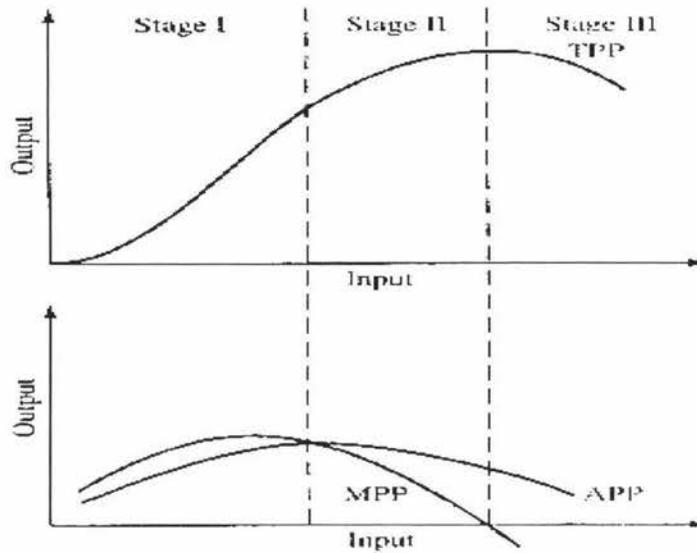


Figure 2.12 Graphical illustration of a production function (Kay & Edwards, 1994).

In this situation, information like price of the product is necessary to determine the input level that will generate higher profit. The total value product (TVP) is the term used in economics to define gross income or total income, when discussing input levels. It is calculated by multiplying the quantity of output (TPP) by its price (Kay & Edwards, 1994). In order to determine how much input to use, two variables are described (Kay & Edwards, 1994) as follows:

- marginal value product (MVP): “the additional income received from using an additional unit of input”:

$$\text{MVP} = \frac{\Delta \text{ total value product}}{\Delta \text{ input level}} \quad \text{Equation 2.3}$$

- marginal input cost (MIC): “the change in total input cost caused by using an additional unit of input”.

Marginal value product and marginal input cost are important tools to determine the optimum input level. It is desired that the additional cost of using one more unit of input does not exceed the additional revenue received from that input. Additional profit by using more input can be expected when MVP is greater than MIC. However, the business would be more profitable by using less input, if MVP is lower than MIC (Kay & Edwards, 1994).

2.5.2. Financial key performance indicators

The process of comparing indicators within and between businesses in order to identify the best results is an important part of benchmarking between businesses (Brier & Shadbolt, 2001). “Benchmarking is a systematic and continuous measurement process; a process of continuously measuring and comparing an organisation’s business processes against business process leaders anywhere in the world to gain information which will help the organisation take action to improve its performance” (Watson, 1993). Benchmarking is based on the identification of those companies recognised as industry leaders to identify the best practice and achieve superior performance (Brier & Shadbolt, 2001).

Large number of key performance indicators, both physical and financial, can be used to measure the performance of a farm business (Shadbolt, 1997). The relevance and interpretation of the financial key performance indicators of profitability and efficiency used in this study are described below. More details about financial indicators are in Section 4.6.

2.5.2.1. *Profitability measures*

These measures describe the relative profit performance of a business. The measures used to evaluate profitability are operating profit, called in New Zealand economic farm surplus, operating profit margin and return on assets.

Economic farm surplus (EFS) is a commonly used measure of farm operating profitability in New Zealand and it represents the ability of the farm to generate revenue and save costs (Rawlings, 1999). It is calculated as gross farm income less total operating expenses. However, it does not represent the overall profitability of the business (Shadbolt, 1998, 2001a), because funding costs are not included and can often contribute significantly to total farm costs.

Operating profit margin measures the proportion of earnings remaining after operating expenses are paid (Shadbolt, 2001a). It indicates the ability of the business to control costs and increase revenues in order to generate profit, and it is calculated as economic farm surplus divided by gross farm income (Boehlje, 1994). Profit margin is a function of input prices, efficiency and product prices. However, most weighting is placed on product prices (Boehlje, 1993). As producers have no control over product prices, control of production costs should receive more emphasis.

Return on assets represents the earning capacity or profitability from the asset base. It is obtained dividing economic farm surplus by the total assets. Because it indicates the profitability per dollar of assets, it can be used for comparison between businesses of different sizes and types (Boehlje, 1994).

2.5.2.2. *Financial efficiency measures*

Any representation of input/output ratio is a measure of efficiency. Therefore, there are a wide range of efficiency ratios. The measures used here to evaluate financial efficiency are assets turnover ratio, revenue to labour ratio and revenue per labour unit.

The assets turnover ratio reflects the overall efficiency at which the assets invested are utilised to generate revenues (Boehlje, 1994). The ratio of gross farm income to total assets indicates the amount of revenue of the business generated by the assets base (Boehlje, 1994).

Revenue per labour unit, obtained as gross farm income divided by total labour unit, reflects how efficient the labour is (Boehlje, 1994). It would be expected that employees are generating their wages at the very least. Revenue to labour ratio, calculated as gross farm income divided by labour cost, indicates how many times the revenue can pay the total labour cost, providing information about the return generated by the investment in labour.

CHAPTER 3

AGMARDT – DAIRY FARM MONITORING PROGRAMME

3.1. INTRODUCTION

The current study was developed to utilise information gathered from nine commercial dairy farms as part of a three-year monitoring project which was partially funded by the Agricultural Marketing and Research Development Trust (AGMARDT). The remaining contribution was from Massey University, from the farmers and from the project manager. The basic aim of the farmers involved is to remain competitive through the efficient use of pasture to feed dairy cows (AGMARDT, 2000). However, they have also identified that high pasture utilisation leads to a certain degree of animal underfeeding and therefore low milk yield per cow, short lactations and pasture degradation, as a consequence of the excessive grazing pressure exerted by the high stocking rates. While agreeing that pasture has to be well utilised, farmers felt that it is also necessary to focus on a better balance between pasture production, pasture utilisation and animal performance. These are achieved by manipulation of stocking rate, sward characteristics and strategic use of supplements to increase levels of feeding and productivity through increased per cow performance (Matthews, 1995). This chapter briefly discusses some concepts involved in the AGMARDT - Dairy Farm Monitoring Programme, as well as its objectives and outcomes.

3.2. BACKGROUND

In the late 1980's, a group of farmers from the Southern North Island in New Zealand and their consultant, started to question the underlying concepts and philosophies of dairy production in New Zealand. At that stage, aiming at a maximum utilisation of pasture by the herd, they had reached a plateau of around 4 cows and 1044 kg milksolids per hectare, with limited opportunity for further progress (Cassells & Matthews, 1995). They identified that the main reason for the low production per cow and short lactations was the high stocking rate used.

High stocking rates required a late calving date followed by a premature drying off, as the diminishing feed supply over the summer limited production for such high number of cows. Furthermore, such high stocking rates resulted in a deficit of pasture supply and failure to meet the cow's requirement in early lactation. High feed demand per hectare depressed reproductive performance, and liveweight/condition score remained under target during the whole season. There was also a high expenditure on supplementary feed plus grazing off in order to maintain the high number of cows over the dry period (Cassells & Matthews, 1995). Facing this situation, it was concluded that overall productivity and profitability could be increased by decreasing stock number and exploring the opportunity of higher production per animal.

Over the years, the new philosophy of increased production per animal was gradually put in practice (Cassells & Matthews, 1995). The first step was the reduction of stocking rate in combination with higher utilisation of supplements which resulted in higher animal intake. This higher feeding level increased production per cow, lactation length and feed supply over autumn (Table 3.1). Supplements was utilised to overcome periods of limited pasture supply rather than supporting higher stocking rates or balancing diets. The outputs of this first step showed that production per cow and per

hectare could be raised through improved cow nutrition (Table 3.1). From 1993 forwards, the second step was to reduce the stocking rate even further, and advance the calving date to 1 August. The amount of supplements increased and it was mainly fed over the summer and autumn period. Nitrogen use also increased. Average monthly rate of decline over the summer was 9.4%, as opposed to the 13.9% value of the 1980-1988 period. Similarly, despite the 23% reduction in stocking rate, the evolution of the system resulted in an increased average lactation length of 278 days, and increases of 55% and 20% in milksolids production per cow and per hectare, respectively (Cassells & Matthews, 1995).

Table 3.1 The effects of stocking rate and supplement use on milksolids production and lactation length (Cassells & Matthews, 1995).

Period	Calving date	Stocking rate (cows/ha)	Feed inputs (kg DM/ha)	Milksolids production		Lactation length (days)
				Kg/cow	Kg/ha	
1980-1988	14 Aug	3.93	2993	264	1035	205
1989-1993	7 Aug	3.47	1156	318	1107	212
1994-1995	1 Aug	3.03	3379	409	1239	278

The key factors for the operation of such a system were the control of pre and post grazing herbage mass and stock policies to allow high per animal intake of high quality feed (Matthews, 1994; Matthews, 1995). Improved levels of intake of high quality pasture was achieved by reducing pre grazing levels and increasing post grazing residuals.

This approach to grassland farming also presented new challenges, such as measuring the effects on milk production resulting from the higher peak yields. Furthermore, it was necessary to identify the best autumn feeding strategies to extend lactation and further improve per cow and per hectare production. Consequently, there was a need to

establish a monitoring programme to collect data from the participating farms in order to identify limitations of the system and possible solutions (AGMARDT, 2000).

In 1997, a formal discussion group was established in order to share experiences and concepts, including improvements in production and profitability and strategic use of supplements. In the same year, an application for a progressive farming grant was approved by the Agricultural Marketing and Research Development Trust (AGMARDT), which enabled the establishment of an intensive on-farm monitoring project.

In March 1998, an enthusiastic group of farmers representing 12 farms agreed to participate in the AGMARDT - Dairy Farm Monitoring Programme Group. The group was based on a common philosophy and desire to improve per cow nutrition in order to improve farm productivity and profitability. The scientific project manager was Mr. Parry Matthews, from the Institute of Veterinary, Animal and Biomedical Sciences, Massey University.

The AGMARDT – Dairy Farm Monitoring Programme was a three-year project. Starting on 1st May 1998, the programme was implemented on four farms in order to evaluate the techniques, which would be used in all of them. The full technical and financial recording programme started on all farms on 1st June 1998. The first year of the programme (1998/1999) allowed data collection, measurement techniques, recording and reporting procedures to be developed.

Activities of the first year included discussion groups, dairy cow nutrition workshops and research at Massey University funded by AGMARDT, teaching and visits on the case study farms by national and international groups. Over the three years of monitoring, some farms were added to the programme (such as No. 4 Dairy Unit,

Massey University) in order to replace farms that could not participate anymore, due to changes in land holding and adverse climate conditions (such as severe flooding).

In the second and third seasons (1999/2000 and 2000/2001), twelve farms participated in the project involving 3671 cows and 1417 effective hectares, with an average farm size of 118 effective hectares milking 306 cows. The results for the seasons 1999/2000 and 2000/2001 containing information about climate, milksolids production, nitrogen use, feed consumption, sward conditions, post peak decline and daily milk yield per cow are presented in the corresponding annual reports (AGMARDT, 2000, 2001). Results for the 1999/2000 season were also presented at the Massey Dairy Farms Conference (Matthews *et al.*, 2001).

3.3. OBJECTIVES

The objectives of the project were to:

- Establish pasture and animal performance indicators associated with high per hectare production achieved through improved per cow performance while maintaining efficient utilization of pasture;
- Evaluate the use of strategic supplementation on farm production and profitability;
- Investigate and evaluate management strategies to overcome new challenges such as:

- i. overcoming the rapid decline in per cow performance and total milk production during the immediate post peak production period,
- ii. identify strategies to successfully and economically extend lactation in autumn to improve both per cow and per hectare performance.

3.4. DESIGN

To achieve the objectives detailed above, the project was committed to monitor pasture targets and animal performance. The project can be defined as a long term monitoring programme aimed at establishing on-farm relationships between sward condition, pasture utilization and animal performance. Monitoring such targets involved daily recording of pre and post grazing herbage mass levels, milk production, as well as weekly measurements of average pasture cover (for the second year only) and supplements conserved and fed. Pre and post grazing estimates were used to calculate herbage intakes. The data were measured and collected by the farmers and a technician contracted to the programme. The technician was also responsible for data processing and results presentation.

3.5. PROJECT BENEFITS

- The farms were located over four different regions in the Southern North Island, covering a range of soils and climate, which made the outcomes more representative;

- A unique three-year detailed data collection which enabled the farmers to better understand the limitations of the system and the opportunities for improvement;
- The discussion groups provided opportunity for the exchange of information and ideas;
- Valuable source of on-farm information was provided for the scientific community (post graduate studies, research and teaching).

3.6. PROJECT OUTCOMES FOR THE SEASON 1999/2000

3.6.1. Milksolids production

Favourable climate conditions and pasture growth rates resulted in increased lactation length and total milksolids production for the season. In comparison to the previous season (1998/1999), which was characterised by a long dry summer, production increased around 12% for both per cow and per hectare (AGMARDT, 2000). Table 3.2 shows milk production for the AGMARDT farms and for the district averages. The AGMARDT farms showed 17% and 14% higher milksolids production per cow and per hectare, respectively, than the district average.

Table 3.2 Milksolids production for the AGMARDT farms and for the district averages (1999/2000 season) (AGMARDT, 2000).

	Milksolids production	
	Kg MS/cow	Kg MS/ha
AGMARDT group average	405	1061
AGMARDT group range	332-465	839-1291
District average	338	913
District top 10%	394	1281

The average milksolids production per cow among the AGMARDT farms was 1.54 kg MS/cow/day, the average peak yield based on monthly average across all farms was 2.05 kg MS/cow/day and average lactation length for all farms was 263 days.

3.6.2. Feed consumption

Annual feed consumption per cow averaged 5840 kg DM among all farms. Pasture represented 80% of total intake and supplement (including material conserved on farm, bought in or grazing off) constituted the remaining 20%. The majority of supplements were fed during summer and autumn, with turnips and pasture silage as the main supplements for each period, respectively. Over the winter period, grazing-off was the main supplementary feed.

3.6.3. Feed conversion efficiency

The average feed conversion efficiency was 69 g MS/kg DM intake or 14.4 kg DM intake/kg MS. In general the estimates of feed consumed were higher than the theoretical values based on the levels of production achieved. Since supplement intake was measured most accurately, it was likely that the estimation of pasture intake using pre and post grazing herbage mass levels was less accurate.

CHAPTER 4

MATERIALS AND METHODS

4.1. INTRODUCTION

This research involved collection of information from nine case study dairy farms in the Southern North Island region (only eight farms were involved in the financial analyses). The data were collected, processed and analysed to evaluate the biological and financial performance for the 2000/2001 season (1st June 2000 to 31st May 2001). The objective was to obtain yield and quality data of the components influencing the performance of the case study farms as well as financial information (Figure 4.1), in order to identify factors affecting farm production, efficiency and profitability.

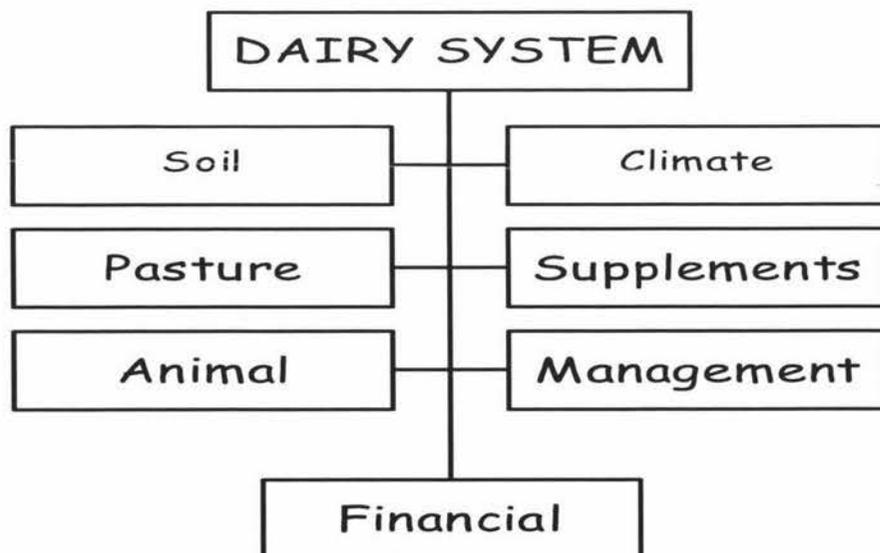


Figure 4.1 Factors influencing the outcomes of a pastoral dairy system.

The information collected for this project complemented basic information collected for AGMARDT – On Farm Monitoring Project. Although the AGMARDT – On Farm Monitoring Project involved twelve dairy farms, only nine farms were analysed in this case study because of incomplete data provided by three farms.

4.2. CASE STUDY

Yin (1994) defines case study as “an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident”. Casley & Lury (1982) also define a case study as “the detailed study of a small number of units, selected as representative of the group or groups relevant to the issue under consideration, but not necessarily representative of the population as a whole”.

A case study could provide detailed information and a broad investigation of a particular situation (Casley & Lury, 1982); but this brings disadvantages as only a small number of cases can be examined (Maxwell, 1986). Case study farms were not randomly selected, which decreases the population accuracy and therefore, the findings of this study can not be extrapolated to a whole population of dairy farms in New Zealand. As stated by Maxwell (1986), a group of case study farms may be formed based on similar constraints and challenges, being a representative group within a population. As described in Chapter 3, the present case study farms are based on the same philosophies and objectives. In addition, case study research provides opportunities for the farmers to incorporate their valuable knowledge into the research (Sherlock, 1997), which creates a more dynamic process.

The use of experimentation in this research was not considered because the objective was to work with the system as a whole, without controlling the process. This case

study involved close contact with producers, documentation of information and collection of samples. As concluded by Maxwell (1986), the case study methods provides an optimal combination of time, cost, coverage and accuracy.

4.3. FARMS DESCRIPTION

The farms are located in three regions in the Southern North Island of New Zealand: Rangitikei, Manawatu, and Northern Wairarapa. These regions cover a range of climate (NZMS, 1979), soil types (Appendix 4.2) and soil fertility (Table 4.1).

Table 4.1 Characteristics of the case study farms for the season 2000/2001.

Farm	Area (ha)		Stocking rate (cows/effect.ha)	Phosphorus ² (ug/ml)	Rainfall ³ (mm/year)
	Total	Effective ¹			
1	231	213	2.7	35	1200
2	141	125	2.4	31	1180
3	133	122	2.7	32	840
4	197	155	2.6	29	840
5	55	52	2.8	36	940
6	73	69	2.4	35	1600
7	102	81	2.7	31	1000
8	74	70	3.0	36	1300
9	92	87	2.9	35	1020
<i>Average</i>	<i>122</i>	<i>108</i>	<i>2.7</i>	<i>33.3</i>	<i>1102</i>
<i>Total</i>	<i>1098</i>	<i>974</i>			

¹ Total area discounting major buildings, wood lands, rivers and waste areas; ² data from latest soil analysis (Olsen P); ³ average of 30 years (1941-1970).

The herds consisted of Holstein-Friesian and Jersey crossbred animals. Some of the herds characteristics are illustrated in Table 4.2. The predominant pasture species on the properties were perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*). Eight of the farms also allocated an area for turnips (*Brassica campestris*) as a summer forage crop.

Table 4.2 Characteristics of the herds for the season 2000/2001.

Farm	Peak number of cows on farm	BW value ¹	PW value ²
1	570	62	71
2	295	76	96
3	326	66	78
4	405	61	72
5	148	50	56
6	164	80	101
7	215	56	55
8	210	91	112
9	253	52	72
<i>Average</i>	287	66	79
<i>Total</i>	2586		

¹ Breeding worth; ² Production worth (LIC, 1996).

All properties were utilised as milking platforms, where only adult animals (mainly lactating) were maintained on the farm. The young stock and a proportion of the dry animals were transferred to runoff areas or to contract grazing off farm. In the current work, only management related to milkers and dry cows was analysed; the young stock were not considered.

4.4. BIOLOGICAL MEASUREMENTS AND CALCULATIONS

4.4.1. Sward measurements

Pasture samples and data were collected in order to obtain an overview of sward productivity, characteristics and management (Figure 4.2). Yield measurements were made of pre and post grazing herbage mass (see Section 4.4.1.1). Sward quality involved analysis of pasture samples cut before grazing; to grazing height and to ground level. Grazing level herbage samples were collected in order to estimate the quality of herbage consumed by the cows (see Section 4.4.1.2). Ground level herbage samples

were collected in order to obtain information about the total sward canopy (see Section 4.4.1.3).

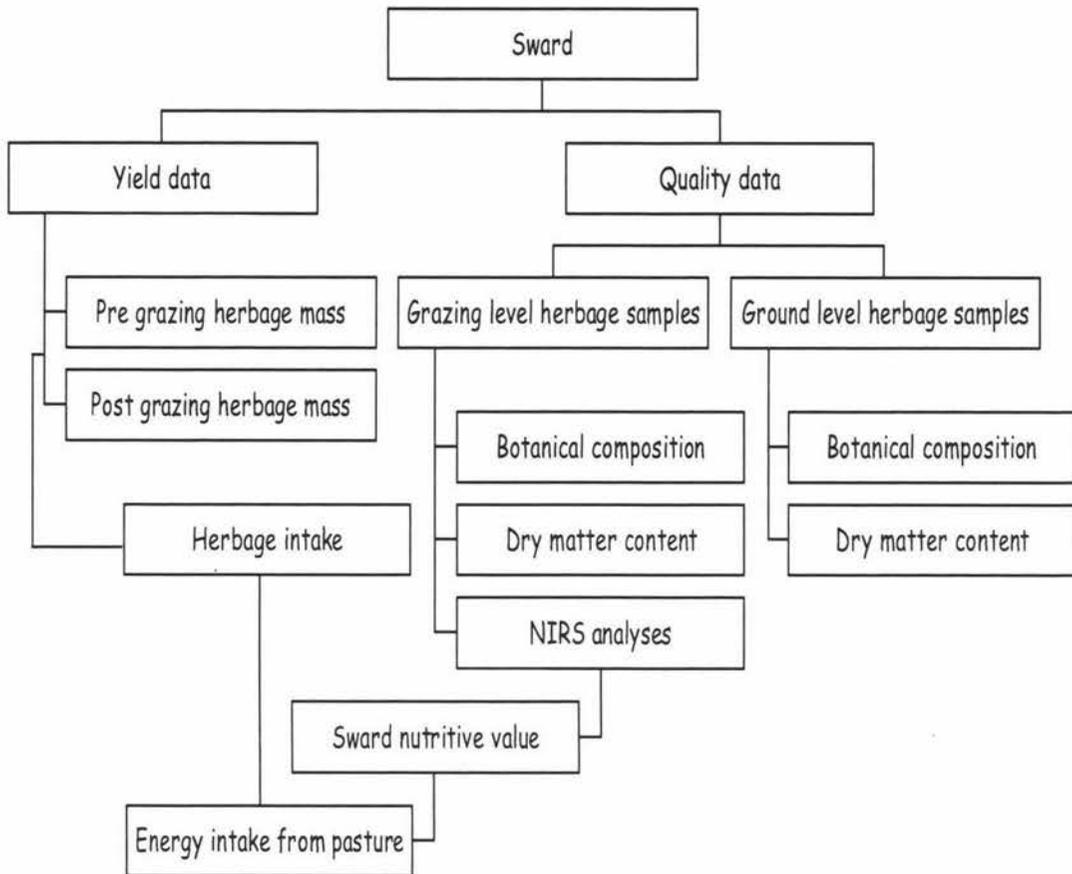


Figure 4.2 Sward data collection and measurements.

4.4.1.1. Herbage mass

Pre and post grazing herbage mass (kg DM/ha) were measured daily for all grazing events. They were estimated by the farmers, using visual assessment (Hodgson *et al.*, 1999; L'Huillier & Thomson, 1988), which were calibrated as follows. Once a month, pre and post grazing herbage mass for 15-20 paddocks selected randomly for each farm were measured by the technical staff involved in the AGMARDT Project. These measurements were made using an Ashgrove Rising Plate Meter (RPM) (Hodgson *et*

al., 1999) and standardised monthly calibration equations developed by Livestock Improvement and Dairying Research Corporation (Hainsworth, 1999). The same paddocks were measured by the farmers using visual assessment. Regression analyses were used to derive monthly equations between RPM readings and visual sward assessment for each farm, in order to standardise pasture measurements between farms (Appendix 4.1), (AGMARDT, 2000). These calibration equations were then used to adjust individual estimations from visual assessment. The corrected herbage data were used as the values of pre and post grazing herbage mass and to calculate pasture intake (see Section 4.4.5.2).

4.4.1.2. *Grazing level herbage samples*

From 23rd August 2000 to 31st January 2001, samples of pre grazing herbage mass were hand plucked (Cosgrove *et al.*, 1998) every 10 days by the farmers at the estimated grazing height along one transect line, crossing the paddock area from corner to corner. For each 10-day period, one sample per paddock from three different pre grazing paddocks was collected and thoroughly mixed to obtain a single sample, which was frozen and stored on farm for further analyses. From 1st February to 31st May 2001, samples were collected at monthly intervals. For each month, one sample per paddock, from three different pre grazing paddocks was taken and processed as described above.

The samples were then thawed, thoroughly mixed and sub-divided by the researchers, to obtain two sub samples of approximately 300 g fresh weight. These sub samples were used for Near Infrared Reflectance Spectroscopy (NIRS) analysis and botanical composition dissection.

The first pasture sub sample was dried at 60°C to constant weight, ground through a 1 mm sieve for subsequent NIRS analysis using calibrations based on wet chemistry methods (Corson *et al.*, 1999; Ulyatt *et al.*, 1995). The main variables analysed in the

NIRS were metabolisable energy (ME), crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF) and organic matter digestibility (OMD). Pasture samples were not collected from 1st June to 23rd August, 2000. Therefore, the respective NIRS results for these months were assumed from September, 2000 and May, 2001 values.

The second sub sample was further mixed and reduced to approximately 80 g fresh weight for botanical composition. This sample was separated manually into grass leaf, grass vegetative stem, grass reproductive stem, clover, weeds and dead material, to determine their relative proportions (Plate 4.1, p.59). Herbage which was no longer green, was classified as dead material. Partly green leaves were classified as green leaf when more than 50% of the leaf was green, otherwise it was classified as dead material. Once separated, the constituents were dried at 80°C to constant weight and a 0.01g precision scale was used for weighing. Each component was expressed as a percentage of the total dry matter.

4.4.1.3. *Ground level herbage samples*

One sample per paddock from three randomly selected pre grazing paddocks was collected monthly by the researchers and technical staff from September 2000 to May 2001. Along one transect line, crossing the paddock area from corner to corner, several small sub-samples from each paddock were cut to ground level using garden shears in order to provide a single paddock sample. The samples from each paddock were thoroughly mixed and bulked to obtain a single sample of approximately 300g fresh weight. This sample was further mixed and reduced to approximately 80g fresh weight for botanical composition.

This sample was then separated manually into its components to determine the proportions of grass leaf, grass vegetative stem, grass reproductive stem, clover, weeds and dead material (Plate 4.1, p.59), following the same procedure described for grazing

level herbage samples (see Section 4.4.1.2). Most of the samples were processed fresh. However, some samples were frozen for future dissection.

4.4.1.4. *Grazing and ground level dry matter samples*

From December 2000 to May 2001, one sample per paddock from three randomly selected pre grazing paddocks was collected monthly by the researchers and technical staff, at grazing and ground levels (see Section 4.4.1.2 and Section 4.4.1.3 for procedures). The samples were weighed before and after they were dried at 80°C to constant weight and the dry matter content was expressed as percentage of fresh weight.

4.4.2. **Supplementary feed measurements**

Samples of supplements and feeding records were collected in order to obtain an overview of supplementary feed characteristics and supplement management (Figure 4.3). The range of supplements fed on the case study farms consisted of apple pomace, baleage, barley grain, barley silage, brewers grain, carrot pomace, corn waste, grazing off, hay, maize grain, maize silage, molasses, oat silage, palm kernel, pasture silage, squash and turnips. However, not all the farms used all of these supplements.

4.4.2.1. *Quantity of supplement fed*

The quantities of all supplementary feeds were recorded by the farmers every time they were offered to the cows. The amount of supplements (kg fresh weight) were determined utilising feeding wagons fitted with load cells or with the use of a bucket on front-end loaders. In some cases, the fresh weight of bales or bags of supplement were also used to determine the quantity of supplementary feed. The amount of each supplement offered was then divided by the number of cows that received that type of food (milkers or dry cows) in order to calculate the intake of each type of supplement per animal (kg fresh weight/cow/day). For all supplements from which the dry matter

content was not provided by the farmers, at least two fresh samples were taken by the researchers and technical staff for dry matter content determination. The samples were weighed before and after they were dried at 80°C to constant weight. Dry matter content was expressed as percentage of fresh weight, and was utilised to determine dry matter intake of each type of supplement per animal (kg DM/cow/day).

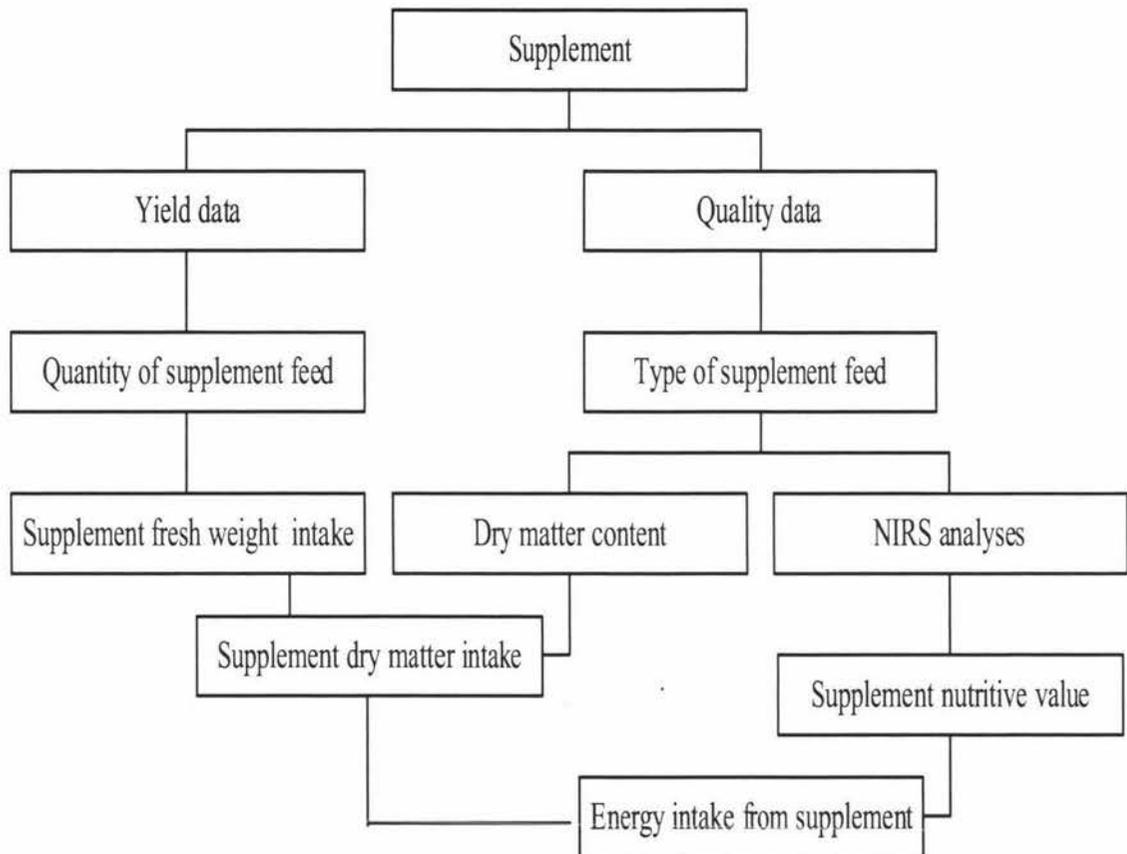


Figure 4.3 Supplement data collection and measurements.

For turnips, five small areas defined by a rectangular quadrat (0.5m x 0.5m) were harvested (Hodgson *et al.*, 1999) to estimate the whole plant (bulb and leaf) yield per hectare. The fresh weight of 0.25 m² was determined by averaging the five samples collected. One of the five samples (0.5m x 0.5m) was dried at 80°C to constant weight to determine dry matter percentage. The turnips yield (TYDM, kg DM/ha) was then calculated as follows:

$$\text{TYDM} = \frac{\text{TYquadrat} \times 10,000}{0.25} \quad \text{Equation 4.1}$$

Where:

TYquadrat = Average turnip yield per quadrat (kg DM/0.25 m²).

This procedure was carried out twice, on each farm where turnips were grown. The average of these two estimations was used to determine average crop yield (kg DM/ha) during the feeding period. The area fed each day was also recorded by the farmers. Therefore, turnip intake (kg DM/cow/day) was calculated by multiplying the turnip yield by the area of the crop fed each day. The result was then divided by the number of milkers grazing on that day.

It was assumed 5% wastage for all types of supplements whenever they were fed on the trough. For turnip and supplements fed on the paddocks 10% wastage was assumed.

4.4.2.2. *Type and composition of supplement*

Samples of each type of supplementary feed were collected by the farmers for NIRS analyses. One sample of each type of supplement used was collected every ten days, from 23rd August to 31st January. From 1st February to 31st May 2001, the samples were collected monthly. Each sample consisted of several handfuls from different points of the feeding line. The samples were frozen and stored on farm for subsequent analysis. Supplement samples were not collected from 1st June to 23rd August, 2000. Therefore, the respective NIRS values for the supplements used during this period were assumed averaging the values of the same supplements fed after 23rd August, 2000.

The preparation of supplement samples for NIRS analysis followed the same procedures of pasture samples (see Section 4.4.1.2). However, it was not possible to determine the metabolisable energy values (ME) for apple pomace, barley grain, brewers grain, maize

grain and squash by NIRS, because there were no equations available for predicting ME from proximate analyses. Therefore, their ME values were predicted by comparing their concentrations of protein, lipid, ash, acid detergent fibre (ADF), neutral detergent fibre (NDF) and soluble carbohydrates (CHO) measured by NIRS with the standard values of the same components (MAFF, 1992; NRC, 1988).

For carrot pomace, palm kernel and turnips, published values of ME were used (MAFF, 1992; NRC, 1988). For grazing off, 10.5 MJ ME/kg DM was assumed; the crude protein, ADF and NDF were estimated as the average of the concentration values of those components in the pasture samples containing 10.5 MJ ME/kg DM. The same values were utilised for the nine farms.

4.4.3. Animal measurements

4.4.3.1. Numbers (stock reconciliation)

Numbers of animals in each stock class (dry cows, milkers and dry cows grazing off) as well as transfers between classes, stock sales, stock purchases and stock deaths, were recorded daily by the farmers.

4.4.3.2. Liveweight and condition score

A random sample of cows representing approximately 25 % of each herd, was weighed and condition scored in late September, late November, mid March and late May/early June. The condition score system utilised was based on the Livestock Improvement Corporation, scale (1 – 10) (LIC, 2000) (Plate 4.2, p. 59). Due to time and labour constraints, it was not possible for the same person to assess the cows' condition score on all occasions. However, there was standardisation of procedures between the three people involved.



Plate 4.1 Botanical composition of thawed sample collected at grazing level (left) and botanical composition of fresh sample collected at ground level (right).

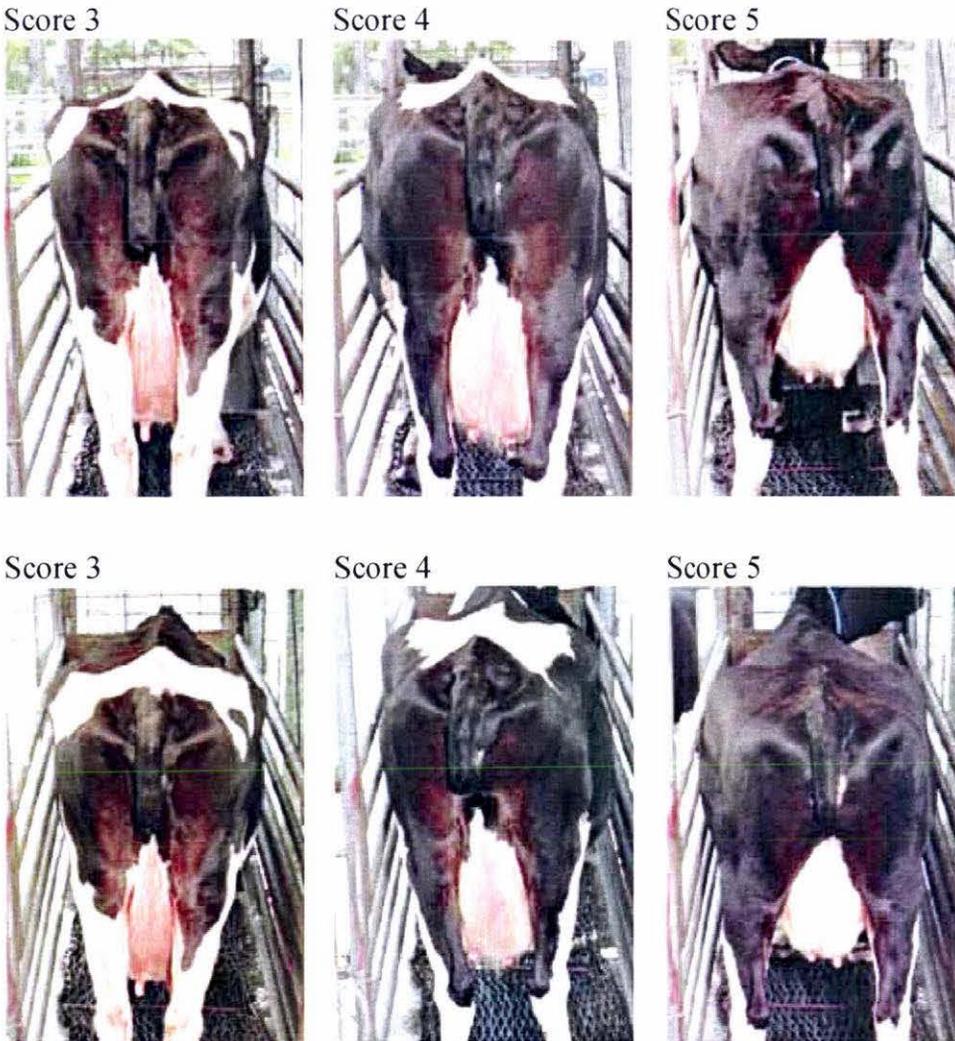


Plate 4.2 Examples of condition scoring system for Friesian cows (LIC, 2000).

4.4.3.3. *Milk yield and composition*

Daily data for the yield and composition of milk produced on each farm was obtained from the milk statement provided monthly by Kiwi Co-operative Dairies. The information was then used to compile production data for the whole herd and to calculate daily yields per cow. Only milk yield supplied to the factory was used in this project. Therefore total production was underestimated because the milk used to feed the calves was not measured by the farmers.

4.4.4. **Management measurements**

Management information was gathered routinely throughout the season, as follows:

- Decisions regarding supplementary feed;
- Manipulation of stock numbers;
- Supplement inventory;
- Grazing off dates;
- Calving and drying off dates, calving pattern;
- Decisions regarding disposal of stock;
- Nitrogen fertiliser application.

4.4.5. **Derived variables**

4.4.5.1. *Stocking Rate*

Stocking rate (cows/ha) was calculated by dividing the peak number of cows on farm by total farm effective area (ha).

4.4.5.2. Pasture intake (dry matter)

Apparent pasture dry matter (DM) intake and grazing intensity were calculated separately for milkers and dry cows. Pasture intake (kg DM/cow/day) was estimated as the difference between adjusted pre and post grazing herbage mass (kg DM/ha) divided by grazing intensity (cows/ha/day) (Matthews *et al.*, 1999). Grazing intensity was defined as the number of animals grazing divided by the area grazed per 24 hours (Matthews *et al.*, 1999).

To transform the daily pasture DM intake per cow to daily pasture DM intake per herd (kg DM/herd/day), the per cow values were multiplied by the number of animals from the respective mobs. The herd annual pasture DM intake (kg DM/herd/year) was calculated by adding the per herd daily values of pasture DM intake, for the whole year (1st June 2000 to 31st May 2001). This procedure was performed separately for each mob. Consequently, the annual pasture DM intake by all cows (milkers plus dry animals) was obtained by adding the values of annual pasture DM intake of milkers and dry cows.

Annual pasture DM intake per cow (kg DM/cow/year) and per hectare (kg DM/ha/year) were calculated separately for the different mobs (milkers, dry cows and milkers plus dry cows). The first variable was obtained by dividing the mobs' respective annual pasture DM intake per herd by the peak number of cows on farm. Annual pasture DM intake per hectare was obtained by dividing the same numerator by total farm effective area (ha).

The same procedure was used to calculate pasture dry matter intake by the milkers, both per cow (kg DM/cow/period) and per hectare (kg DM/ha/period), for the first (from the first day of lactation for each farm up to 31st of December) and second (from 1st of January to the last day of lactation for each farm) periods of lactation. However, instead

of adding the per herd daily values of pasture DM intake for the whole year, it was added for the correspondent periods, obtaining then the herd pasture DM intake for the first and second periods of lactation.

4.4.5.3. *Pasture intake (energy)*

Daily pasture metabolisable energy (ME) intake per animal was calculated separately for milkers and dry cows (MJ ME/cow/day) as daily pasture DM intake of each mob (kg DM/cow/day) multiplied by the daily pasture ME concentration (MJ ME/kg DM). Pasture ME concentration was obtained from samples collected every 10 days or monthly (see Section 4.4.1.2).

The same procedure as for pasture DM intake was used to obtain annual pasture ME intake, both per cow (MJ ME/cow/year) and per hectare (MJ ME/ha/year) for all mobs and pasture ME intake by the milkers, both per cow (MJ ME/cow/period) and per hectare (MJ ME/ha/period), for the first and second parts of lactation.

4.4.5.4. *Supplement intake (dry matter)*

To convert the daily supplement DM intake per cow (kg DM/cow/day) (see Section 4.4.2.1) to daily supplement DM intake per herd (kg DM/herd/day), the per cow values were multiplied by the number of animals from the respective mobs. The herd annual supplement DM intake (kg DM/herd/year) was calculated by adding the per herd daily values of supplement DM intake, for the whole year (1st June 2000 to 31st May 2001). This procedure was performed separately for each mob. The supplement DM intake by all cows (milkers plus dry animals) was obtained by adding the values of annual supplement DM intake of milkers and dry cows.

Annual supplement DM intake per cow (kg DM/cow/year) and per hectare (kg DM/ha/year) were then calculated separately for the different mobs (milkers, dry cows

and milkers plus dry cows). The first variable was obtained by dividing the mobs' respective annual supplement DM intake per herd by the peak number of cows on farm. Annual supplement DM intake per hectare was obtained by dividing each mob's annual supplement DM intake per herd by total farm effective area (ha).

The same procedure was used to calculate supplement dry matter intake both per cow (kg DM/cow/period) and per hectare (kg DM/ha/period) for milkers, for the first and second periods of lactation.

4.4.5.5. *Supplement intake (energy)*

Daily supplement metabolisable energy intake (ME) per animal was estimated separately for milkers and dry cows (MJ ME/cow/day), by multiplying each type of supplement DM intake (kg DM/cow/day) by its respective ME concentration. Supplement ME concentration was obtained from samples collected every 10 days or monthly (see Section 4.4.2.2). Finally, the ME intakes from the different supplements were added in order to obtain the total daily energy intake from all supplements (MJ ME/cow/day).

The same procedure as for supplement DM intake was used to obtain annual supplement ME intake, both per cow (MJ ME/cow/year) and per hectare (MJ ME/ha/year) for all mobs and supplement ME intake by the milkers, both per cow (MJ ME/cow/period) and per hectare (MJ ME/ha/period) for the first and second parts of lactation.

4.4.5.6. *Total intake (dry matter)*

Annual total DM intake by the milking herd (kg DM/herd/year) was calculated by adding the herd annual pasture DM intake and the herd annual supplement DM intake, for the milkers mob. The same procedure was applied to calculate the annual total DM

intake by dry cows herd (kg DM/herd/year). Subsequently, the annual total DM intake by the dry cows and by the milkers herds were added to obtain the annual total DM intake by all cows (kg DM/herd/year).

Annual total DM intake per cow (kg DM/cow/year) and per hectare (kg DM/ha/year) were calculated separately for the different mobs (milkers, dry cows and milkers plus dry cows). The first variable was obtained by dividing the mobs' respective annual total DM intake per herd by the peak number of cows on farm. The second variable was obtained by dividing the same numerator by total farm effective area (ha).

A similar procedure was used to calculate total dry matter intake by the milkers, both per cow (kg DM/cow/period) and per hectare (kg DM/ha/period), for the first and second periods of lactation.

4.4.5.7. *Total intake (energy)*

The same procedure as for total DM intake was used to obtain annual total ME intake, both per cow (MJ ME/cow/year) and per hectare (MJ ME/ha/year) for all mobs and total ME intake by the milkers, both per cow (MJ ME/cow/period) and per hectare (MJ ME/ha/period), for the first and second parts of lactation.

4.4.5.8. *Milksolids production*

Daily milksolids production per herd (kg/herd/day) was estimated by the addition of the values resulting from the multiplication of the herd's daily milk yield (litres) by its concentration of protein and fat, respectively (g/100 ml). The annual milksolids production per herd (kg/herd/year) was calculated by adding the herd's daily values for the whole year (1st June 2000 to 31st May 2001).

Annual milksolids production per cow (kg/cow/year) and per hectare (kg/ha/year) were calculated by dividing the annual milksolids production per herd by peak number of cows on farm, and by total farm effective area (ha), respectively.

A similar procedure was used to calculate milksolids production, both per cow (kg/cow/period) and per hectare (kg/ha/period), for the first and second periods of lactation.

4.4.5.9. *Lactation length*

Total lactation days were calculated by summing the daily numbers of cows milked throughout the lactation period. The variables lactation days per cow and per hectare were obtained by dividing total lactation days by peak number of cows on farm and by total farm effective area (ha), respectively.

4.4.5.10. *Feed conversion efficiency*

Feed conversion efficiency (g MS/MJ ME intake or g MS/kg DM intake) for the whole lactation was expressed as: the ratio of annual milksolids production per herd (kg/herd/year) to annual total metabolisable energy (MJ ME/herd/year) or dry matter (kg DM/herd/year) intakes by all cows; and as the ratio of the same numerator to annual total ME (MJ ME/herd/year) or DM (kg DM/herd/year) intake by milkers only. Feed conversion efficiency for the first and second parts of lactation were calculated as the ratio of milksolids production per herd (kg/herd/period) to total ME (MJ ME/herd/period) or DM (kg DM/herd/period) intake by milkers, for each period.

4.4.6. **Theoretical metabolisable energy requirements**

Total energy requirement of grazing dairy cows is the sum of metabolisable energy (ME) necessary for the biological processes maintenance, pregnancy, milk production

and liveweight change. The theoretical energy requirements for each biological process was calculated for the period of one year and then compared with the measured values for the season 2000/2001.

4.4.6.1. *Metabolisable energy requirements for maintenance*

Daily maintenance requirements for non-lactating and lactating animals are 0.55 MJ ME and 0.6 MJ ME per kg of metabolic liveweight, respectively (Holmes *et al.*, 2000a). Metabolic liveweight equals liveweight^{0.75} (Kleiber, 1965). The daily values of ME requirements were multiplied by the number of days corresponding to dry and lactating periods, for each farm (Table 5.4). Total metabolisable energy requirement assumed for maintenance for the year was the sum of energy requirements for the dry and lactating periods.

4.4.6.2. *Metabolisable energy requirements for liveweight change*

The metabolisable energy requirements for liveweight gain depend on the amount of liveweight gained and its composition (Holmes *et al.*, 2000a). Values ranging from 31 to 32 MJ/kg LW gain were assumed, according to the average liveweight for the animals for each farm (Table 4.3).

Table 4.3 Mean fat and protein concentrations and metabolisable energy (ME) requirements above maintenance for liveweight gain (LWG) and ME spared through liveweight loss (Holmes *et al.*, 2000a).

Liveweight (kg)	Concentration (g/kg LWG)		ME requirement (MJ/kg LW gain)		ME spared (MJ/kg LW loss)
	Fat	Protein	Dry animals	Lactating	
100	124	161	18	-	12
200	227	148	26	-	17
300	310	139	33	-	21
400	373	134	38	30	24
500	416	133	41	32	26
600	439	130	43	34	28

4.4.6.3. Metabolisable energy requirements for milk production

The metabolisable energy required for lactation depends upon the yield and composition of milk. Milk with higher concentrations of milksolids, particularly fat, requires more energy per unit produced (Holmes *et al.*, 2000a). The ME required per kg of milksolids ranged from 65 to 68 MJ among the case study farms, according to the concentration of milk fat and milksolids (Table 4.4).

Table 4.4 Recommended daily metabolisable energy requirements above maintenance for milk production by dairy cattle grazing leafy pasture (11 MJ ME/kg DM). Adapted from Holmes *et al.* (2000a).

Milk composition						
Milk fat concentration (g/litre of milk)	40	45	50	55	60	65
Milk protein concentration (g/litre of milk)	32	35	37	39	42	44
Milksolids concentration (g/litre of milk)	72	80	87	94	102	109
Dietary						
ME required per litre of milk (MJ/litre)	5.0	5.4	5.8	6.1	6.5	6.9
ME required per kg of milksolids (MJ/kg)	69	68	66	65	64	63

4.4.6.4. Metabolisable energy requirements for pregnancy

The energy requirements for pregnancy depends upon the number and size of the offspring and the time since conception (Table 4.5) (Holmes *et al.*, 2000a). It was assumed calf birthday weights of 35 kg and 1910 MJ ME/year for all farms.

Table 4.5 Metabolisable energy required during different stages of pregnancy by cows (MJ ME/cow/day), in addition to maternal requirements for calf birth weights of 30, 35 and 40 kg (Holmes *et al.*, 2000a).

Stock	Birth weight (kg)	Weeks before birth					Annual Total
		12	8	4	2	0	
Calves	30	6	11	19	25	32	1640
	35	7	12	22	29	38	1910
	40	8	14	25	33	43	2180

Add 75% of these values for twin foetus.

4.5. STATISTICAL ANALYSIS

4.5.1. Correlation and stepwise regression analyses

All the statistical analyses were performed using the MINITAB[™] statistical software (Minitab[™], 2000). A Pearson product moment correlation matrix was used to measure the degree of linear association between each pair of dependent variables (y) and between each predictor variable (x) and the dependent variables. Multiple linear regression analyses were also carried out using selected predictor variables. The predictor variables (x) were selected based on their biological importance and the simple correlation values between them and the dependent variables. Selected predictor variables were then added to the regression equation one by one manually, in order of importance. The objective was to obtain the subset of predictor variables (x) which provided the best explanation of variation in the dependent variables. An F test was carried out to determine the statistical significance of the addition of a new variable (x_2), given that x_1 was already in the model (IIST, 2000; Thompson, 1989). Examples of the procedures used and of the relevant computer print out are given in Section 4.5.1.1 and Section 4.5.1.2.

In a regression procedure, the objective is to produce the line describing the best relationship between the observed (y) and the predictor (x) variables, which is the one that minimizes the sum of squared deviations from the line. The deviations from the line are also called residuals or error. Standard deviation of the residual is abbreviated as “S” in Section 4.5.1.1 and Section 4.5.1.2.

The model fitted by MINITAB[™] is described in Equation 4.2 and the linear equation (Section 4.5.1.1 and Section 4.5.1.2) describing the relationship between x and the y values, is described in Equation 4.3.

$$\text{Observed} = \text{fitted} + \text{residual} \quad \text{Equation 4.2}$$

$$\text{fit} = a + bx \quad \text{Equation 4.3}$$

4.5.1.1. Example of regression equation for x_1

$$\text{MS/C} = 248 + 0.00423 \text{ PME/Cm} \quad \text{Equation 4.4}$$

Where:

MS/C = Annual milksolids production per cow (kg/cow/year)
 PME/Cm = Annual pasture ME intake per cow by milkers (MJ ME/cow/year)

The regression coefficients and standard errors were derived as follows:

Predictor	Coef	SE Coef	T	P
Constant	248.07	38.79	6.40	0.000
PME/Cm	0.004228	0.001005	4.21	0.004

S = 11.09 $R^2 = 0.72$ $R^2(\text{adj}) = 0.68$

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	2179.0	2179.0	17.71	0.004
Residual Error	7	861.2	123.0		
Total	8	3040.2			

4.5.1.2. Example of regression equation for x_1 and x_2

$$\text{MS/C} = 252 + 0.00371 \text{ PME/Cm} + 0.00129 \text{ SME/Cm} \quad \text{Equation 4.5}$$

Where:

$$\text{SME/Cm} = \text{Annual supplement ME intake per cow by milkers (MJ ME/cow/year)}$$

The regression coefficients and standard errors were derived as follows:

Predictor	Coef	SE Coef	T	P
Constant	251.60	39.19	6.42	0.001
PME/Cm	0.003706	0.001148	3.23	0.018
SME/Cm	0.001290	0.001346	0.96	0.375

$$S = 11.16 \quad R^2 = 0.75 \quad R^2(\text{adj}) = 0.67$$

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	2293.3	1146.7	9.21	0.015
Residual Error	6	746.9	124.5		
Total	8	3040.2			

Source	DF	Seq SS
PME/Cm	1	2179.0
SME/Cm	1	114.3

The F value to determine the statistical significance of the addition of a new variable (x_2), given (x_1) was already in the model, was calculated as follows:

$$F = \frac{\text{adSSR adDF}}{\text{MSE}} \quad \text{Equation 4.6}$$

Where:

- adSSR = Additional variation attributed to regression
- adDF = Additional degrees of freedom
- MSE = Mean square error

For Section 4.5.1.1 and Section 4.5.1.2, the F value was calculated as follows:

$$F = \frac{(2293.3 - 2179.0)/1}{124.5} \quad F = 0.918 \quad \text{Equation 4.7}$$

The degrees of freedom associated with the F statistic is 1 (numerator) and 6 (denominator) so that tabled value for 5% level of probability is 5.99. As the calculated F (0.918) is not greater than 5.99, x_2 does not explain a significant amount of the variation of the regression above that explained by x_1 .

In the analysis of variance (see Section 4.5.1.1 and Section 4.5.1.2), "SS" is an abbreviation for sum of squares, which represents the variation in the observed values about the mean (SS Total), variation in the fitted values about the mean (SS Regression) and variation in the residuals (SS Error), where:

$$\text{SS Total} = \text{SS Regression} + \text{SS Residual} \quad \text{Equation 4.8}$$

Each of these sums of squares is associated with its degrees of freedom. Total degrees of freedom is obtained by decreasing 1 from the sample size ($n - 1$). An F statistic (F) is formed by the ratio of the regression variance and the error variance. These variances are called mean squares (MS) and are calculated by dividing the sum of square (SS) by its associated degrees of freedom (df).

The null hypothesis assumed in the regressions is that the model does not fit the data, which means that it explains small variation of the dependent variable y . This hypothesis is generally rejected whenever the P-value (P) is less than 0.05.

R^2 shows the percentage of the total variation (SS Total) of the dependent variable y , that is explained by the predictor variables, as follows:

$$R - sq = \frac{SS \text{ Regression}}{SS \text{ Total}} \quad \text{Equation 4.9}$$

The more variables added to the model, the higher the amount of variation that can be explained. Even if individual variables do not explain much, adding a large number of variables can result in very high values of R^2 . In this situation, the R^2 (adj) allows the comparison between regressions with different numbers of variables.

4.6. FINANCIAL ANALYSIS

The financial analyses were based on the cost of production of eight case study farms, a group production function and a comparison of financial key performance indicators. From the nine farms involved in this project, only eight farms were used for the financial analysis due to lack of information from one farm.

4.6.1. Cost of production

The cost of production of the eight case study farms was calculated as total farm cost and net milk cost. The total farm cost involved the cost to produce both milk and non-milk income. The net milk cost involved only the cost to produce milk products and was calculated as the total farm cost minus the non-milk income (IFCN, 2001). The total farm cost was the sum of operating expenses and funding costs.

4.6.1.1. Operating expenses

Operating expenses included cash and non-cash expenses. The cash operating expenses included farm working expenses, repairs and maintenance, vehicle expenses, administration charges, standing charges and rent. The non-cash operating expenses included total depreciation (buildings, plant, machinery and vehicles), a market value of

unpaid family labour and a value for the change in supplement inventory. Values of current account interest, taxation, personal drawings, personal insurance, capital items and debt servicing were not included in the operating expenses.

If the value of supplement at closing (June, 2001) was higher than the opening value (June, 2000), the difference was subtracted from operating expenses. If the value of supplement at opening was higher than the closing value, the difference was added to operating expenses. The same market price was assumed for supplements at opening and closing (Table 4.6).

For family labour, an annual value of NZ\$35,000 was assumed for farms with less than 220 cows and with 1 unpaid labour unit; NZ\$24,500 per year was assumed for the farm with less than 220 cows and with 0.7 unpaid labour unit. For farms with a herd size greater than 220 cows, an annual value of NZ\$140 per cow was used (up to a maximum of NZ\$70,000) for the first labour unit and NZ\$25,000 per year for each subsequent labour unit. These are based on Dexcel (2002, personal communication) estimations adjusted for an increase in current market values of labour.

Table 4.6 Market price utilised in the supplementary inventory (Matthews, 2002, personal communication).

Supplements	Market price (NZ\$/kg DM)
Baleage	0.25
Barley silage	0.19
Brewers grain	0.16
Hay	0.27
Maize silage	0.19
Pasture silage	0.15
Squash	0.19

4.6.1.2. *Cost of funds*

The cost of funds was estimated as 6% of total farm assets for all the farms, which consisted of land, buildings, plant, machinery and livestock. As the property business income (capital gains) was not included in this analysis, the cost of funds was based on the opportunity cost of capital for farming only. Farming assets are commonly leased at 5 to 7% of assets value, so a 6% cost of funds was applied. As the financial information was not available to more accurately identify individual farm's cost of debt and the project did not allow time to determine each farm's cost of equity, the same cost of funds was applied to all farms. Plant and machinery assets were obtained from the farms accounts. The same national average market value of different categories of livestock was used at opening and closing (IRD, 2001). Values for land and buildings assets were estimated as the average of values calculated by the following three different methods:

- value based on government valuation: the capital value (land and buildings) was used for the milking platform, but only the land value was for the runoff, when it was applied. The total land and buildings assets based on government valuation was the sum of these two values;
- value based on average milksolids production: a value of NZ\$19 per kg of milksolids produced (McCarthy, 2002, personal communication) was used for the milking platform. Milksolids production was the average of three seasons (1998/99 – 2000/2001). The land value from government valuation for the runoff was used, when it was applied. This value was added to the value of the milk platform based on average milksolids production, to estimate the total value of assets for this method;

- value based on per hectare production: NZ\$16,000 per hectare was used, based on current market value (McCarthy, 2002, personal communication). However, this value was weighted depending on annual pasture intakes per hectare. The annual pasture intake of each farm was divided by the average of annual pasture intake for all farms. This coefficient was then multiplied by the base value of NZ\$16,000 to give the adjusted value per hectare for each farm. Land value from government valuation for the runoff was added to the value of the milk platform based on average price per hectare, to estimate the total value of assets for this method.

4.6.1.3. *Income*

The income was divided into milk and non-milk income. Gross farm income (GFI) was calculated as the sum of milk and non-milk income minus stock purchases plus or minus any change in livestock inventory. Milk income included milksolids payment (NZ\$5.00 per kg MS) and colostrum sales. Non-milk income included all other income, such as stock sales, grazing, rebates and reimbursements, and was calculated by subtracting milk income from gross farm income. Change in livestock inventory was subtracted from the income if the value of livestock at closing (Junc, 2001) was lower than the opening value (June, 2000). It was added to the income if the value of livestock at opening was lower than the closing value.

4.6.2. **Key performance indicators**

The financial performance indicators used in this project are described as follows:

- Economic farm surplus (EFS): gross farm income (GFI) - total operating expenses (OE);

- EFS/H: economic farm surplus / total farm effective area (ha);
- GFI/H: gross farm income / total farm effective area (ha);
- GFI per dry matter (DM): gross farm income / total DM intake (kg);
- GFI per metabolisable energy (ME): gross farm income / total ME intake (MJ);
- Cost per DM: total farm cost / total DM intake (kg);
- Cost per ME: total farm cost / total ME intake (MJ);
- Cost per milksolids: net milk cost / total farm milksolids production (kg);
- Return on assets: EFS / total assets;
- Operating profit margin: EFS / GFI;
- Assets turnover ratio: GFI / total assets;
- Revenue to labour ratio: GFI / S value of paid staff + S value of unpaid labour;
- Revenue per labour unit: GFI / total labour units;

CHAPTER 5

RESULTS

5.1. GENERAL DESCRIPTION

5.1.1. Climate

Most of the farms experienced dry conditions over the summer and early autumn. The annual rainfall recorded for the season 2000/2001 at No. 4 Dairy Unit, Massey University, Palmerston North was 875 mm, which was 12% lower than the 60 years average (Figure 5.1). Even though the annual rainfall for the season 2000/2001 was only 8.8 mm less than the previous season, the period from January to April had a decrease of 100 mm compared to the same period in 1999/2000.

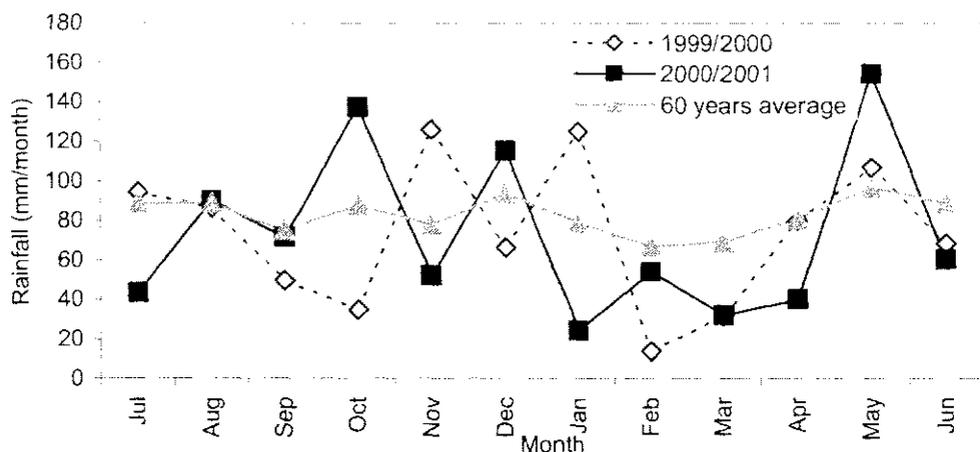


Figure 5.1 Monthly rainfall recorded at No. 4 Dairy Unit, Massey University, Palmerston North.

5.1.2. Sward conditions

The average values for all farms of adjusted pre and post grazing herbage mass of milkers and dry cows are illustrated in Figure 5.2. Data for individual farms are illustrated in Appendix 5.1. Both are shown as 10-days period averages. Farm 1 had autumn and spring calving (Appendix 5.1, Farm1) which explains the pre and post grazing herbage mass values for milkers during the whole period (1st of June 2000 to 31st May 2001) (Figure 5.2). In the same way, Farm 6 was responsible for the continuous values of pre and post grazing herbage mass of dry cows over the whole year (Figure 5.2) because “leaders/followers” grazing management was used on the farm to improve pasture quality (Appendix 5.1, Farm 6).

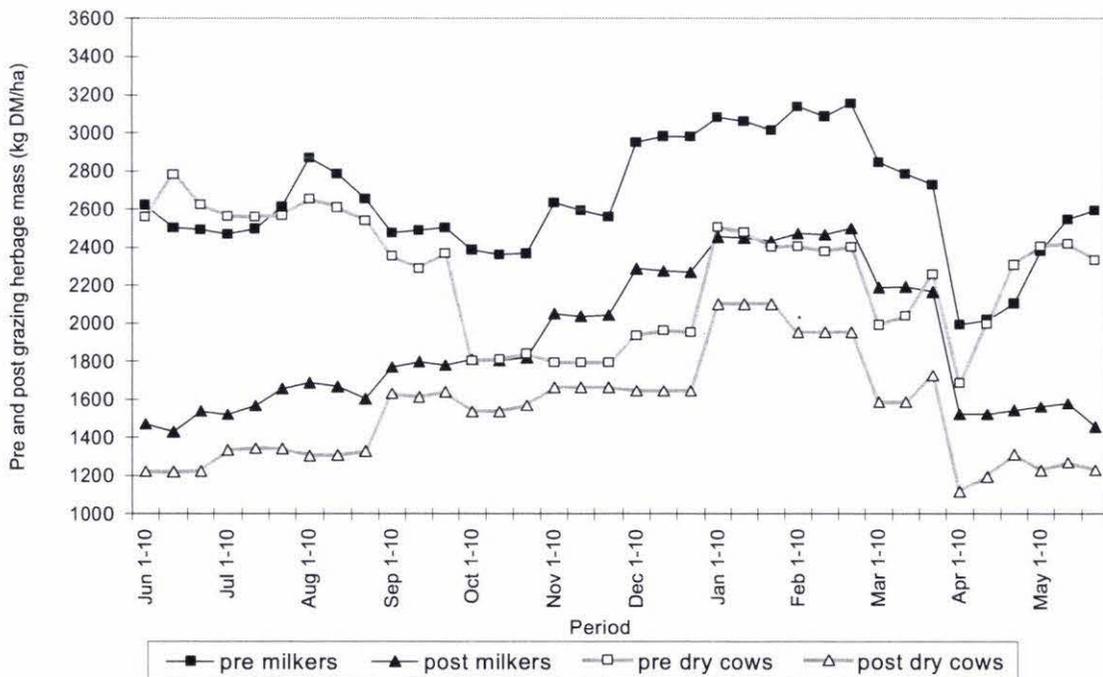


Figure 5.2 Average adjusted pre and post grazing herbage mass values for all case study farms (kg DM/ha) of milkers and dry cows (season 2000/2001).

The average values for all farms of pasture dry matter content (%) for samples cut to grazing height and ground level are illustrated in Figure 5.3. Mean dry matter content (DM) of all case study farms from December/2000 to June/2001 were 20% and 23% for pasture samples cut to grazing height and ground level, respectively. As expected, pasture dry matter content was inversely proportional to rainfall. January and March were the driest months in the 2000/2001 season (Figure 5.1) with the highest pasture dry matter content. Increased rainfall after March resulted in reduction in pasture dry matter content.

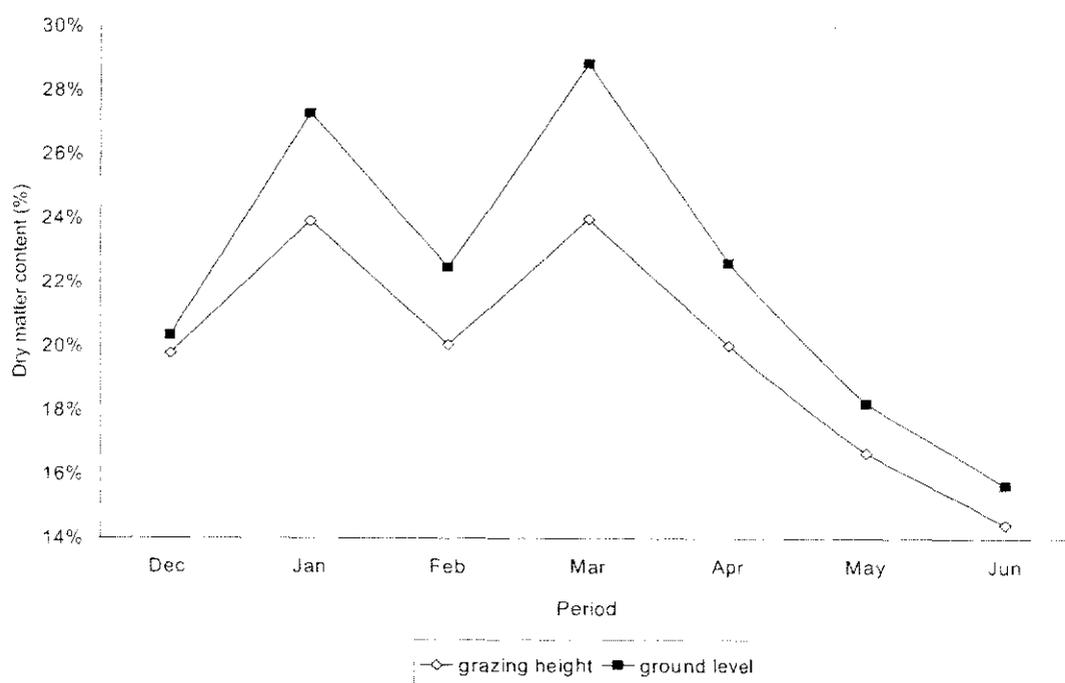


Figure 5.3 Pasture dry matter content for samples cut to grazing height and ground level. Average values for all case study farms for the season 2000/2001.

5.1.3. Pasture quality

The average metabolisable energy (ME), crude protein, acid detergent fibre (ADF) and neutral detergent fibre (NDF) concentrations for all case study farms are illustrated in

Figure 5.4. Data for individual farms are shown in Appendix 5.2 and Appendix 5.3. The depicted values represent 10-days period averages. Pasture nutritive values (Table 5.1) show that on average, the case study farms had high pasture quality throughout the year (ME values were higher than 10.5 MJ ME/kg DM) (Hodgson & Brookes, 1999). Average botanical composition for all case study farms of pasture samples cut to grazing height (August 2000 to May 2001) and ground level (September 2000 to May 2001), are shown in Figure 5.5 a and b, respectively. Botanical composition of pasture samples cut to grazing height for individual farms are illustrated in Appendix 5.4.

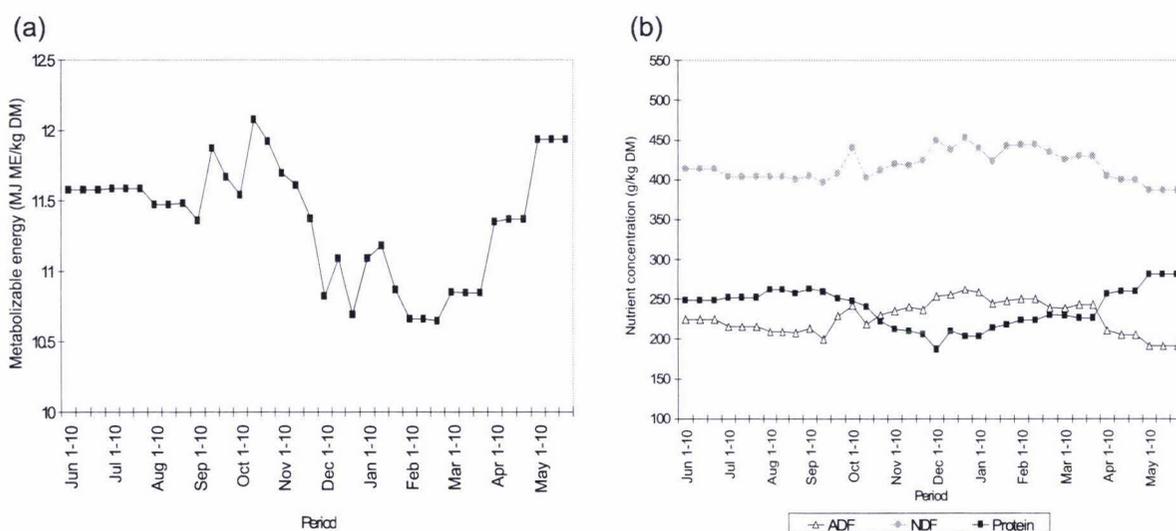


Figure 5.4 Average metabolisable energy (ME) (a), crude protein, acid detergent fibre (ADF) and neutral detergent fibre (NDF) (b) for all case study farms, for pasture samples cut to grazing height (season 2000/2001).

Table 5.1 Average pasture nutrient values of all case study farms for samples cut to grazing height (season 2000/2001).

Nutrients	Mean	Maximum	Minimum
Metabolisable energy (MJ ME/kg DM)	11.4	12.1	10.6
Crude protein (g/kg DM)	239	281	185
Acid detergent fibre (g/kg DM)	227	262	191
Neutral detergent fibre (g/kg DM)	417	453	387
Organic matter digestibility (g/kg DM)	801	845	742

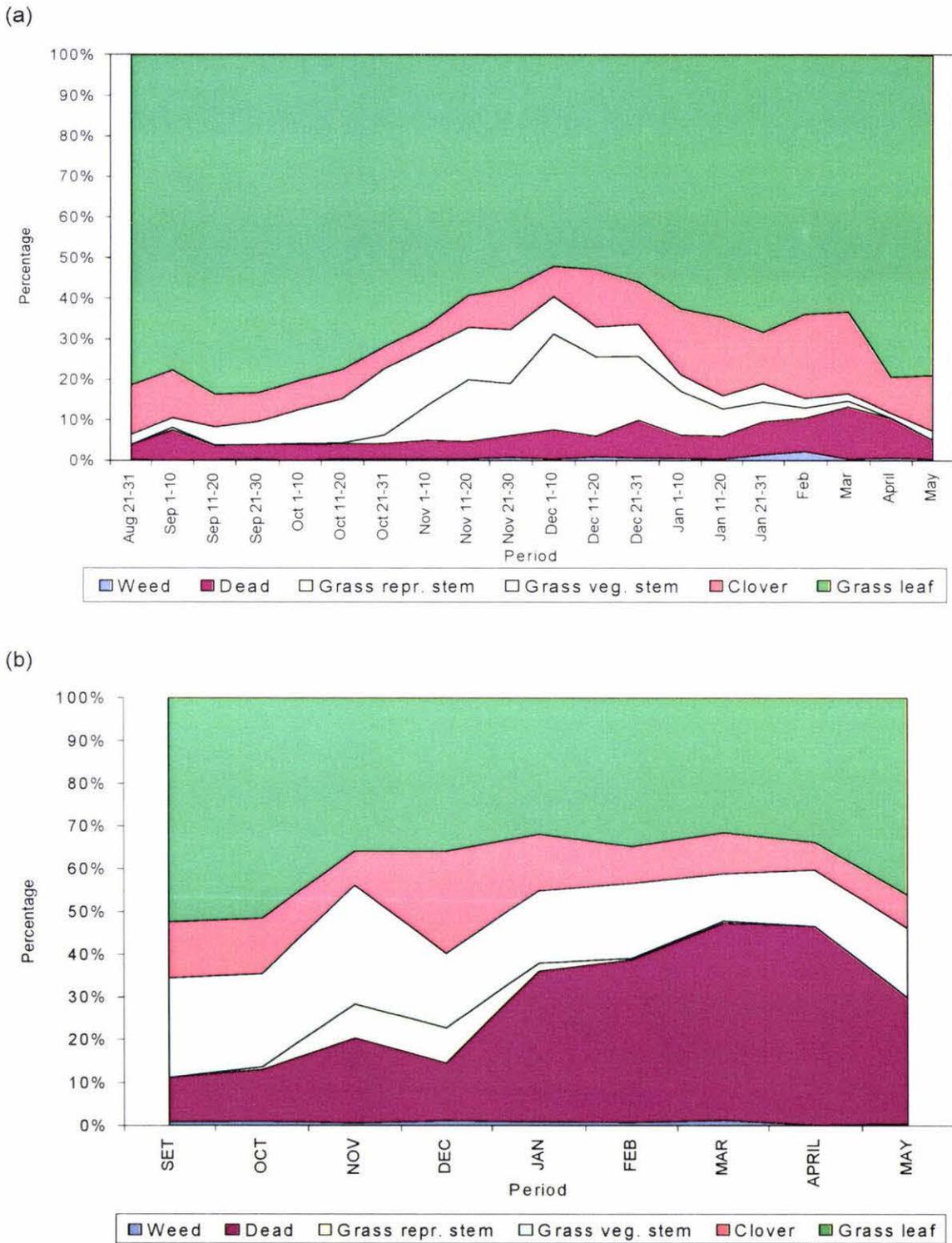


Figure 5.5 Average botanical composition for all case study farms of pasture samples cut to grazing height (a) and to ground level (b) for the season 2000/2001.

The botanical composition of pasture samples cut to grazing height showed higher amounts of grass reproductive stem (maximum of 24%) in the period from late October to late November, which resulted in decreased grass leaf and clover proportions, reducing pasture quality. Dead material appeared to be relatively constant, with higher proportion in late summer and early autumn (maximum of 13%). The botanical composition of pasture samples cut to grazing height for each farm is depicted in Appendix 5.4. The contrast with the botanical composition of pasture samples cut to ground level was mainly related to the dead material content, which achieved a maximum of 46% in autumn. The grass leaf proportion of pasture samples cut to ground level remained relatively constant in the period from November to April, achieving its maximum of 52% in spring.

5.1.4. Nitrogen use

The average nitrogen use among all the case study farms for the season 2000/2001 was 125 kg N/ha/year, ranging from 80 to 150 kg N/ha/year. Nitrogen application in spring represented approximately 38% of the annual nitrogen applied, with 36% in autumn, 19% in winter and only 7% in summer. Data for each farm are described in Table 5.2.

Table 5.2 Nitrogen application for individual farms for the season 2000/2001.

	Farms								
	1	2	3	4	5	6	7	8	9
Nitrogen (kg N/ha/year)	140	150	110	128	125	125	142	124	80

5.1.5. Supplement quality

Daily intake and contribution of pasture and supplements to total feed intake throughout the year are shown in Figure 5.6. The average nutritive values for the range of supplements used in the case study farms are illustrated in Table 5.3. Appendix 5.5

shows the contribution of each type of feed to total feed intake, for all case study farms. Grazing off was the main supplement consumed by dry animals and represented approximately 35% of total intake in June and July. In most cases the dry mob was divided into cows on farm and animals grazing off farm. In these cases, total dry animal's intake was calculated as the weighted average between on farm and off farm feeding in June and July. Supplement intake by lactating cows was characterised by turnips and pasture silage in summer and autumn. Pasture was the main feed throughout the whole season, both for milkers and dry animals. The highest pasture intake values were obtained from August to November, when pasture comprised approximately 84% to 88% of total feed dry matter intake.

Table 5.3 Average metabolisable energy (MJ ME/kg DM), crude protein (g/kg DM), acid detergent fibre (ADF, g/kg DM) and neutral detergent fibre (NDF, g/kg DM), for the range of supplements utilised on all case study farms in the season 2000/2001. Some values were assumed from the literature (see Section 4.4.2.2).

Supplements	ME	Protein	ADF	NDF
Apple pomace	11.4	91	320	445
Baleage	10.0	136	373	575
Barley grain	13.5	70	71	134
Barley silage	10.0	105	360	636
Brewers grain	11.4	247	214	386
Carrot pomace	13.0	95	80	90
Corn waste	9.3	65	387	670
Grazing off	10.5	213	251	460
Hay	8.8	110	380	610
Maize grain	13.5	87	28	89
Maize silage	10.4	68	272	432
Molasses	12.0	40	-	-
Oat silage	8.5	71	467	763
Palm Kernel	11.6	170	470	690
Pasture Silage	10.8	141	364	543
Squash	12.0	159	200	289
Turnips	12.5	180	225	400

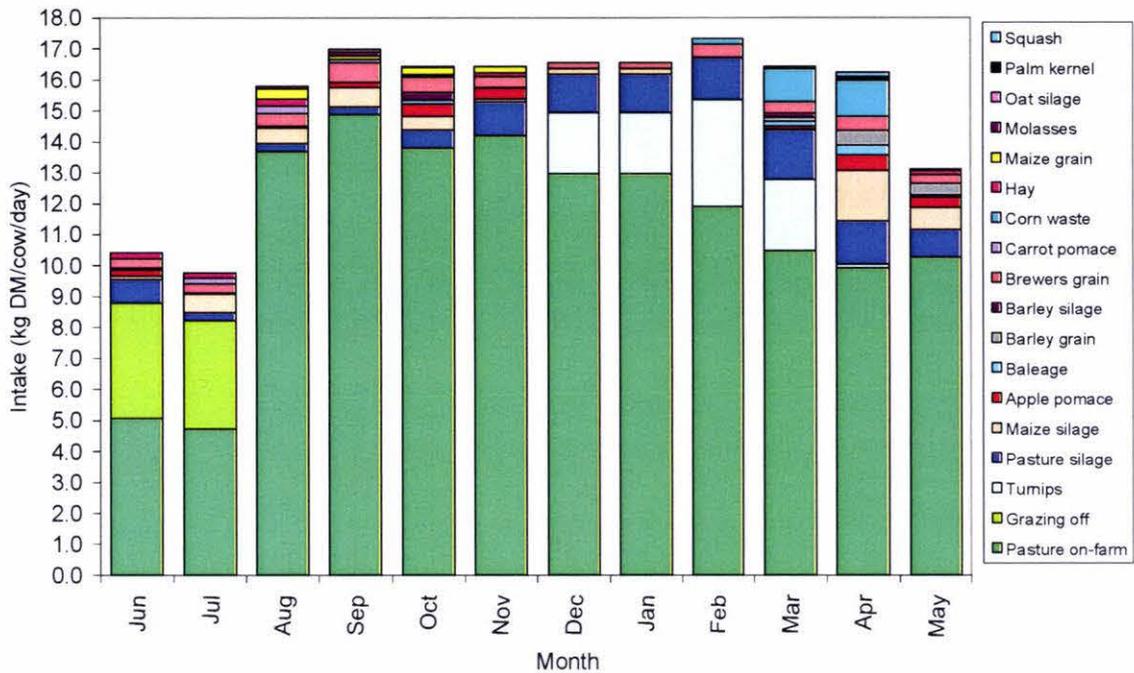


Figure 5.6 Average daily intake per cow for all farms (kg DM/cow/day) by milkers (Aug to May) and dry cows (Jun and Jul), for the season 2000/2001.

5.1.6. Liveweight and condition score

The cows were weighed and condition scored four times during the year: late September (peak of production), late November (after peak of production), mid March (intermediate period) and late May/early June (drying off date). The average liveweight and condition score for all farms for the whole period were 487 kg and 4.4, respectively. Measurements of liveweight and condition score for each farm are illustrated in Appendix 5.6.

5.2. BIOLOGICAL DATA FOR THE WHOLE LACTATION

5.2.1. Milksolids production

The mean annual milksolids production for all case study farms in the season 2000/2001 was 401 and 1,070 kg per cow and per hectare, respectively (Table 5.4). The mean annual milk yield for the same season were 4,713 and 12,585 litres per cow and per hectare, respectively (Table 5.4). The average annual milksolids concentration among all case study farms was approximately 85 grams per litre of milk.

The mean peak daily production per cow for all farms were 2.06 kg of milksolids and 24.5 litres of milk (Table 5.4). The milksolids production curve and the number of milkers throughout the whole season are illustrated for individual farms in Appendix 5.7.

5.2.2. Feed consumption

The annual feed intake per cow and per hectare, by milkers plus dry cows, are described in Figure 5.7. Total feed intake, pasture intake and milksolids production for the whole season for each farm are illustrated in Appendix 5.8.

The average annual pasture intake for all farms represented 75% (72% to 78%) and 76% (73% to 79%) of total annual feed consumed by all cows, as dry matter and metabolisable energy intake, respectively. The remaining dry matter and metabolisable energy intakes consisted of different types of supplements. Appendix 5.5 shows the proportion of each feed included in the total intake for individual farm.

Table 5.4 Annual milksolids production and annual milk yield, both per cow and per hectare, lactation days and daily peak production per cow for each farm (season 2000/2001).

	Farms											
	Mean	Max	Min	1	2	3	4	5	6	7	8	9
Milksolids production per cow (kg/cow/year)	401	432	372	424	390	432	410	424	421	401	421	372
Milksolids production per hectare (kg/ha/year)	1,070	1,264	921	1,135	921	1,155	1,070	1,206	1,002	1,064	1,264	1,082
Peak daily production (kg/cow/day) ¹	2.06	2.26	1.92	2.05	2.03	2.26	2.18	1.92	1.94	1.97	2.19	2.02
Milk yield per cow (litres/cow/year)	4,713	5,267	4,299	5,267	4,371	5,013	4,732	5,165	4,655	4,919	4,829	4,299
Milk yield per hectare (litres/ha/year)	12,585	14,701	10,316	14,094	10,316	13,396	12,365	14,701	11,065	13,056	14,487	12,502
Peak daily production (litres/cow/day) ¹	24.5	26.0	22.3	25.3	22.9	26.0	25.7	24.5	22.3	24.4	25.7	23.8
Lactation days per cow	258	278	235	278	266	273	249	268	264	250	253	235

¹ The daily peak of production was assumed as the highest production per cow after calving. However, for farms 3 and 4, it was assumed the second highest production per cow, when 70% of the herd had calved.

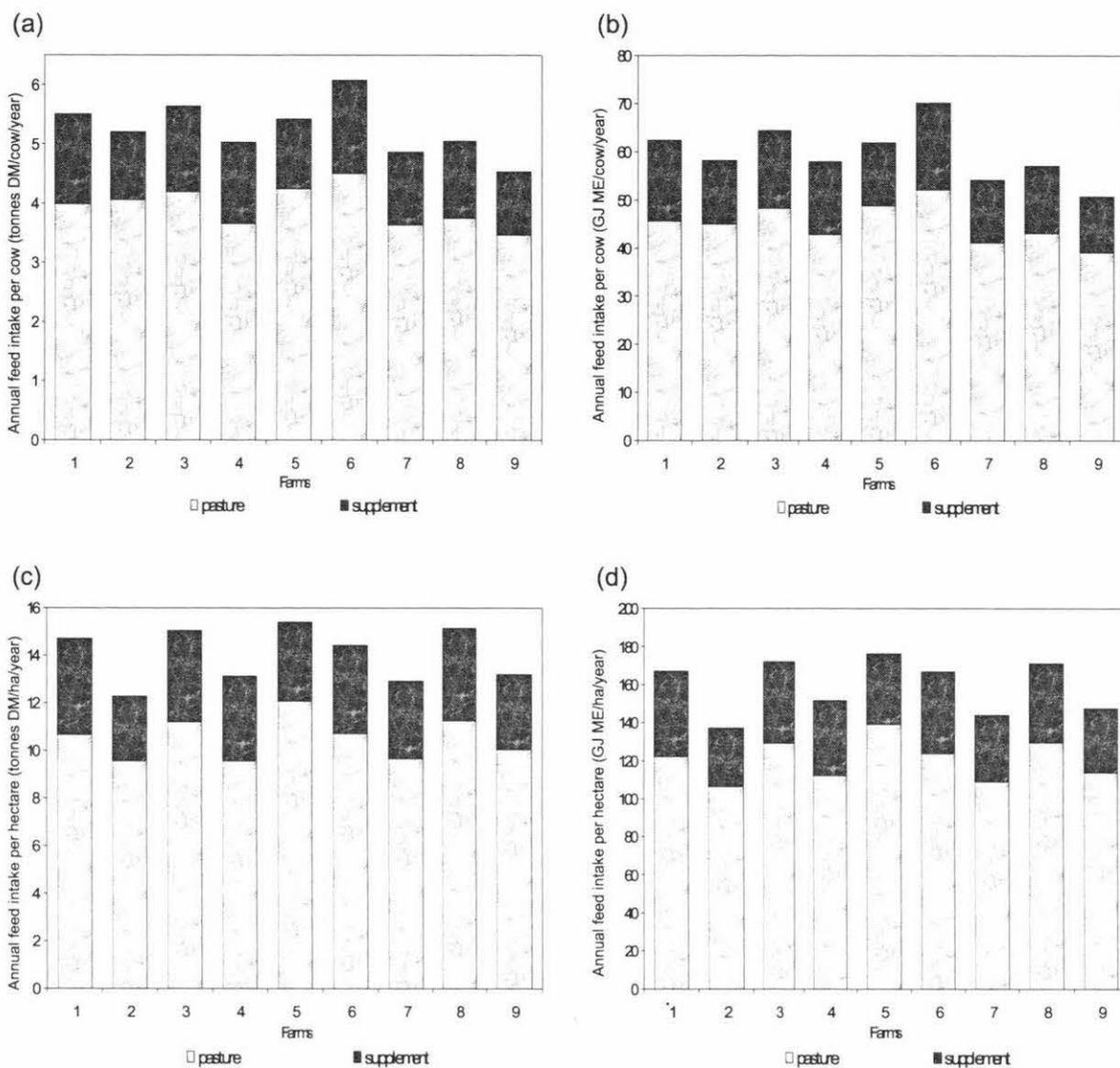


Figure 5.7 Annual feed intake per cow and per hectare, by milkers plus dry cows, expressed in dry matter (a and c) and metabolisable energy (b and d), for each farm (season 2000/2001).

5.2.3. Feed conversion efficiency

Feed conversion efficiency values (FCE) calculated for all cows and feed conversion efficiency calculated for milkers only for each farm are described in Figure 5.8. As expected, FCE calculated for the milkers only showed higher values than FCE calculated for all cows, because the latter included feed intake by dry animals.

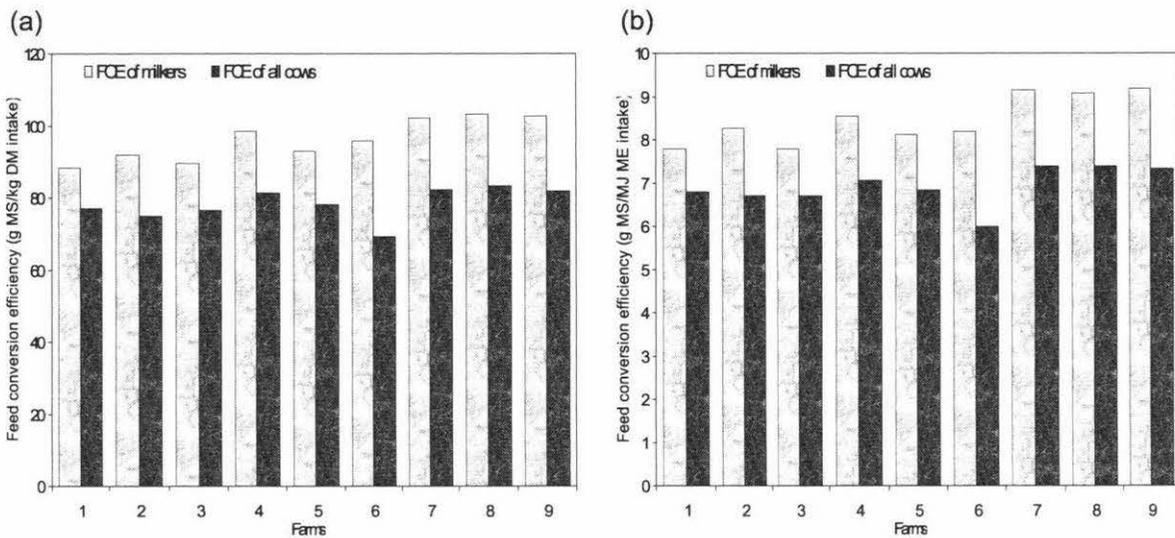


Figure 5.8 Feed conversion efficiency of all cows and feed conversion efficiency of milkers, expressed in dry matter intake (DM) (a) and metabolisable energy intake (ME) (b), for each farm (season 2000/20001).

5.3. FACTORS ASSOCIATED WITH MILK PRODUCTION AND FEED CONVERSION EFFICIENCY FOR THE WHOLE LACTATION

5.3.1. Dependent (y) and predictor (x) variables

The variables analysed in this section were described previously and represent the whole lactation for the season 2000/2001 (1st June 2000 to 31st May 2001). Most farms showed a period when all cows were dry. Therefore, it was also important to determine the influence of non-lactating animals in the whole system. Four dependent

variables (Table 5.5) and fifteen predictor variables (Table 5.6) were used for statistical analysis.

Table 5.5 Dependent variables analysed in the whole lactation.

Variable	Description	Section
MS/C	Annual milk solids production per cow (kg/cow/year)	4.4.5.8
MS/H	Annual milk solids production per hectare (kg/ha/year)	4.4.5.8
FCE(ME)md	Feed conversion efficiency of all cows (g MS/MJ ME total ¹ intake by all cows ²)	4.4.5.10
FCE(ME)m	Feed conversion efficiency of milkers (g MS/MJ ME total ¹ intake by milkers)	4.4.5.10

¹ total intake = pasture plus supplements; ² all cows = milkers plus dry cows.

Table 5.6 Predictor variables analysed in the whole lactation.

Variable	Description	Section
PME/Cmd	Annual pasture ME intake per animal by all cows ¹ (MJ ME/cow/year)	4.4.5.3
PME/Cm	Annual pasture ME intake per animal by milkers (MJ ME/cow/year)	4.4.5.3
PME/Hmd	Annual pasture ME intake per hectare by all cows (MJ ME/ha/year)	4.4.5.3
PME/Hm	Annual pasture ME intake per hectare by milkers (MJ ME/ha/year)	4.4.5.3
SME/Cmd	Annual supplement ME intake per animal by all cows (MJ ME/cow/year)	4.4.5.4
SME/Cm	Annual supplement ME intake per animal by milkers (MJ ME/cow/year)	4.4.5.4
SME/Hmd	Annual supplement ME intake per hectare by all cows (MJ ME/ha/year)	4.4.5.4
SME/Hm	Annual supplement ME intake per hectare by milkers (MJ ME/ha/year)	4.4.5.4
TME/Cmd	Annual total ² ME intake per animal by all cows (MJ ME/cow/year)	4.4.5.6
TME/Cm	Annual total ME intake per animal by milkers (MJ ME/cow/year)	4.4.5.6
TME/Hmd	Annual total ME intake per hectare by all cows (MJ ME/cow/year)	4.4.5.6
TME/Hm	Annual total ME intake per hectare by milkers (MJ ME/cow/year)	4.4.5.6
SR	Stocking rate (cows/ha)	4.4.5.1
LD/C	Lactation days per cow (days)	4.4.5.9
LD/H	Lactation days per hectare (days)	4.4.5.9
PREHMm	Pre grazing herbage mass of milkers (kg DM/ha)	
PREHMd	Pre grazing herbage mass of dry cows (kg DM/ha)	
POSHMm	Post grazing herbage mass of milkers (kg DM/ha)	
POSHMd	Post grazing herbage mass of dry cows (kg DM/ha)	

¹ all cows = milkers plus dry cows; ² total intake = pasture plus supplements

The statistical analyses were based on linear regressions, because the number of points did not justify a more complex analysis. However, in the particular situation of feed conversion efficiency of all cows, the quadratic regression between annual total intake per animal by milkers plus dry cows (TME/Cmd) and annual milksolids production per cow (MS/C) was used (Figure 5.13). The same applied for feed conversion efficiency of milkers, which showed the quadratic regression between annual total intake per animal by milkers (TME/Cm) and annual milksolids production per cow (MS/C) (Figure 5.16). Both graphs are the base of further discussion in Section 6.3.4.4.

5.3.2. Correlation matrix

The simple correlation values of the linear relationship between all the variables analysed for the whole lactation are illustrated in Table 5.7, Table 5.8, Appendix 5.9 and Appendix 5.10.

Table 5.7 Pearson correlation (r) matrix between pairs of dependent variables (y) and between predictor (x) and dependent variables.

Predictor variables	Dependent variables			
	MS/C	MS/H	FCE(ME)md	FCE(ME)m
MS/H	0.524			
FCE(ME)md	-0.391	0.401		
FCE(ME)m	-0.632	0.043	0.730*	
LD/C	0.720*	0.063	-0.624	-0.808**
LD/H	0.507	0.925***	0.304	-0.168
SR	-0.005	0.843**	0.730*	0.461
PREHMm	0.787*	0.411	-0.406	-0.688*
POSHMm	-0.052	-0.167	0.152	-0.081
PREHMd	0.438	0.500	0.269	-0.291
POSHMd	0.179	-0.088	-0.474	-0.256

*p < 0.05, **p < 0.01, ***p < 0.001. The Pearson correlation (r) value squared equals R² showed in the regression analysis.

The intake variables were expressed either as total (pasture plus supplements) or partial intake (pasture and supplement as components of the total intake). For all the dependent variables (MS/C, MS/H, FCE (ME)md and FCE(ME)m) a simple regression equation using total ME intake variables was calculated. Similarly, multiple regressions were produced for the dependent variables. However, to calculate the multiple regression equations, the partial variables were used with the purpose of determining the relation between pasture, supplement and dependent variables.

Table 5.8 Pearson correlation (r) matrix between the variables pasture, supplement and total intake (x) with the dependent variables (y).

	Dependent variables			
	MS/C	MS/H	FCE(ME)md	FCE(ME)m
Partial ME intake variables				
PME/Cmd	0.706*	-0.025	-0.898**	-0.771*
PME/Cm	0.845*	0.395	-0.582	-0.830**
PME/Hmd	0.732*	0.763*	-0.246	-0.406
PME/Hm	0.694*	0.860**	0.020	-0.402
SME/Cmd	0.707*	-0.056	-0.711*	-0.653
SME/Cm	0.507	-0.223	-0.478*	-0.721*
SME/Hmd	0.831**	0.497	-0.335	-0.490
SME/Hm	0.704*	0.372	-0.261	-0.737*
Total ME intake variables				
TME/Cmd	0.756*	-0.038	-0.894**	-0.783*
TME/Cm	0.862**	0.221	-0.664	-0.935***
TME/Hmd	0.840**	0.752*	-0.301	-0.475
TME/Hm	0.799*	0.804*	-0.087	-0.556

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. The Pearson correlation (r) value squared equals R^2 showed in the regression analysis.

5.3.3. Milksolids production per cow

All the intake predictor variables were highly correlated to milksolids production per cow (Table 5.8). The values for total annual ME intake per cow by the milkers only showed the highest relationship with MS/C (Table 5.8). PME/Cm and SME/Hmd had the highest correlation with MS/C, among the pasture and supplement ME intake variables, respectively (Table 5.8). However, biological principles suggested that annual ME intake per animal by the milkers only (PME/Cm, SME/Cm and TME/Cm) was more likely to explain the variation in annual milksolids production per cow. Consequently, only annual ME intake per animal of milkers was used in the simple and multiple regression analyses. Figure 5.9 shows the simple linear regression for the variables MS/C and TME/Cm. For the multiple linear regressions (see Section 5.3.3.1), the partial ME intake variables were utilised.

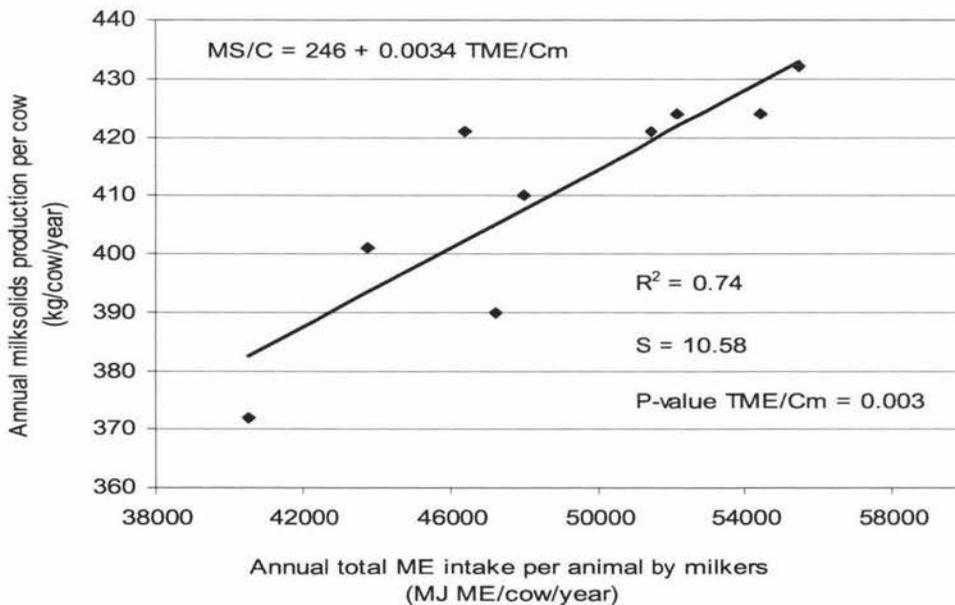


Figure 5.9 Simple linear regression for the variables MS/C and TME/Cm.

5.3.3.1. Addition of predictor variables

Among the partial intake variables (Table 5.8), PME/Cm showed the highest correlation with MS/C. Therefore, it was the first variable (x_1) included in the model, as follows:

$$\text{MS/C} = 248 + 0.00423 \text{ PME/Cm} \quad \text{Equation 5.1}$$

Where:

$$\begin{array}{ll} R^2 & = 0.71 \\ S & = 11.13 \\ \text{P-value PME/Cm} & 0.004 \end{array}$$

To improve the accuracy of the regression, other predictor variables (PREHMm, LD/C and SME/Cm) were added individually to Equation 5.1, following the decision criteria described in Section 4.5.1. However, the F test showed no other predictor variable to be statistically significant, after x_1 was added. Nevertheless, due to the emphasis given to analyses of supplementary feed in the present work, SME/Cm was added to Equation 5.1, as follows:

$$\text{MS/C} = 241 + 0.00381 \text{ PME/Cm} + 0.00218 \text{ SME/Cm} \quad \text{Equation 5.2}$$

Where:

$$\begin{array}{ll} R^2 & = 0.76 \\ S & = 11.11 \\ \text{P-value PME/Cm} & = 0.013 \\ \text{P-value SME/Cm} & = 0.349 \\ \text{P-value of regression} & = 0.014 \\ \text{Seq SS PME/Cm} & = 2173 \\ \text{Seq SS SME/Cm} & = 127 \end{array}$$

5.3.4. Milksolids production per hectare

Intake predictor variables (total and partial) were also highly correlated to milksolids production per hectare (Table 5.8). Annual total ME intake per hectare by milkers only showed the highest correlation with MS/H (Table 5.8). PME/Hm and SME/Hmd had the highest correlation with MS/H, among the pasture and supplement ME intake variables, respectively (Table 5.8). However, biological principles suggested that annual ME intake per hectare by milkers only (PME/Hm, SME/Hm and TME/Hm) was more likely to explain the variation in annual milksolids production per hectare. Consequently, only annual ME intake of milkers per hectare were used in the simple and multiple regression analyses. Figure 5.10 shows the simple linear regression for the variables MS/H and TME/Hm. For the multiple linear regressions (see Section 5.3.4.1), the partial intake variables were utilised.

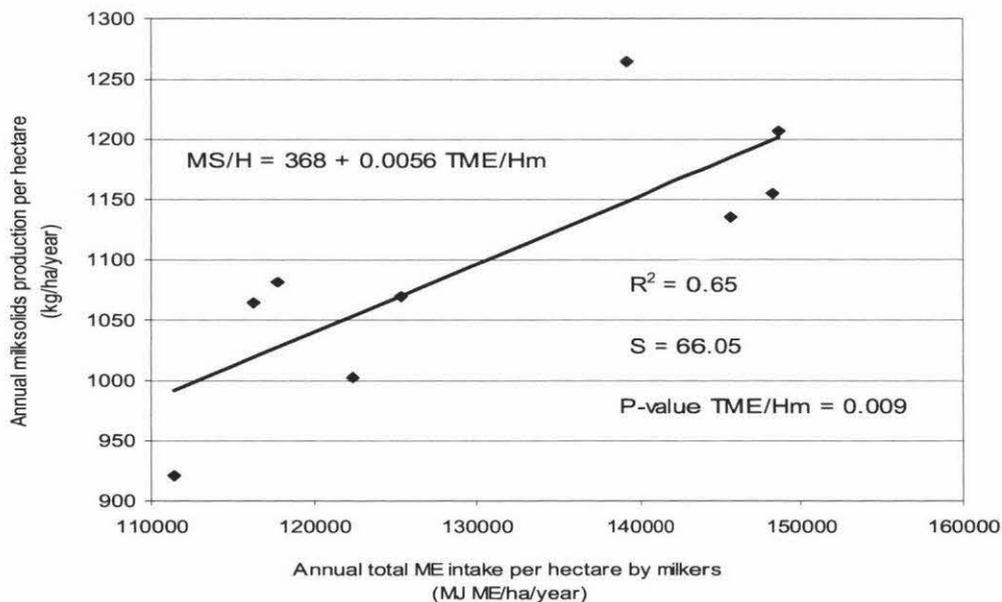


Figure 5.10 Simple linear regression for the variables MS/H and TME/Hm.

5.3.4.1. Addition of predictor variables

The three predictor variables showing the best correlation with MS/H were LD/H, PME/Hm and SR (Table 5.8 and Table 5.7). Even though PME/Hm had the second highest correlation with MS/H, it was included as the first predictor variable (x_1) in the model, due to its probable major biological effect on milksolids production per hectare. The simple linear equation of MS/H on PME/Hm is as follows:

$$\text{MS/H} = 403 + 0.00677 \text{ PME/Hm} \quad \text{Equation 5.3}$$

Where:

$$\begin{aligned} R^2 &= 0.74 \\ S &= 56.82 \\ \text{P-value PME/Cm} &= 0.003 \end{aligned}$$

Five other predictor variables (LD/H, SR, PREHMd, PREHMm and SME/Hm) were included individually in the model as the second predictor variable (x_2), following the decision criteria described in Section 4.5.1. However, the F test showed that SR was the only predictor variable that explained a significant additional amount of the variation of the regression, as follows:

$$\text{MS/H} = - 84 + 0.00444 \text{ PME/Hm} + 270 \text{ SR} \quad \text{Equation 5.4}$$

Where:

$$\begin{aligned} R^2 &= 0.93 \\ S &= 31.89 \\ \text{P-value PME/Cm} &= 0.005 \\ \text{P-value SR} &= 0.007 \\ \text{P-value of regression} &= 0.000 \end{aligned}$$

No other significant predictor variable could be added to the model, after x_1 and x_2 were included. However, due to the importance of supplement analysis in the current work, SME/Hm was added to Equation 5.4, despite its small contribution to explain the variation in MS/H, as follows:

$$\text{MS/H} = -170 + 0.00347 \text{ PME/Hm} + 0.00289 \text{ SME/Hm} + 309 \text{ SR} \quad \text{Equation 5.5}$$

Where:

R^2	=	0.94
S	=	32.40
P-value PME/Hm	=	0.070
P-value SME/Hm	=	0.409
P-value SR	=	0.012
P-value of regression	=	0.002
Seq SS PME/Hm	=	63947
Seq SS SME/Hm	=	1878
Seq SS SR	=	15437

5.3.5. Feed conversion efficiency of all cows (g MS/MJ ME intake by all cows)

PME/Cmd and SME/Cmd showed the highest correlation with the dependent variable FCE (ME)md, among the pasture and supplement ME intake variables, respectively (Table 5.8). Among the total ME intake variables, TME/Cmd showed the highest correlation with FCE (ME)md (Table 5.8). Figure 5.11 shows the simple linear regression for the variables FCE (ME)md and TME/Cmd, Figure 5.12 shows the simple linear regression between the variables FCE (ME)md and MS/C and Figure 5.13 shows the quadratic regression between the variables MS/C and TME/Cmd. For the multiple linear regressions (see Section 5.3.5.1), the partial intake variables were utilised.

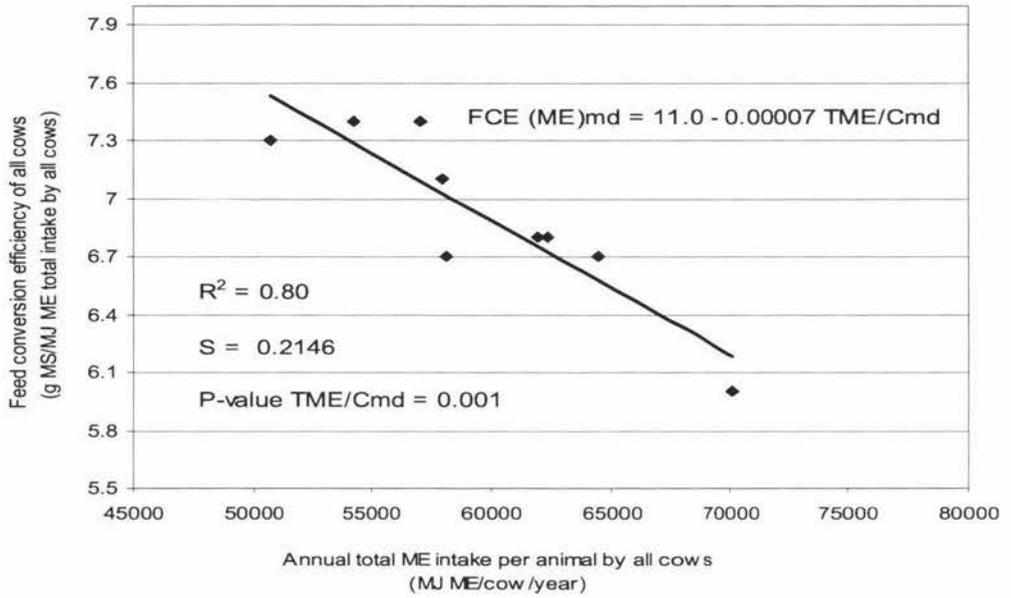


Figure 5.11 Simple linear regression for the variables FCE (ME)md and TME/Cmd.

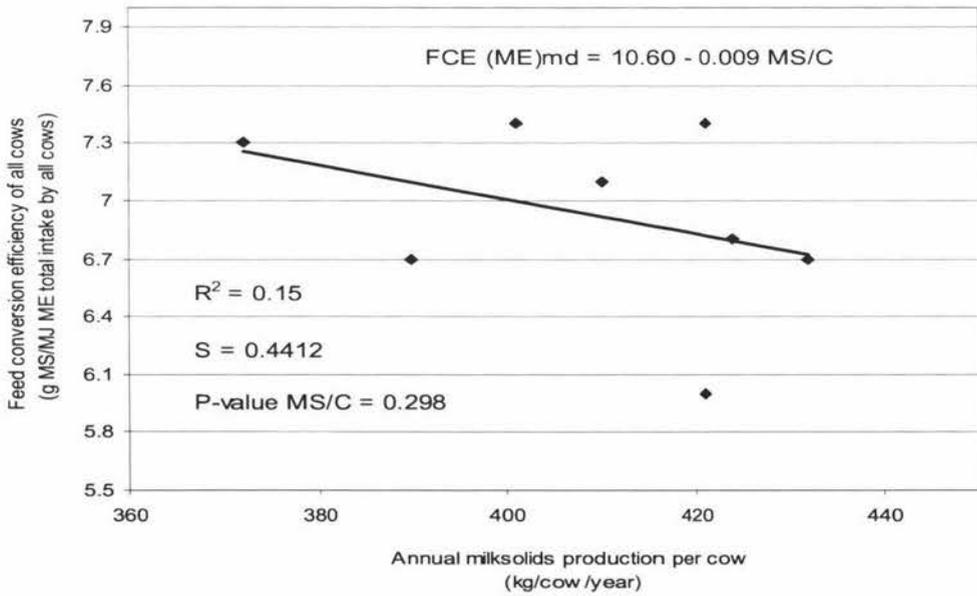


Figure 5.12 Simple linear regression for the variables FCE (ME)md and MS/C.

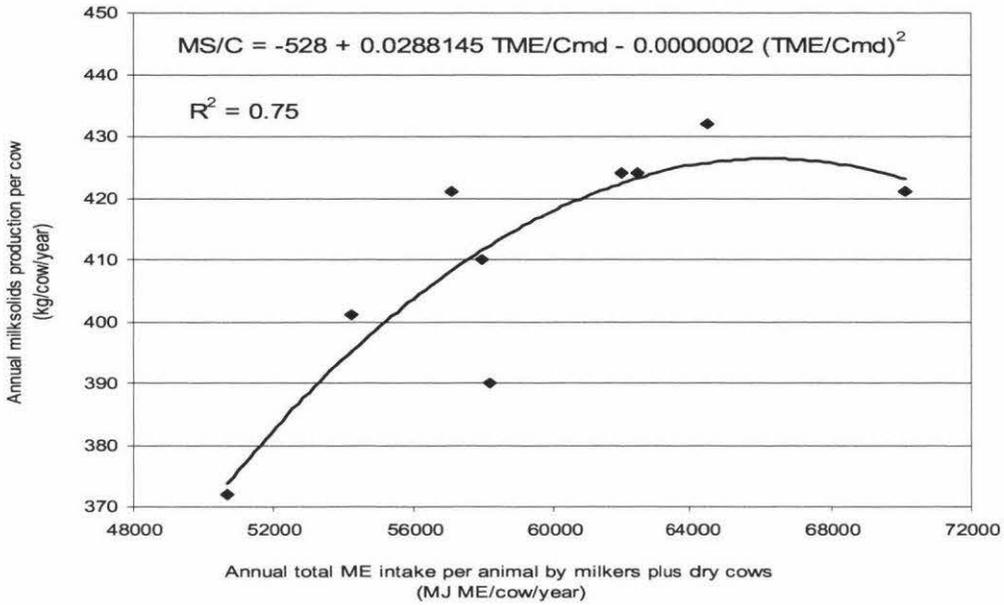


Figure 5.13 Quadratic regression for the variables MS/C and TME/Cmd

5.3.5.1. Addition of predictor variables

The eight variables illustrating the highest correlation with FCE(ME)md were PME/Cmd, SR, SME/Cmd, LD/C, POSHMd, PREHMm MS/H and MS/C. PME/Cmd was the first variable (x_1) considered to explain the variation of the dependent variable FCE(ME)md because it had the highest correlation with FCE(ME)md, as follows:

$$FCEmd (ME) = 11.3 - 0.000098 \text{ PME/Cmd} \quad \text{Equation 5.6}$$

Where:

$$\begin{aligned}
 R^2 &= 0.81 \\
 S &= 0.2111 \\
 \text{P-value PME/Cmd} &= 0.001
 \end{aligned}$$

The variables MS/H, MS/C and SR explained a significant additional amount of the variation of the regression, after x_1 was included. However, only when MS/C was included as the second predictor variable, SME/Cmd (x_3) explained a significant amount of the variation of the regression, as follows:

$$\text{FCE (ME)md} = 8.45 - 0.000135 \text{ PME/Cmd} + 0.0111 \text{ MS/C} \quad \text{Equation 5.7}$$

Where:

R^2	=	0.92
S	=	0.1436
P-value PME/Cmd	=	0.000
P-value MS/C	=	0.023
P-value of regression	=	0.000

$$\begin{aligned} \text{FCE (ME)md} = 7.30 - 0.000116 \text{ PME/Cmd} + 0.0149 \text{ MS/C} - \\ 0.000089 \text{ SME/Cmd} \end{aligned} \quad \text{Equation 5.8}$$

Where:

R^2	=	0.99
S	=	0.0487
P-value PME/Cmd	=	0.000
P-value MS/C	=	0.000
P-value SME/Cmd	=	0.001
P-value of regression	=	0.000
Seq SS PME/Cmd	=	1.29701
Seq SS MS/C	=	0.18813
Seq SS SME/Cmd	=	0.11189

No other predictor variable was significant to be included in the model, after x_1 , x_2 and x_3 were added.

5.3.6. Feed conversion efficiency of milkers (g MS/MJ ME intake by milkers)

PME/Cm and SME/Cm showed the highest correlations with the dependent variable FCE (ME)m, among the pasture and supplement ME intake variables, respectively (Table 5.8). Among the total ME intake variables, TME/Cm showed the highest correlation with FCE (ME)m (Table 5.8). Figure 5.14 shows the simple linear regression for the variables FCE (ME)m and TME/Cm, Figure 5.15 shows the simple linear regression between the variables FCE (ME)m and MS/C and Figure 5.16 shows the quadratic regression between the variables MS/C and TME/Cm. For the multiple linear regressions (see Section 5.3.6.1), the partial ME intake variables were utilised.

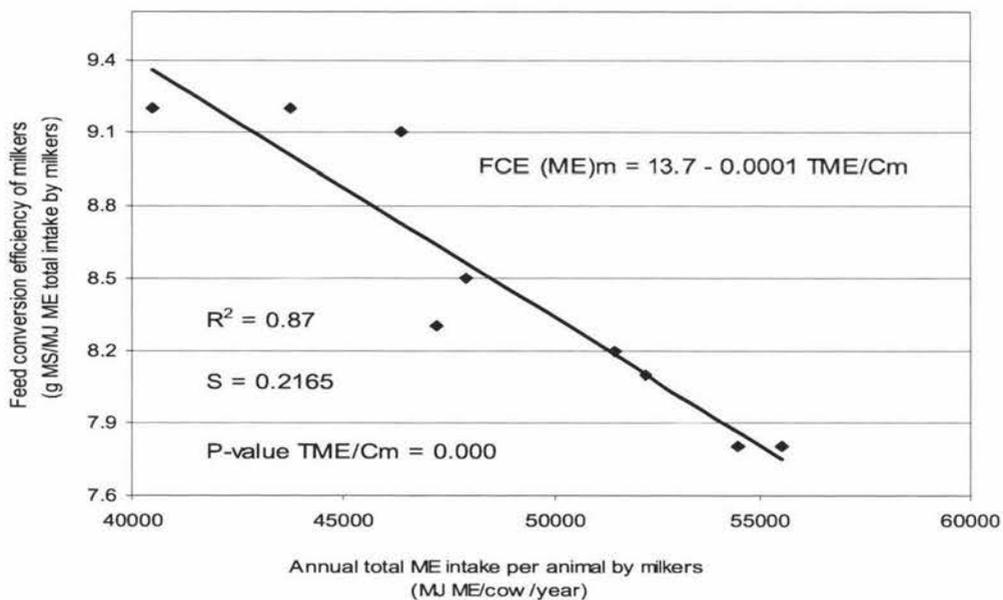


Figure 5.14 Simple linear regression for the variables FCE (ME)m and TME/Cm.

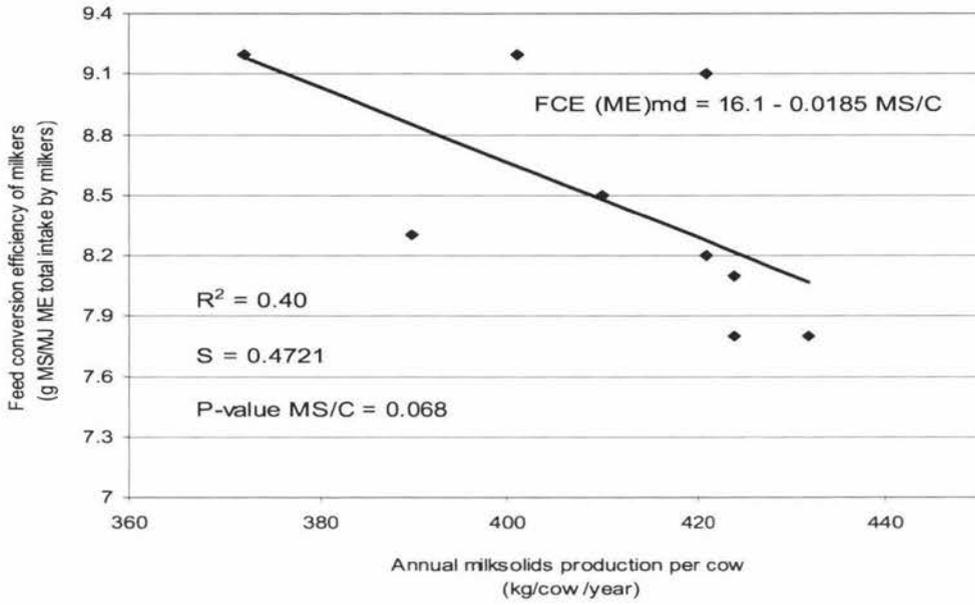


Figure 5.15 Simple linear regression for the variables FCE (ME)m and MS/C.

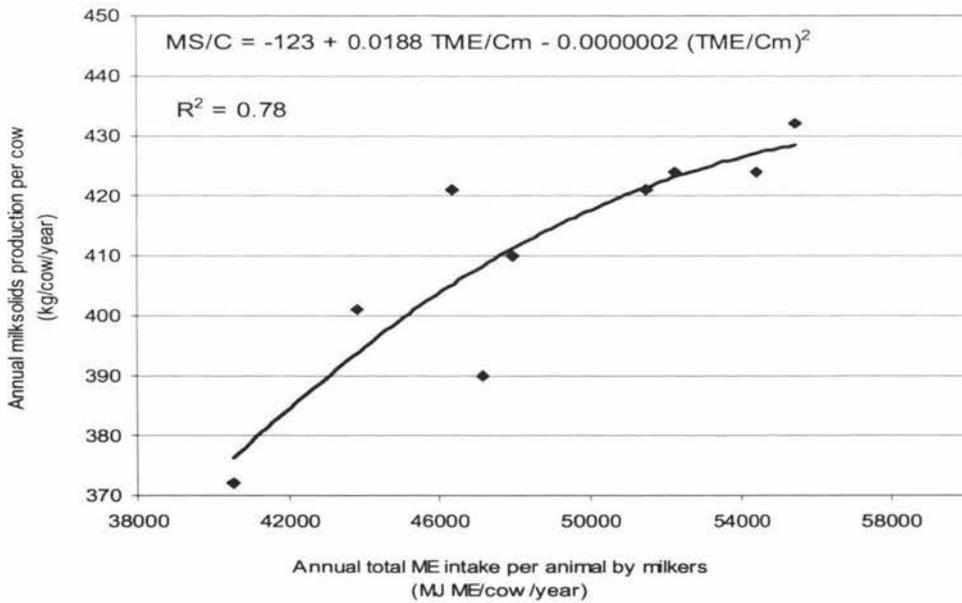


Figure 5.16 Simple quadratic regression for the variables MS/C and TME/Cm.

5.3.6.1. Addition of predictor variables

The five variables showing the best correlations with FCE(ME)_m were PME/C_m, LD/C, SME/C_m, PREHM_m and MS/C (Table 5.8 and Table 5.7). PME/C_m showed the highest relationship with FCE (ME)_m, therefore it was included first in the model.

$$\text{FCE (ME)}_m = 13.1 - 0.000121 \text{ PME/C}_m \quad \text{Equation 5.9}$$

Where:

$$\begin{aligned} R^2 &= 0.69 \\ S &= 0.3395 \\ \text{P-value SME/C}_m &= 0.006 \end{aligned}$$

SME/H_m was the only variable that explained a significant additional amount of the variation of the regression, after x_1 was included, as follows:

$$\text{FCE (ME)}_m = 13.6 - 0.000095 \text{ PME/C}_m - 0.000138 \text{ SME/C}_m \quad \text{Equation 5.10}$$

Where:

$$\begin{aligned} R^2 &= 0.88 \\ S &= 0.2230 \\ \text{P-value PME/C}_m &= 0.005 \\ \text{P-value SME/C}_m &= 0.019 \\ \text{P-value of regression} &= 0.002 \end{aligned}$$

Four other variables (LD/C, PREHM_m, SR and MS/C) were included individually in the model as the third predictor variable (x_3), following the decision criteria described in Section 4.5.1. However, MS/C was the only one that added a significant amount to explain the variation of the regression, as follows:

$$\text{FCE (ME)}_m = 8.92 - 0.000168 \text{ PME/Cm} - 0.000180 \text{ SME/Cm} + 0.0192 \text{ MS/C} \quad \text{Equation 5.11}$$

Where:

R^2	=	0.99
S	=	0.0705
P-value PME/Cm	=	0.000
P-value SME/Cm	=	0.000
P-value MS/C	=	0.001
P-value of regression	=	0.000
Seq SS PME/Cm	=	1.79315
Seq SS SME/Cm	=	0.50848
Seq SS MS/C	=	0.27352

No other predictor variable was significant to be included in the model, after x_1 , x_2 and x_3 were added.

5.4. BIOLOGICAL DATA FOR PART LACTATION

The lactation for the season 2000/2001 was divided into two parts. The first part was from the first day of lactation for each farm up to 31st of December. The second part was from 1st of January to the last day of lactation for each farm. This division coincided with a major change in supplement use in most farms, from strategic to broad use (Appendix 5.8).

5.4.1. Milksolids production

The mean milksolids production for all farms were 238 and 166 kg per cow and 639 and 444 kg per hectare for the first and second part of lactation, respectively (Table 5.9). Average milk yield for all farms were 2864 and 1872 kg per cow and 7692 and 5008 kg per hectare, for the first and second part of lactation, respectively (Table 5.9).

5.4.2. Feed consumption

The feed intake per cow and per hectare by milkers, for the first and second parts of lactation are described in Figure 5.17 and Figure 5.18, respectively.

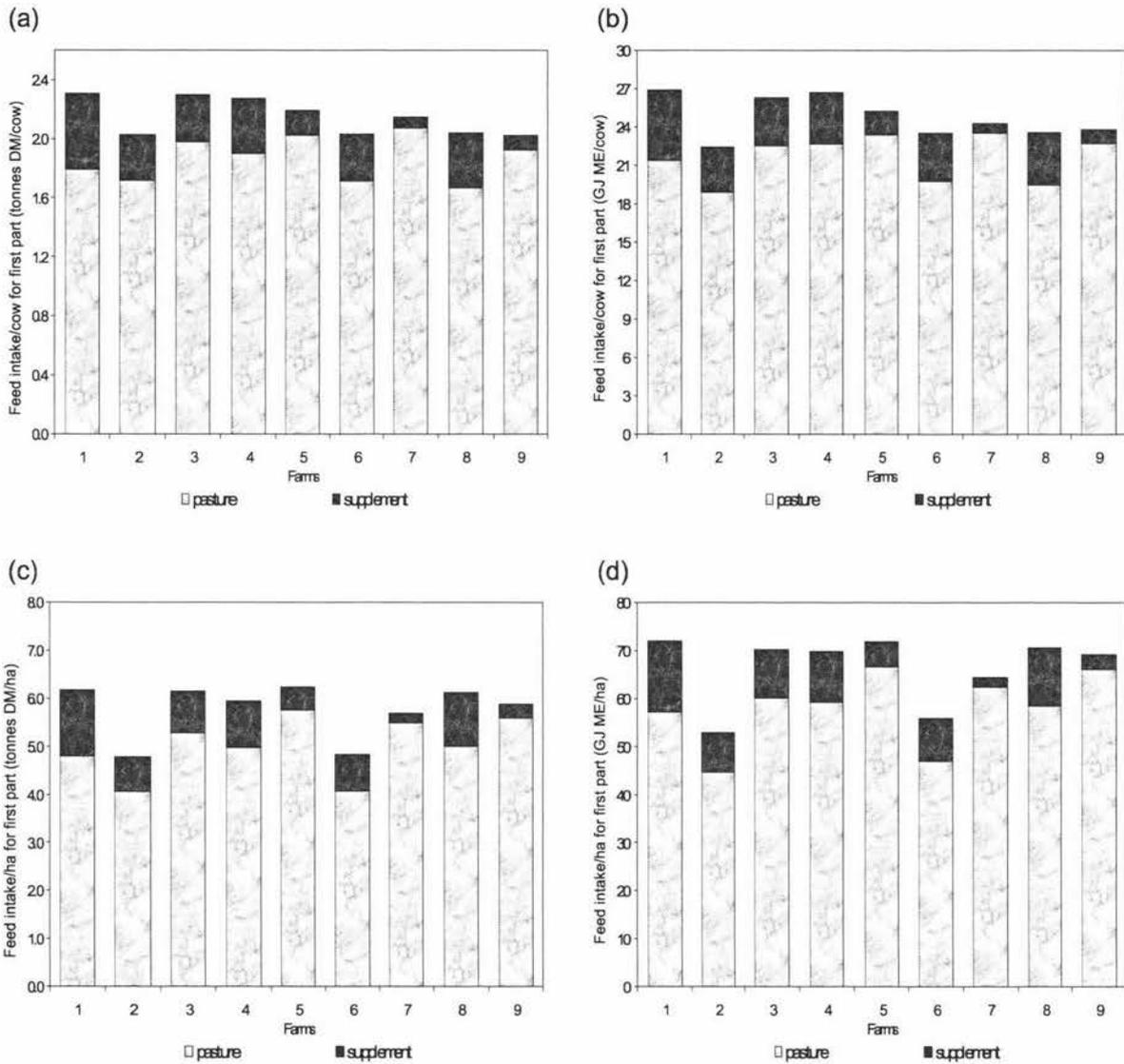


Figure 5.17 Feed intake per cow and per hectare by milkers for the first part of lactation, expressed in dry matter (a and c) and metabolisable energy (b and d), for each farm (season 2000/2001).

Average pasture intake on all farms represented 87% of total feed consumed in the first part of lactation, for both dry matter and metabolisable energy. In the second part of lactation, average of pasture intake for all farms represented 69% and 68% of total feed consumed for dry matter and metabolisable energy, respectively. The remaining dry matter and metabolisable energy intakes consisted of different types of supplements.

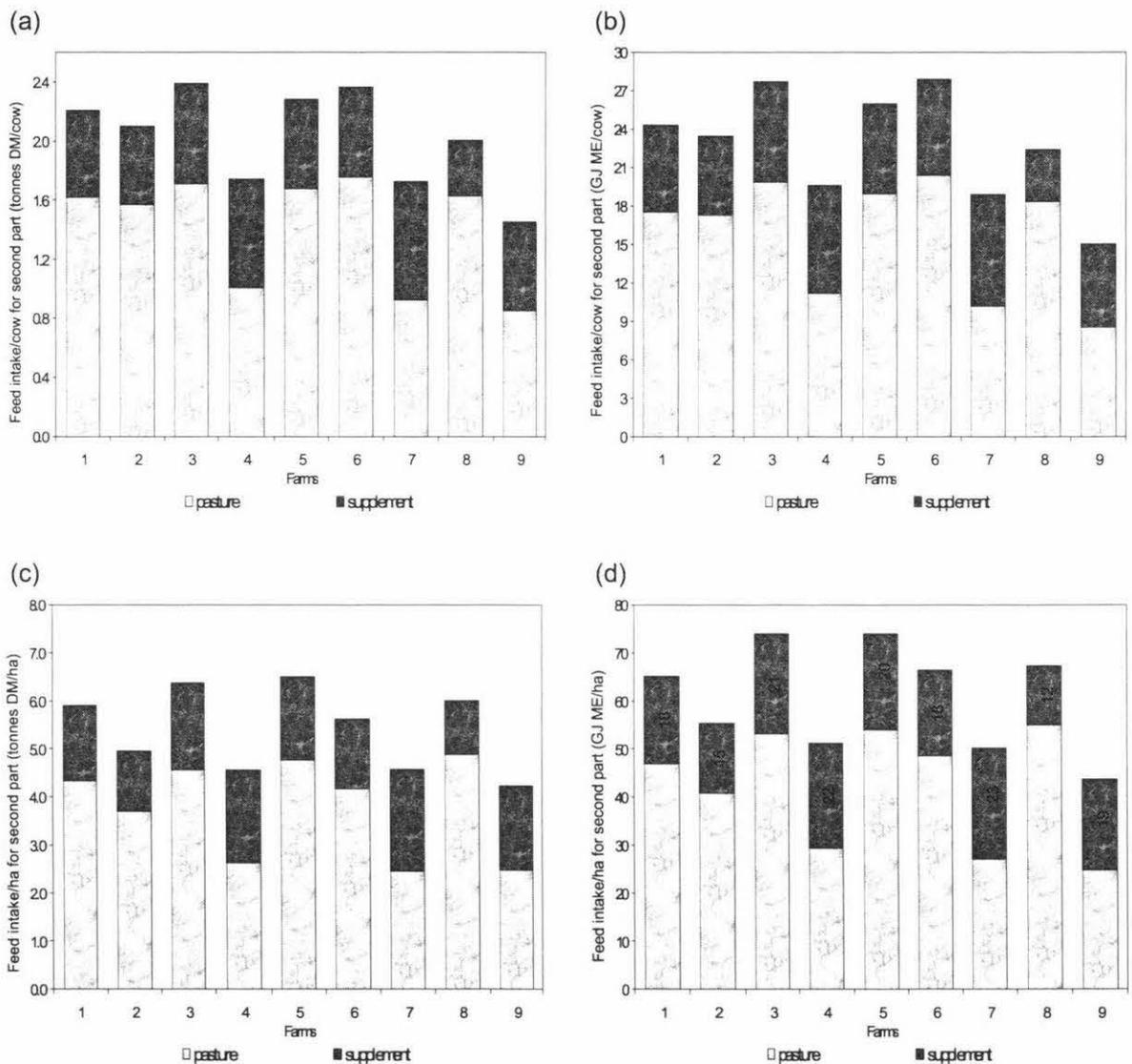


Figure 5.18 Feed intake per cow and per hectare by milkers for the second part of lactation, expressed in dry matter (a and c) and metabolisable energy (b and d), for each farm (season 2000/2001).

Table 5.9 Milksolids production and milk yield per cow and per hectare for the first and second part of lactation, for each farm (season 2000/2001).

	Farms											
	Mean	Max	Min	1	2	3	4	5	6	7	8	9
FIRST PART OF LACTATION												
Calving date				20-Jul	4-Aug	1-Aug	27-Jul	4-Aug	13-Aug	3-Aug	4-Aug	27-Aug
Period length (days)	152	164	140	164	149	152	157	149	140	150	149	157
Milksolids production per cow (kg/cow)	238	259	220	236	220	254	259	237	222	239	246	229
Milksolids production per hectare (kg/ha)	639	737	520	633	520	678	676	676	528	633	737	667
Milk yield per cow (litres/cow)	2,864	3,050	2,549	3,019	2,557	3,002	3,050	2,966	2,549	2,999	2,903	2,734
Milk yield per hectare (litres/ha)	7,692	8,709	6,035	8,079	6,035	8,022	7,970	8,442	6,057	7,961	8,709	7,951
SECOND PART OF LACTATION												
Drying off date				31-May	31-May	31-May	4-May	31-May	31-May	30-May	31-May	26-May
Period length (days)	146	150	123	150	150	150	123	150	150	149	150	145
Milksolids production per cow (kg/cow)	166	199	131	173	164	172	142	181	199	159	174	131
Milksolids production per hectare (kg/ha)	444	523	371	462	387	460	372	515	474	421	523	380
Milk yield per cow (litres/cow)	1,872	2,139	1,431	2,084	1,752	1,945	1,596	2,139	2,107	1,881	1,913	1,431
Milk yield per hectare (litres/ha)	5,008	6,087	4,135	5,577	4,135	5,198	4,171	6,087	5,007	4,993	5,739	4,162

5.4.3. Feed conversion efficiency

Feed conversion efficiency values (FCE) of milkers for the first and second parts of lactation, for each farm are described in Figure 5.19. FCE for the first part of lactation showed higher values than FCE for the second part of lactation for all farms.

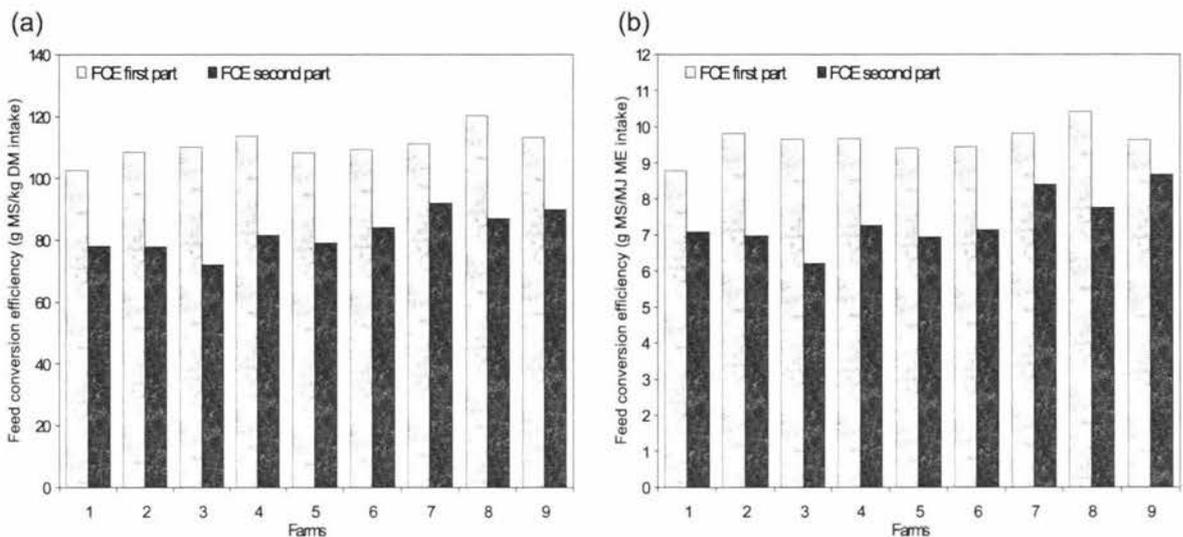


Figure 5.19 Feed conversion efficiency of milkers (MS/total intake by milkers) for the first and second parts of lactation, expressed in dry matter intake (DM) (a) and metabolisable energy intake (ME) (b), for each farm (season 2000/20001).

5.5. FINANCIAL DATA

5.5.1. Cost of production

The cost of production per kg of milksolids (MS) differed between farms. The average cost among all farms was NZ\$3.55/kg MS, ranging from NZ\$3.18 to NZ\$3.83/kg MS. Figure 5.20 shows the cost per kg of milksolids for individual farms and the corresponding entrepreneur's profit for three different prices of milksolids. The milk payment of NZ\$3.4 was based on the average of ten years (1990/91 to 1999/00) (LIC,

2001), the value of NZ\$4.2 is the forecast for the season 2002/2003 and NZ\$5.0 was the milk payment for the season 2000/2001 (LIC, 2001).

The average feed cost per kg of dry matter (DM) and per MJ of metabolisable energy (ME) consumed varied between farms and included the cost of funds. The mean values among all farms were NZ\$0.32/kg DM (NZ\$0.28 to NZ\$0.41) and NZ\$0.03/MJ ME (NZ\$0.02 to NZ\$0.04). Figure 5.21 shows the average cost per kg of dry matter and per MJ of metabolisable energy consumed, for each farm. The denomination “average” cost refers to a mean cost of production of all feed offered, including pasture and supplements. The total cost of production and gross farm income for individual farms are summarised in Appendix 5.11. The same data per effective hectare are illustrated in Appendix 5.12.

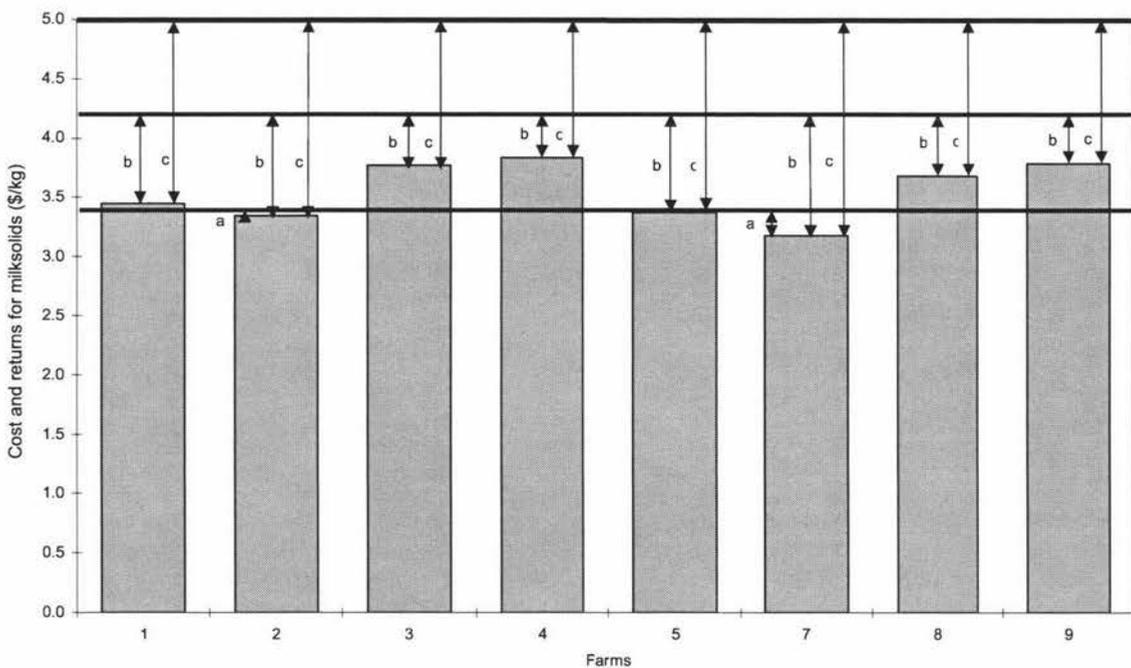


Figure 5.20 Cost per kg of milksolids (bars) for each farm and their respective entrepreneur’s profit for three prices of milksolids (MS): NZ\$3.4/kg MS (a), NZ\$4.2/kg MS (b) and NZ\$5.0/kg MS (c).

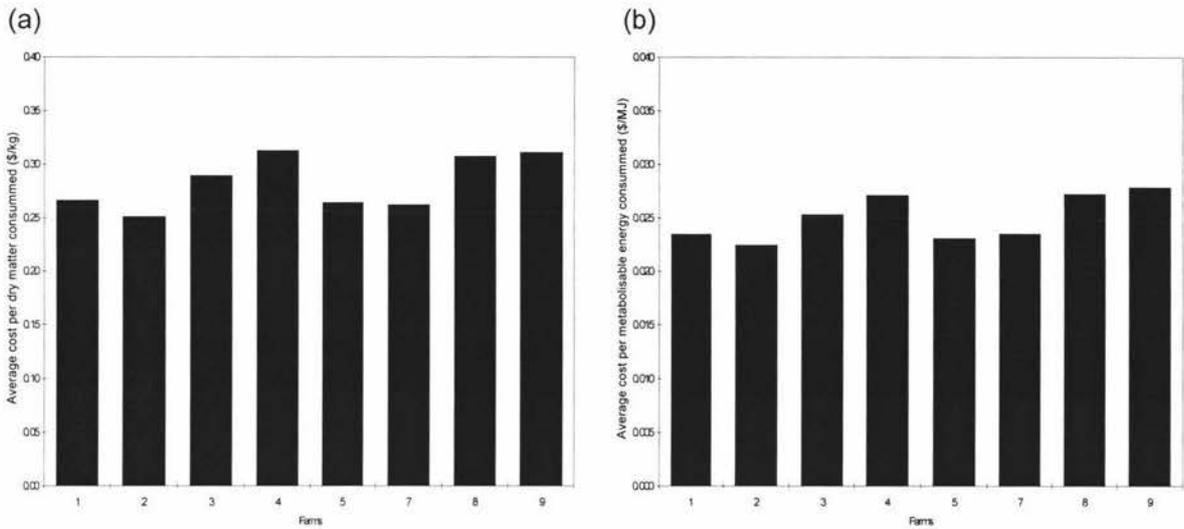


Figure 5.21 Average cost per kg of dry matter (a) and MJ of metabolisable energy (b) consumed, for individual farms.

5.5.2. Key performance indicators

The main financial key performance indicators for each farm are shown in Table 5.10.

Table 5.10 Economic farm surplus per hectare (EFS/H), gross farm income per hectare (GFI/H), return on assets (ROA), operating profit margin (OPM), assets turnover ratio (GFI/A), revenue to labour ratio (GFI/L) and revenue per labour unit (GFI/LU), for the case study farms.

Farms	1	2	3	4	5	7	8	9
EFS/H (NZ\$)	3,114	2,640	2,657	2,425	3,867	3,436	3,206	3,274
GFI/H (NZ\$)	6,260	5,127	5,769	5,342	6,813	6,101	6,344	6,739
ROA (%)	14.2	14.4	13.5	12.7	12.2	13.8	12.6	10.0
OPM (%)	50	52	46	45	57	56	51	49
GFI/A (%)	29	28	29	28	22	24	25	21
GFI/L (NZ\$)	7.8	8.6	8.3	8.9	10.1	9.7	7.9	9.1
GFI/LU (NZ\$)	360,392	267,020	281,503	376,363	354,255	290,675	222,034	293,168

5.5.3. Production function

In the present study, a group production curve was obtained from the quadratic regression between annual milksolids production per hectare (MS/H) and annual total dry matter (DM) intake per hectare by milkers (TDM/Hm), over all farms (Figure 5.22). It is acknowledged that the sample size is small and that each farm will have its own production curve, so not too much can be extrapolated from the group production curve. Its presentation here is to illustrate how a regression equation can be used to determine an economic level of efficiency. For this group of eight farms the differences in their feed conversion efficiency, their position on the group production curve and their profitability are useful indicators of their performance. The input was the annual total dry matter intake per hectare by milkers (TDM/Hm), which ranged from 10,000 to 13,000 kg DM/ha/year (Appendix 5.13). The total physical product (TPP) (kg MS/ha/year) was calculated using the quadratic regression equation from Figure 5.22 (Appendix 5.13).

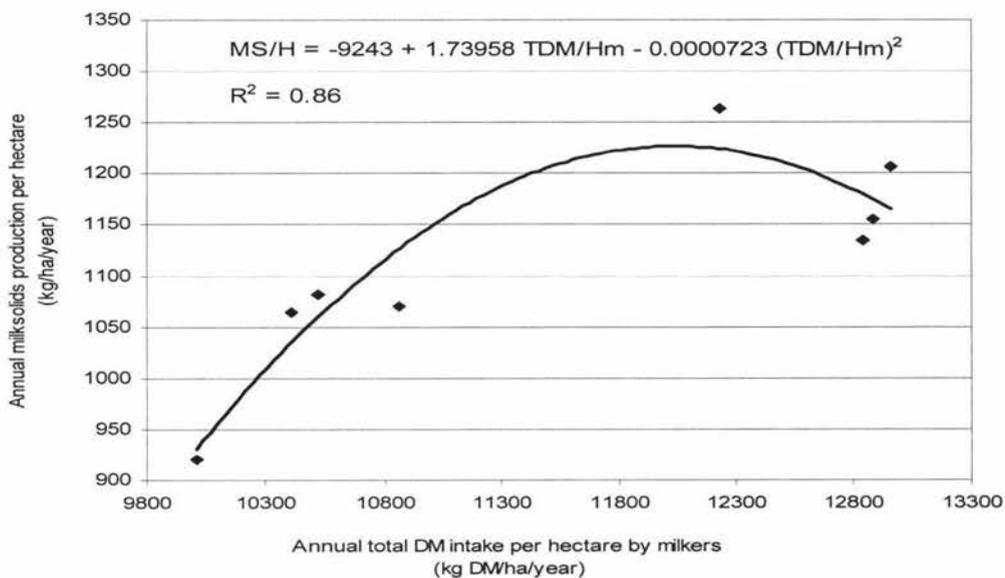


Figure 5.22 Quadratic regression for the variables MS/H and TDM/Hm, involving the eight case study farms utilised for the financial analysis.

Average physical product (APP) and marginal physical product (MPP) are illustrated in Figure 5.23 a and b, respectively. The values of total physical product, average physical product (APP) and marginal physical product (MPP) are shown in Appendix 5.13. Total value product for each input was calculated by multiplying the quantity of output (TPP) by its selling price, which was NZ\$5,00 per kg of milksolids (Appendix 5.13). Marginal value product (MVP) is shown in Appendix 5.13. The marginal input cost (MIC) was assumed as NZ\$0.18/kg DM. This value was based on the market price of supplementary feed. Appendix 5.13 shows that 11,800 kg DM/ha/year is the maximum input level where marginal value product is higher than the marginal input cost. This break-even point is represented by arrows in Figure 5.23 a and b. As indicated at the literature review (see Section 2.5.1) most of the time profit can still be increased by utilising higher inputs, despite the declining value of average physical product.

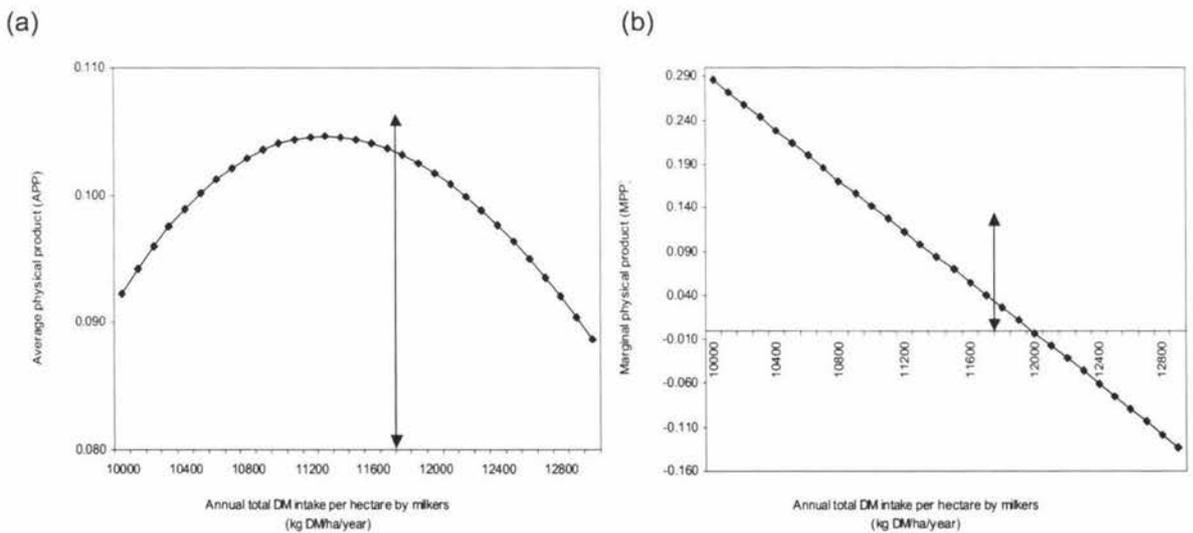


Figure 5.23 Average physical product (APP) and marginal physical product (MPP).

CHAPTER 6

GENERAL DISCUSSION

6.1. INTRODUCTION

In this Chapter the research results are discussed in relation to the following objectives: a) to understand and identify factors affecting productivity, efficiency and profitability of the case study farms; b) to compare the physical and financial performance among the case study farms and with industry data; c) to identify opportunities for further improvement in the efficiency of both physical and financial management of the case study farms.

6.2. MATERIALS AND METHODS

6.2.1. Sample size

Two fundamental elements contributing to the accuracy of statistical analysis are a large number of replicates and a small variance (Collins & Seeney, 1999; Gomez & Gomez, 1984; Sachs, 1984). Because of the nature of this study, there were numerous uncontrolled sources of variation in a relatively small group of farms. Therefore, when analysing the results it should be considered that the sample size is small to draw general conclusions for dairy farms throughout New Zealand. However, analyses of commercial case study farms reflect the trade-off between accuracy and reality (Yin, 1994).

6.2.2. Intake estimation

Pasture intake was estimated as the difference between adjusted pre and post grazing herbage mass (kg DM/ha) divided by grazing intensity (cows/ha/day) (see Section 4.4.5.2). This is the simplest method to estimate intake and is widely used at farm level. One constraint of this technique is the fact that the difference between pre and post grazing herbage mass may not represent the amount of grass actually eaten by the animals, due to loss (e.g. treading damage). Therefore, pasture disappearance does not necessarily mean pasture consumed by the animals. Also, this method does not take into account daily pasture growth, which could lead to pasture intake underestimation. However, due to the scale of the project, nine commercial dairy farms involving 974 effective hectares and 2586 cows, this was the only feasible monitoring technique.

Further, it is discussed in this Chapter that the estimates of feed consumed are high and seem to be overestimated relative to theoretical values (see Section 6.3.3). This might be related to the adjustment of dry matter figures to be in accordance with the national standardised monthly calibration equations (Hainsworth, 1999) (see Section 4.4.1.1). The different grazing management used on these case study farms might mean that the standard calibration equations were not appropriate.

The data for pasture and supplement intake provided by the farm monitoring project was measured on a daily basis in kg DM per animal, using the daily number of animals for calculations. This data was transformed to estimates of annual intake of pasture and supplementary feed per herd and then divided by peak number of cows on farm to obtain annual pasture and supplement dry matter intake per cow (see Section 4.4.5.2 and Section 4.4.5.4). Even though this method resulted in smaller estimates of animal intake than measurements based on actual daily number of cows, it was used in order to

agree with the intake measurements utilised previously in the farm monitoring project and also in the industry.

Assumed values for metabolisable energy of pasture had to be used for June, July and the first half of August. Pasture samples were not collected during this period (see Section 4.4.1.2), because the animals were dry for most of the time and sample analyses were expensive. This might have influenced the accuracy of pasture metabolisable energy intake at this period. Some values of metabolisable energy were also assumed for few types of supplementary feed (see Section 4.4.2.2). Again, this could have influenced the validity of metabolisable energy intake for those types of supplements.

6.3. PHYSICAL PERFORMANCE

6.3.1. Comparisons between the case study farms and industry data

The average stocking rate for all case study farms (2.7) is very similar to the national average of 2.6 cows per effective hectares (LIC, 2001). Despite the small difference in stocking rate, the average of annual milksolids production per effective area (1,100 kg MS/ha/year) for the case study farms was 49% higher than the national average (737 kg MS/ha/year) (LIC, 2001). Similarly, the average of annual milksolids production per cow (411 kg MS/cow/year) for the case study farms was also 49% greater than the national average (275 kg MS/cow/year) (LIC, 2001).

When compared to data from the Manawatu region, the average stocking rate for the case study farms was 8% higher than the regional average data (Table 6.1). Stocking rate values from Waikato and Taranaki regions for average and top 10% farms are also illustrated in Table 6.1. The average of annual milksolids production per cow and per hectare for the case study farms were higher than all regional values (Table 6.1). Mean

annual milksolids production per cow of the case study farms were 34% and 36% higher than the mean values reported by MAF and LIC, respectively. Mean annual milksolids production per hectare of the case study farms were 39% and 43% higher when compared to LIC and MAF values, respectively (LIC, 2001; MAF, 2001).

Table 6.1 Effective area (ha), herd size, stocking rate (cows/ha) and annual milksolids (MS) production per cow (kg MS/cow/year) and per hectare (kg MS/ha/year), for the case study farms and regional averages (LIC, 2001; MAF, 2001; Dexcel, 2002, personal communication).

	Manawatu region			Waikato region*		Taranaki region*			
	Case study farms			LIC	MAF	Economic survey			
	Mean	Max	Min	Mean	Mean	Mean	Top 10%	Mean	Top 10%
Effective area	108	213	52	107	80	87	68	66	77
Herd size	287	570	148	273	200	225	216	182	231
Stocking rate	2.7	3.0	2.4	2.5	2.5	2.6	3.2	2.7	3.0
MS per ha	1,100	1,264	921	788	769	827	1074	846	1088
MS per cow	411	432	372	303	307	318	340	309	361

* Waikato and Taranaki data were used because data from Manawatu were unavailable.

The mean annual milksolids production per hectare of the case study farms was higher than the top 10% farms in Taranaki and Waikato, as a result of higher per cow performances at lower stocking rates, which is in accordance with the project objective (see Section 3.3). The comparison between the physical values of the case study farms with the national and regional information from Manawatu, Waikato and Taranaki regions, showed that on average, the case study farms can be classified as highly productive dairy systems in New Zealand.

6.3.2. Grazing management

6.3.2.1. Background

Pasture grown can either be harvested by the animal or lost through senescence and decomposition. The rate of net pasture production of a sward will be restricted either by low pasture growth rates or by the increasing rates of senescence and decay at low (< 900-1200 kg DM/ha) and high (> 2500-3000 kg DM/ha) herbage mass, respectively (Korte *et al.*, 1987). However, between these two values, net pasture production achieves its maximum and it is relatively insensitive to changes in herbage mass and management. This means that managing pastures between these two points offers opportunity for the grazing animals to consume high levels of high quality forage. For ryegrass/white clover dairy pastures these parameters were defined as 1200-1400 kg DM/ha and 2500-3000 kg DM/ha as the low and high herbage mass values, respectively (Matthews, 1994).

The strategic use of supplements to overcome pasture deficits and to control pasture quality is an important grazing management tool to obtain high production per animal. Considering that low herbage residuals cause a decrease in herbage intake, post grazing herbage mass levels determine when supplementary feed should be included in the system, thus preventing the residual herbage mass from falling below target levels in order to avoid a decrease in herbage intake, animal performance and pasture growth (Matthews, 1995). Pre grazing herbage mass levels control pasture quality and herbage growth (Matthews, 1995). High levels of pre grazing herbage mass will cause an increase in pasture losses and a decrease in herbage nutritive value, resulting in reduced pasture growth rate and decreased intake of high quality forage.

6.3.2.2. *Case study farms*

The average pre and post grazing herbage mass for lactating cows on the case study farms were 2,650 and 1,900 kg DM/ha respectively, within the range identified as optimum net pasture production. The minimum post grazing herbage mass value for the case study farms was approximately 1,300 kg DM/ha, which was still in the optimum range. However, in the period between late December and early March (Figure 5.2), the average pre grazing herbage mass value for all case study farms for lactating animals was higher than the recommended 3,000 kg DM/ha. This high value might have contributed to decrease the sward quality at this time of the year (Figure 5.4).

Another important factor affecting pasture quality in summer and early autumn was the reproductive stage of the sward, which often results in lower forage nutritive level and palatability to stock (Valentine & Matthew, 1999). In early November, values of acid detergent fibre (ADF) and neutral detergent fibre (NDF) started to increase (Figure 5.4b) while metabolisable energy (ME) (Figure 5.4a) and crude protein (Figure 5.4b) concentrations began to decrease. This coincided with greater proportion of reproductive stem in the sward as determined from samples cut to grazing height (Figure 5.5a). In accordance to literature (Hodgson & Brookes, 1999), pasture nutritive value was closely related to the sward botanical composition of samples cut to grazing height, for all farms. In general, the ME values decreased when reproductive stem, vegetative stem and dead material increased (Appendix 5.2 and Appendix 5.4), whereas ME concentration increased as leaf and clover content increased. Crude protein concentration followed the same trend as ME concentration (Appendix 5.2 and Appendix 5.3). The highest values of ADF and NDF coincided with the period of highest vegetative and reproductive stem content (Appendix 5.3 and Appendix 5.4).

The nutritive value of pastures on all farms were relatively high (Table 5.1). In spring and autumn when pasture consists predominantly of green leaf, Hodgson & Brookes

(1999) quoted values of 815-870 g/kg DM, 11.5-12.0 MJ/kg DM, 250-300 g/kg DM, and 300-350 g/kg DM, for organic matter digestibility, metabolisable energy, crude protein and neutral detergent fibre on the sward, respectively. The comparison of these values obtained in spring with the data illustrated in Table 5.1 for the whole season shows that the case study farms had good sward quality. Low metabolisable energy values were found in Farm 9 from early December to late March (Appendix 5.2), probably related to the substantial proportions of tall fescue (*Festuca arundinacea*) and cooksfoot (*Dactylis glomerata*) in this farm. These grasses have the ability to grow better than perennial ryegrass in dry summers, but have lower nutritive values (Kemp *et al.*, 1999).

Even with the high levels of pre grazing herbage mass combined with the plant mature stage observed in the period between late December and early March, the average herbage nutritive values of all case study farms were still high. Hodgson & Brookes (1999) stated that increased concentration of fibre (NDF 450-550 g/kg DM) associated with depressed levels of crude protein (< 200 g/kg DM), organic matter digestibility (< 700 g/kg DM) and metabolisable energy (< 10.5 MJ/kg DM) are observed at this time of the year. As a result of good pasture management, the average values for the case study farms (NDF 439 g/kg DM, crude protein 218 g/kg DM, organic matter digestibility 761 g/kg DM and metabolisable energy 10.8 MJ/kg DM) over the summer and early autumn period compared very favourably with the published values.

The high levels of pre grazing herbage mass from late December to early March are probably related to the greater difficulty of pasture management at this period of the year, caused by the onset of flowering, which implies increase in pasture growth rate and associated management problems (Valentine & Matthew, 1999); and by the higher dry matter content of the sward at this period (Figure 5.3). Figure 6.1a shows that the unadjusted pre grazing herbage mass values (farmers' visual assessment) were much

lower than the adjusted or actual values (Ashgrove Rising Plate Meter) at this period of the year (see Section 4.4.1.1). The farmers' estimation of pre grazing herbage mass followed a similar pattern throughout the year (Figure 6.1a), with a steady decline over the summer and autumn. However, the adjusted data indicated an abrupt increase in pre grazing herbage mass levels from late December to early March (Figure 5.2 and Figure 6.1a). A similar trend was found in the post grazing herbage mass values (Figure 5.2 and Figure 6.1b). This difference could be a result of pasture dry matter underestimation by the farmers' visual assessment and/or an overestimation by the Ashgrove Rising Plate Meter that rely on standardised national monthly equations (see Section 4.4.1.1). The high values of adjusted pasture mass illustrated in this period might also raise the question: on a dry matter basis, because of sward changes, should target values for herbage mass be higher in summer than for other periods of the year?

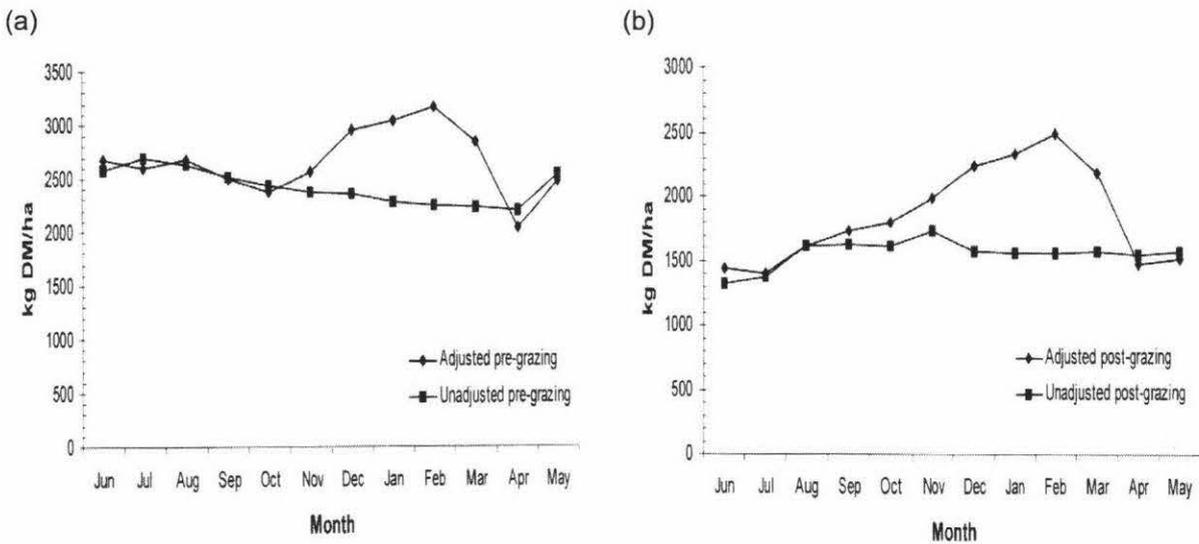


Figure 6.1 Comparison of adjusted and unadjusted estimates of pre (a) and post (b) grazing herbage mass (AGMARDT, 2001).

The overall objective of the grazing management of the case study farms was to maintain high per hectare milksolids production through improved animal performance (see Section 3.3). Their grazing strategies were based on moderate stocking rates and on the use of pre and post grazing herbage mass targets (see Section 6.3.2.1) to control supplementary feed inputs and pasture quality in order to provide a high allowance of high quality forage (see Section 2.2.2). The results indicated that the farmers were able to manage pre and post grazing herbage mass levels and pasture quality successfully, as high pasture quality was offered to the animals.

6.3.3. Feed intake

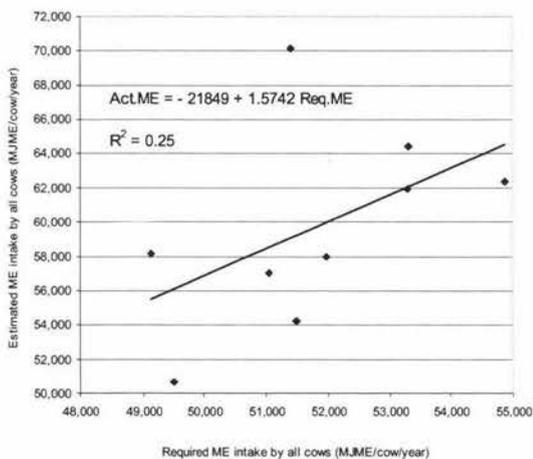
Differences in pasture and supplementary feed intakes both per cow and per hectare (Figure 5.7) between farms resulted in different milksolids production (Table 5.4) and feed conversion efficiencies (Figure 5.8). A comparison between measured annual total metabolisable energy (ME) intake per animal by all cows and theoretical calculated annual metabolisable energy requirements per animal by all cows (Holmes *et al.*, 2000a) (Table 6.2) showed that the measured ME intake values were higher than the theoretical values, for all the case study farms.

The linear regression between measured and theoretical ME intakes with or without liveweight change (Figure 6.2) showed the same R^2 value (0.25). The lack of relationship between the theoretical and measured value was probably the result of uncontrolled sources of variation of measured intakes and assumptions used to estimate theoretical intakes. Excluding Farm 6, which has the highest difference between the measured and theoretical ME intakes, a much higher correlation between the two variables was observed (R^2 equal 0.57 and 0.61, with and without liveweight change, respectively).

Table 6.2 Comparison between theoretically calculated requirements of annual total metabolisable energy (ME) intake per animal by all cows and measured annual total metabolisable energy intake per animal by all cows, for the season 2000/2001.

Farms	Required ME intake (MJ ME/cow/year)	Measured ME intake (MJ ME/cow/year)	Difference (%)
1	53,861	62,367	14
2	48,750	58,166	19
3	53,041	64,424	21
4	51,284	57,961	12
5	52,710	61,924	17
6	50,732	70,135	37
7	51,189	54,209	6
8	50,613	57,049	12
9	48,563	50,669	3
<i>Mean</i>	<i>51,543</i>	<i>59,656</i>	<i>16</i>

(a)



(b)

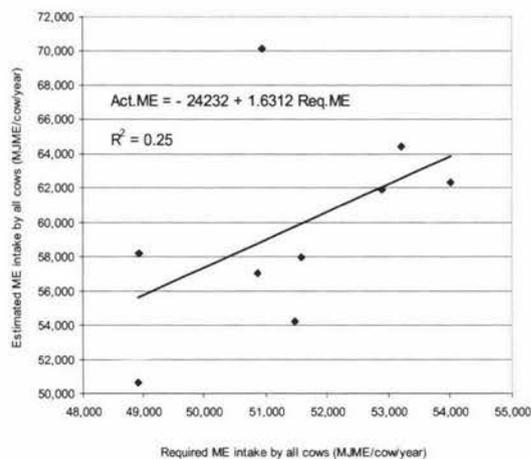


Figure 6.2 Simple linear regressions across all farms between estimated and required (theoretical) annual metabolisable energy (ME) intake by all cows with (a) and without (b) liveweight change during the season 2000/2001 (Present data).

The results from the case study farms were compared with a farmlet trial conducted by Penno (2001). Even considering that milk yields were different between the case study

farms and the experimental trial, and the experiment was under controlled grazing management, comparison was useful since the experiment was run in farmlets and they were similar to a real situation. Four of the farmlets were stocked at 4.41 cows/ha and the last one at 3.35 cows/ha, for three complete years. The quantity of pasture dry matter eaten per cow each day was also calculated from the difference between pre and post grazing herbage mass. Herds on the higher stocked farmlets were offered either no supplementary feed from off farm sources (Control), or supplementary feeds of rolled maize grain (MG), whole maize crop silage (WCS), or a nutritionally balanced ration (BR). The herd grazing on the lower stocked farmlet (LS) was offered pasture silage conserved on that farmlet. The mean intake of the three years for each treatment (excluding the control) showed annual ME intakes (Table 6.3) higher than the theoretical required values of the case study farms (Table 6.2), ranging from 14% to 26%. The average measured ME intake of all case study farms (Table 6.2) was lower than the mean intake of the three years for treatments MG, BR and LS analysed by Penno (2001).

Table 6.3 Annual total metabolisable energy (ME) intake per animal by all cows and annual total milksolids yield per cow. Adapted from Penno (2001).

	Control	MG	WCS	BR	LS
Annual total ME intake per animal by all cows (MJ)					
Year 1	49,298	63,157	60,339	63,954	63,803
Year 2	48,031	69,988	61,396	67,747	62,801
Year 3	44,243	62,883	54,712	62,438	56,754
<i>Mean</i>	<i>47,191</i>	<i>65,343</i>	<i>58,816</i>	<i>64,713</i>	<i>61,119</i>
Annual milksolids yield per cow (kg)					
Year 1	301	394	385	387	387
Year 2	247	416	356	419	357
Year 3	260	389	348	416	340
<i>Mean</i>	<i>269</i>	<i>400</i>	<i>363</i>	<i>408</i>	<i>361</i>

The comparison of these two data sets raises some important points. Firstly, considering that measured ME intakes from both case study farms and research conditions are higher than the theoretical values, there is a possibility that the theoretical values are underestimated. Alternatively, assuming that the theoretical values are correct, both the experimental and the study case farms appear to have been offering more feed than necessary. However, there is a chance that the on-farm techniques used to measure both data sets overestimated intake and in practice, measured intake higher than theoretical requirements. It is most likely that measures of pasture intakes using pre and post grazing herbage mass levels is less accurate than measures of supplementary feed intakes (see section 6.2.2). All this discussion raises the question: are these farms using feed effectively for the production they are achieving or are they wasting resources?

6.3.4. Factors associated with milk production and feed conversion efficiency for whole lactation

6.3.4.1. Stepwise regression

Different procedures can be used to determine the sequence for inclusion of predictor variables in regression analyses. The determination of the order of entry of the variables could rely on their statistical properties (e.g., forward selection, backward elimination, stepwise), on the experimenter's criteria (hierarchical, blockwise) or have no order of entry (simultaneous) (Osborne, 2000). Current practice favours analyst-controlled entry and discourage the selection of the variables based on statistical properties, because it does not consider the biological importance of the variables (Osborne, 2000). Stepwise methods select the next most significant variable given the presence of previous variables. This dependence or conditionality makes the stepwise analysis questionable (Schafer, 1991, 1992; Thompson, 1989). Taking these factors in consideration, in the present study, the predictor variables were included in the multiple

regression following the researcher's criteria based on the correlation matrix values and on their expected biological importance.

6.3.4.2. *Milksolids production per cow*

There is usually a close relationship between nutrient intake and performance of grazing animals (Hodgson, 1990), and "the level of production achieved by a grazing animal is an indirect measure of the feeding value of the forage consumed" (Holmes *et al.*, 1987). Feeding value is the product of the quantity of feed intake and its concentration of nutrients (Holmes *et al.*, 1987). As expected, Figure 5.9 shows a high positive correlation ($R^2 = 0.74$) between annual total metabolisable energy (ME) intake per animal by milkers (TME/Cm) and annual milksolids production per cow (MS/C). Caird & Holmes (1986) also demonstrated that total intake of grazing dairy cows was positively correlated with milk yield. The marginal response in milksolids obtained was equivalent to 3.40 g MS/MJ ME intake. This value is considerably smaller than the 15 g MS/MJME theoretically possible if all the additional ME provided by feed were used directly for milk synthesis (Holmes *et al.*, 1987). Penno (2001) found total responses to supplementary feeding measured at high stocking rates (4.41 and 3.35 cows/ha) in a long term experiment ranging from 7.3 to 7.8 g MS/MJME, which is higher than the value found in this study, but also smaller than the theoretical value. The difference in marginal milksolids return between the experimental data and the case study farms is probably because the present study is dealing with uncontrolled conditions and also the value of 3.4 g MS/MJ ME was from a regression equation between nine different systems (Figure 5.9). Moreover, supplementary feed was used in the case study farms to maintain the system's targets of average pasture cover and body condition score and therefore, did not show an immediate effect on milksolids production.

The regression analysis showed that only the annual pasture ME intake per animal by milkers (PME/Cm) was significantly related to annual milksolids production per cow

(Equation 5.1). The high R^2 value (0.71) was probably because pasture ME intake per cow of milkers represented approximately 79% of total feed intake (annual average for all farms). Equation 5.2 showed that the addition of supplementary feed into the multiple regression did not explain a significant additional amount of the variation of annual milksolids production per cow. However, the equation was important to illustrate the relative importance between pasture and supplementary feed, showing that pasture intake (PME/Cm) explained 17 times more the variation of annual milksolids per cow than supplements (SME/Cm). Both predictor variables PME/Cm and SME/Cm showed positive correlations with milksolids production per cow, meaning that an increase in either of the predictor variables is associated with increases in milksolids production per cow. Supplementary feed was used in the case study farms as a buffer of the system against pasture shortages. Therefore, the supplement effect is probably seen in the long term (see Section 2.4.1), as increases or maintenance of pasture cover (managed substitution, see Section 2.4.2) and animal condition score.

6.3.4.3. *Milksolids production per hectare*

Annual total metabolisable energy (ME) intake per hectare by milkers (TME/Hm) showed a significant correlation ($R^2 = 0.65$) with annual milksolids production per hectare (MS/H) (Figure 5.10). The regression coefficient showed a marginal response in milksolids of 5.60 g MS/MJ ME intake, which was also smaller than the theoretical value and the information published by Penno (2001). This value was also different from that obtained by the relation between annual milksolids production and energy intake per animal (see Section 6.3.4.2), for which there was no clear explanation.

The multiple linear regression showed that annual pasture ME intake per hectare by milkers (PME/Hm) and stocking rate (SR) were the only predictor variables which were significantly related to annual milksolids production per hectare. A high R^2 value (0.93) was obtained when both predictor variables were used (Equation 5.4), with both

variables explaining a significant amount of the variation of the regression. Even though the effect of annual supplement ME intake per hectare by milkers (SME/Hm) was not statistically significant, it was included (Equation 5.5), in order to show the relative importance of pasture and supplementary feed. PME/Hm explained 4 and 34 times more of the variation of annual milksolids production, when compared to SR and SME/Hm, respectively. However, after SME/Hm was added to the model, PME/Hm was no longer statistically significant, while SR still maintained a significant value. All three predictor variables showed a positive correlation with annual milksolids production per hectare (MS/H), therefore an increase in any of the predictor variables is associated with increases in milksolids production. Again, supplementary feed was more likely to make indirect contributions as long term effects (see Section 6.3.4.2).

6.3.4.4. *Feed conversion efficiency*

A close relationship between intake and feed conversion efficiency was observed. Annual total metabolisable energy (ME) intake per animal by all cows (TME/Cmd) showed a significant correlation ($R^2 = 0.80$) with feed conversion efficiency of all cows, FCE(ME)md (Figure 5.11). Even a higher correlation ($R^2 = 0.87$) was observed between annual total metabolisable energy intake per animal by milkers (TME/Cm) and feed conversion efficiency by milkers, FCE(ME)m (Figure 5.14). The slope was negative for both correlations, which means that increases in TME/Cmd and TME/Cm are associated with decreases in FCE(ME)md and FCE(ME)m, respectively.

Annual milksolids production per cow (MS/C) and feed conversion efficiency of all cows were also negatively correlated, contrary to expectations (Figure 5.12), but not statistically significant ($R^2 = 0.15$). The same was observed between (MS/C) and FCE(ME)m ($R^2 = 0.40$) (Figure 5.15). Even though the correlations were not statistically significant, it is important to discuss the probable reasons for the negative associations. As commented before (see Section 5.3.1), the statistical analyses were

based on linear regressions. However, the quadratic regression between annual total ME intake per animal by milkers plus dry cows (TME/Cmd) and annual milksolids production per cow (MS/C) (Figure 5.13) was justified. The same applied for the variables annual total ME intake per animal by milkers (TME/Cm) and annual milksolids production per cow (MS/C) (Figure 5.16). Both quadratic regressions showed a diminishing return curve, which means that as MS/C increases, a constant amount of extra ME per cow produces a smaller increase in MS/C and as a consequence, feed conversion efficiencies decrease. This is supported by Broster & Thomas (1981) who showed that increasing energy intake of dairy cows results in an curvilinear increase in milk yield. This might be explained by the fact that cows are achieving their maximum udder capacity or by the increased partitioning of ME intake into liveweight, instead of milksolids production (see Section 6.3.6 for more explanation).

Figure 5.13 shows that after the plateau values in MS/C are reached, annual milksolids production per cow tends to decrease as annual intake increases even further. However, this is not realistic in biological terms. Milksolids production could be relatively insensitive to increases in intake, but it would not decrease. An asymptotic function would probably fit better the biological trend, but the sample size was too small to justify more complex analysis.

The multiple linear regression using selected predictor variables showed that annual pasture ME intake per animal by all cows (PME/Cmd), annual milksolids production per cow (MS/C) and annual supplement ME intake per animal by all cows (SME/Cmd) were the statistically significant predictor variables that explained the variation of FCE(ME)md (Equation 5.8). For FCE(ME)m, the predictor variables were annual pasture ME intake per animal by milkers (PME/Cm), annual milksolids production per cow (MS/C) and annual supplement ME intake per animal by milkers (SME/Cm)

(Equation 5.11). The high R^2 values of 0.99 for both regression equations reflect the simple mathematical relationships between all these variables (see Section 4.4.5.10). However, its use was justified to examine the relative contribution of the predictor variables to variation in efficiency across farms. PME/Cmd explained 7 and 12 times more of the variation of FCE(ME)md, when compared to MS/C and SME/Cmd, respectively; and PME/Cm explained 3 and 6 times more the variation of FCE(ME)m than SME/Cm and MS/C, respectively. MS/C explained the same amount of variation in both regressions relative to PME/Cmd and PME/Cm. However, supplementary feed had a much higher influence relative to pasture to explain the variation of FCE(ME)m than the variation in FCE(ME)md. The reason of this difference is probably the much higher proportion of total energy input as supplement consumed by milkers (71%) than by dry animals (29%) (see Section 6.3.5).

Equation 5.8 and Equation 5.11 showed that according to expectations, pasture (PME/Cmd and PME/Cm) and supplement intakes (SME/Cmd and SME/Cm) still maintained a negative correlation with FCE(ME)md and FCE(ME)m, as did TME/Cmd and TME/Cm. However, MS/C was positively correlated with both feed conversion efficiencies, in contrast to the negative relationships apparent in the original simple correlation analysis.

6.3.5. Supplementary feed

The use of supplementary feed differed between farms and also between stock classes within farms. The average annual supplement intake for all case study farms represented 25% (22% to 28%) and 24% (21% to 27%) of total annual feed consumed by all cows, as dry matter (DM) and metabolisable energy (ME) intake, respectively. For the dry cows, the average annual supplement intake for all case study farms represented 41% (27% to 55%) as dry matter and 39% (24% to 53%) as metabolisable

energy of total annual feed consumed. Grazing off was classified as supplementary feed, which explains the high proportions of supplement intake by dry animals. If grazing off was classified as pasture, the average annual supplement intake for all case study farms would represent 35% as dry matter and 30% as metabolisable energy of total annual feed consumed by the dry animals. For the milkers, the average annual supplement intake for all case study farms represented 21% of total annual feed consumed, for both dry matter and metabolisable energy intakes, ranging from 17% to 27%. On average for all case study farms, approximately 29% of the total metabolisable energy input in the system as supplements was consumed by dry animals (grazing off was also classified as supplementary feed). The remaining 71% was consumed by the milkers.

The use of supplementary feed in the case study farms varied throughout lactation. The average proportion of supplement consumed by milkers for all case study farms in the first part of lactation (13% for both DM and ME intake) was much lower than in the second part of lactation (31% and 32% for DM and ME intakes, respectively). This was expected, as the first part of lactation was the spring and early summer, when higher pasture production (Figure 2.2) and sward nutritive value are expected in the Manawatu region.

Table 6.4 shows that two (Farm 7 and Farm 9) of the three farms with the lowest supplementary feed use in the first part of lactation used the highest amount of supplements in the second part of lactation. These two farms experienced dry summer conditions in the 2000/2001 season and supplementary feed was used to overcome a pasture deficit, rather than to increase the size of the system. Even though these two farms used the highest proportion of supplements in the second part of lactation, they produced low daily milksolids yield per cow during that period (Table 5.9), which is probably caused by limitations in feed quantity and quality.

Table 6.4 Average of daily total feed intake (pasture plus supplement) and daily pasture intake per animal by milkers, for the first and second parts of lactation. Percentage of supplementary feed of total metabolisable energy (ME) intake in the first and second parts of lactation.

Farm	Pasture intake per cow by milkers (MJ ME/cow/day)	Total feed intake per cow by milkers (MJ ME/cow/day)	% of supplement intake (ME) by milkers
First part of lactation			
2	154	183	16%
6	156	190	16%
8	156	189	17%
1	164	201	21%
4	169	197	15%
3	170	198	14%
9	173	180	4%
5	174	188	7%
7	181	187	3%
<i>Mean</i>	<i>166</i>	<i>190</i>	<i>13%</i>
Second part of lactation			
7	89	162	46%
9	98	158	43%
4	107	182	43%
2	126	173	26%
1	135	186	28%
8	144	179	18%
5	145	198	27%
6	147	202	27%
3	152	208	28%
<i>Mean</i>	<i>127</i>	<i>183</i>	<i>32%</i>

Appendix 5.5 illustrates the proportion of each type of supplement used by all farms, and Table 5.3 shows their respective nutritive values. The analyses of these numbers for Farm 4, Farm 7 and Farm 9 showed that pasture was the component of the diet with the highest quality (Table 5.1). These farms also had the shortest lactation length (Table 5.4) probably because they could not support a system relying so heavily on supplement

inputs for a longer period. It is important to note that their lactation length would be even shorter if supplements were not included.

Even if mean total metabolisable energy intake was only 4% lower in the second part of lactation than in the first part (Table 6.4), mean daily milksolids production per cow and per hectare was approximately 30% lower (Table 5.9). This implies inefficient use of feed in the second part of lactation, which may be partially explained by a decline in pasture quality in summer period (see Section 6.3.2.2) or by a need for some recovery in body reserves over this period. No associations were observed between supplementary feed use, economic farm surplus per hectare, return on assets and cost of milksolids production.

6.3.6. Feed conversion efficiency

Feed conversion efficiency of all cows, $FCE(ME)_{md}$ and $FCE(DM)_{md}$, was expressed as annual milksolids produced per herd (g) divided by annual intake of metabolisable energy (ME) or dry matter (DM) per herd by all cows; and feed conversion efficiency of milkers was expressed as annual milksolids produced per herd (g) divided by annual intake of ME or DM per herd by milkers. In order to facilitate the discussion regarding factors influencing feed conversion efficiencies in this section, the farms were divided into two groups: Group one – feed conversion efficiencies lower than the average of all farms - and Group two – feed conversion efficiencies higher than the average of all farms - (Table 6.5 and Table 6.6).

The farms from Group two had the four highest values of feed conversion efficiency of all cows (Table 6.5) and feed conversion efficiency of milkers (Table 6.6) and also the lowest DM and ME intakes per animal, which confirms the high negative correlation between ME intakes and feed conversion efficiencies (Figure 5.11 and Figure 5.14).

However, the lower intake values per animal of farms from Group two on average resulted in lower annual milksolids production per cow than those in Group one, the exception were Farm 8 and Farm 2, and the particular situations of these farms are discussed later (see Section 6.4.2).

Table 6.5 Feed conversion efficiency of all cows (g MS/MJ ME and g MS/kg DM), annual metabolisable energy (ME) and dry matter (DM) intakes per animal by all cows (MJ ME/cow/year and kg DM/cow/year), annual milksolids production per cow (MS/C, kg MS/cow/year) and per hectare (MS/H, kg MS/ha/year) and stocking rate (SR, cows/ha), for Group one and Group two. The theoretical FCE(ME)md was calculated dividing the actual milksolids production per cow by the theoretical metabolisable energy intake per cow.

Farm	Actual data							Theoretical
	FCE		ME intake	DM intake	MS/C	MS/H	SR	FCE (ME)md
Group one (lower FCE)								
6	6.0	69	70,135	6,078	421	1,002	2.4	8.2
2	6.7	75	58,166	5,202	390	921	2.4	7.9
3	6.7	77	64,424	5,636	432	1,155	2.7	8.1
1	6.8	77	62,367	5,499	424	1,135	2.7	7.7
5	6.8	78	61,924	5,415	424	1,206	2.8	7.9
<i>Mean</i>	6.6	75	63,403	5,566	418	1,084	2.6	7.9
Group two (higher FCE)								
4	7.1	81	57,961	5,027	410	1,070	2.6	7.9
9	7.3	82	50,669	4,537	372	1,082	2.9	7.5
7	7.4	82	54,209	4,866	401	1,064	2.7	7.8
8	7.4	83	57,049	5,052	421	1,264	3.0	8.2
<i>Mean</i>	7.3	82	54,972	4,870	401	1,120	2.8	7.8

Higher feed conversion efficiencies were not obtained by the farms with higher milksolids production, but by the farms with lower intakes. This was confirmed by the regression equations, which showed that pasture intake explained most of the variation in FCE(ME)md and FCE(ME)m (see Section 6.3.4.4). The diminishing returns curves (Figure 5.13 and Figure 5.16) obtained by the quadratic regression between annual total ME intakes per animal and annual milksolids production per cow, showed that as intake

increases, successive increments of extra ME per cow produce a smaller increase in annual milksolids production per cow (see Section 6.3.4.4). The same shaped curve was obtained by the quadratic regression between annual total DM intake per animal and annual milksolids production per cow (results not shown).

Table 6.6 Feed conversion efficiency of milkers, annual metabolisable energy (ME) and dry matter (DM) intakes per animal by milkers and annual milksolids production per animal, for Group one and Group two.

Farm	FCE(ME) _m (g MS/MJME)	FCE(DM) _m (g MS/kgDM)	ME intake by milkers (MJ ME/cow/year)	DM intake by milkers (kg DM/cow/year)	Milksolids production (kg/cow/year)
Group one					
3	7.8	90	55,501	4,821	432
1	7.8	88	54,448	4,798	424
5	8.1	93	52,233	4,554	424
6	8.2	96	51,451	4,398	421
2	8.3	92	47,196	4,242	390
<i>Mean</i>	<i>8.0</i>	<i>92</i>	<i>52,166</i>	<i>4,563</i>	<i>418</i>
Group two					
4	8.5	99	47,943	4,155	410
8	9.1	103	46,385	4,077	421
7	9.2	102	43,789	3,922	401
9	9.2	103	40,490	3,619	372
<i>Mean</i>	<i>9.0</i>	<i>102</i>	<i>44,652</i>	<i>3,943</i>	<i>401</i>

A comparison between the case study farms (Table 6.5) and the experiment conducted by Penno (2001) (Table 6.7) using five treatments (see Section 6.3.3 for more explanation) demonstrated that, if Farm 6 was excluded, all case study farms had the same or higher feed conversion efficiency of all cows than the maximum value (6.7 g MS/MJ ME) from the experimental treatments. The low feed conversion efficiency of Farm 6 is related to the maintenance of a number of dry animals on the farm for the whole year, grazing after milkers, in order to improve pasture quality. The season 2000/2001 was the first year of the farmer on the property, and this “leaders/followers”

management was necessary. Feed conversion efficiency was substantially improved on Farm 6 (Table 6.6) when only milkers intake was taken into account.

Table 6.7 Feed conversion efficiency of all cows (g MS/MJ ME intake) for treatments receiving no supplementary feed from off farm sources (Control), supplementary feeds of rolled maize grain (MG), whole maize crop silage (WCS), nutritionally balanced ratio (BR) and pasture silage conserved at the farmlet (LS), for three complete years. Adapted from Penno (2001).

	Control	MG	WCS	BR	LS
Year 1	6.1	6.2	6.4	6.1	6.0
Year 2	5.1	5.9	5.8	6.2	5.7
Year 3	5.9	6.2	6.4	6.7	6.0
Mean	5.7	6.1	6.2	6.3	5.9

Broster and Thomas (1981) stated that milk yield per animal responds to changes in energy supply, and provided there is no change in body weight, milk output will essentially be linearly related to energy input. However, in practice, the cow responds to changes in energy supply in terms of both milk production and liveweight change. Figure 6.3 shows that up to an intake of 100 MJ ME above maintenance, milk production is maintained at the expense of body tissue mobilisation; likewise, most of the energy from intake is used for this purpose. Higher energy intakes result in body liveweight gain and therefore, less energy is partitioned towards milk. Appendix 5.6 shows that farms from Group two (annual average 4.3) operated at lower levels of condition score than farms from Group one (annual average 4.4) throughout the year. This divergence in body condition score may be explained by the different amounts of energy offered to the cows by farms from Groups one and two. The liveweight gain of cows from Group one could explain the differences in feed conversion efficiency between the two groups. In order to improve feed conversion efficiency of farms from Group one, there may be two possibilities. Firstly, an increase in stocking rate and secondly an improvement in cows' genetic merit, which should insure a greater

proportion of total intake being used for milk production rather than of body growth (see Section 2.3.2.3).

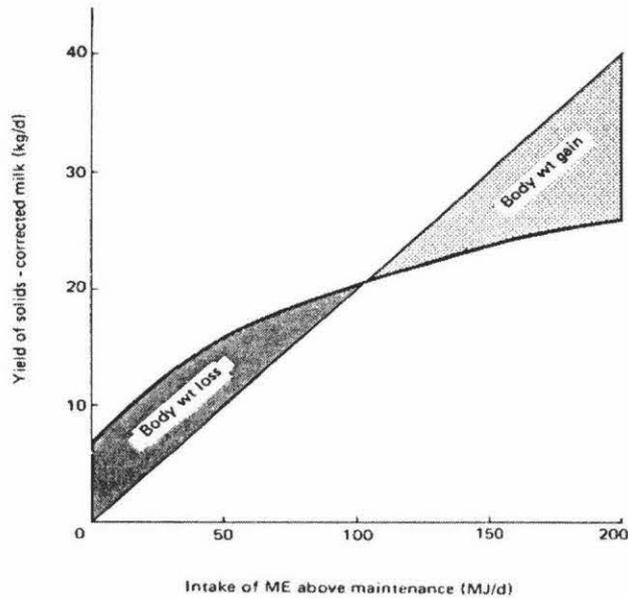


Figure 6.3 The effect of intake of metabolisable energy (ME) on milk output and liveweight change (Broster & Thomas, 1981).

Another explanation for the differences in feed conversion efficiency between the two groups might be that the farms with higher milksolids production per cow were utilising the feed less efficiently, due to wastage. This might be reinforced by the lower average stocking rates of farms from Group one than of farms from Group two (Table 6.5). All these issues related to feed demand, pasture utilisation and animal performance are covered in detail in the literature review (see Section 2.2.2). Table 6.2 shows that the farms from Group one are the ones with greatest difference between estimated and required (theoretical) ME intakes, which may have been due partly to increased waste of feeds. A comparison between the theoretical $FCE(ME)_{md}$ and the measured values for the case study farms showed that the mean value of $FCE(ME)_{md}$ of the case study farms from Group one was 16% lower than the mean theoretical feed conversion efficiency value for the same group (Table 6.5), whereas the mean value of

FCE(ME)_{md} of the case study farms from Group two was only 6% lower than the theoretical FCE(ME)_{md} for the same group (Table 6.5). Comparison between the two groups regarding economic farm surplus (EFS) did not show clear contrast, mean values being NZ\$3,069 for Group one and NZ\$3,085 for Group two. The financial analyses are discussed in more detail in Section 6.4.

Since feed waste was not measured but assumed for all case study farms, it was not possible to take this analysis further. The system of achieving higher production per hectare through higher animal performance represents a new management strategy for these farmers. They still need to improve their management skills in order to improve the whole system. The information analysed in this project shows that there is scope for further improvement in feed efficiency, mainly for the farms achieving higher animal performance.

6.4. FINANCIAL PERFORMANCE

6.4.1. Cost of milksolids production

The entrepreneur's profit is the difference between the price paid per kg of milksolids and the cost to produce the same unit, which included the cost of funds. Figure 5.20 shows that for the price of milksolids equal to NZ\$3.4/kg, only Farm 2 and Farm 7 would have made a small profit. For the remaining case study farms the cost of milk production would be higher than the price received. The value of NZ\$5.0 paid per kg of milksolids (MS) in the season 2000/2001 has been the highest value (adjusted for inflation) achieved since 1975 (LIC, 2001). For the season 2002/2003, a value of NZ\$4.2/kg MS is expected, which is approximately 16% lower than the 2000/2001 season. The historical and forecast information shows that the present high milk price (NZ\$5.0) will probably not be maintained.

The profit margin is a function of input prices, efficiency and product prices (Boehlje, 1993). As farmers have little, if any, control over milksolids prices, the emphasis should focus on cost of production. It is possible to decrease the cost of production of milksolids either by increasing yield with limited increase in total farm cost, or by decreasing total farm costs without affecting milk production.

Total farm cost is the sum of total operating expenses and cost of funds. Total operating expenses involves fixed and variable costs. Fixed operating costs, such as labour and management, are not easily decreased. There is more scope to decrease variable operating costs such as feeds or animal health. The fixed cost of funds is probably the most difficult to decrease, because the 6% of total assets assumed as the opportunity cost for the case study farms is a conservative value. The opportunity cost used by Dexcel in their productivity analysis is 9% (Shadbolt, 2001b). The best option to reduce cost of milksolids production might be to increase total yield from a small or nil increase in total farm costs. This could be attained through a better utilisation of the feed available in the system at high levels of animal performance (see Section 6.3.2.2 and Section 6.3.6) or by increasing the quantity of feeds. This topic leads to a new discussion of production curve and marginal returns (see Section 6.4.2).

6.4.2. Production function

The “quasi” production curve expresses the overall trend for the eight case study farms, of the amount of output (annual milksolids production per hectare) that would be produced by using different input levels (annual total dry matter intake per hectare by milkers) (Figure 6.4). An economically viable increase in milk yield from a small increase in total farm costs is probably achievable through higher intakes of pasture and/or supplements, providing that the cost of extra feed is lower than the marginal value product (MVP).

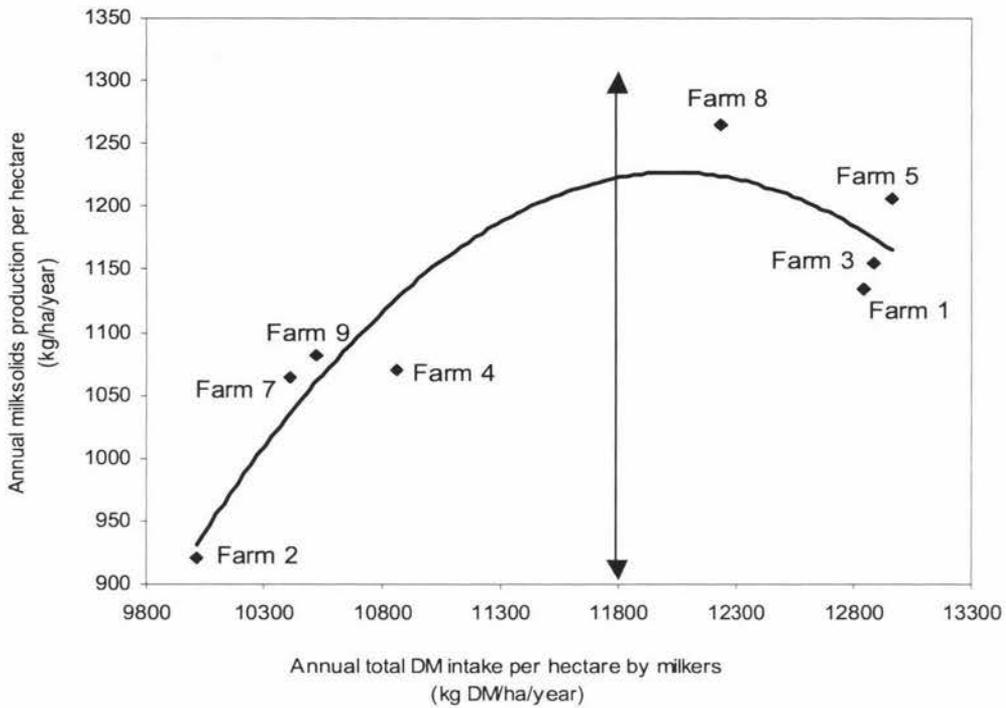


Figure 6.4 Simple quadratic regression for the variables MS/H and TDM/Hm, involving the eight case study farms utilised for the financial analysis.

Firstly, considering the option to increase the quantity of supplementary feed in the system, a marginal input cost of NZ\$0.18/kg DM was assumed. Appendix 5.13 shows the marginal income received (MVP) from using an additional unit of input. The “quasi” production curve across all farms shows that 11,800 kg DM/ha/year is the maximum input level where the additional income received from using one more unit of input exceeds the additional cost of supplement input (NZ\$0.18/kg DM) (Kay & Edwards, 1994). Using more than 11,800 units of input makes the additional income (MVP) lower than the additional cost. It is important to remember that the marginal analysis (Appendix 5.13) was based on a milk payment of NZ\$5.0/kg MS, which will probably not be maintained in the future. Considering the maximum input level as 11,800 kg DM/ha/year, the eight farms could be divided into two groups: those with total intake lower than 11,800 kg DM/ha/year (Group A) and intake higher than 11,800 kg DM/ha/year (Group B).

Total feed intake and pasture intake per hectare are lower in farms of Group A than in farms of Group B (Table 6.8). Therefore, there is scope to increase pasture or supplementary feed intake per hectare for farms of Group A (Figure 6.4). A possible option to increase pasture production is by nitrogen application. The average nitrogen used among all case study farms was 125 kg N/ha/year, ranging from 80 to 150 kg N/ha/year. As discussed in the literature review (see Section 2.2.1), 200 kg N/ha/year was a profitable option (Penno *et al.*, 1996) with low risk of ground water contamination (Clark, 1997). Therefore, the case study farms could invest in nitrogen application in order to increase pasture production. Supplementary feed might also be a satisfactory option to increase total feed intake, mainly for Farms of Group A (except Farm 4), which do not use more supplementary feed than the average of all case study farms (Table 6.8). The farms of Group B (except for Farm 5) used more supplementary feed than the average for all farms (Table 6.8).

Table 6.8 Total feed intake by milkers (kg DM/ha/year), pasture intake by milkers (kg DM/ha/year), stocking rate (cows/ha), cost of milksolids production (NZ\$/kg MS) and proportion of supplementary feed used from annual total dry matter intake by all cows (%), for all case study farms.

Farms	Total intake	Pasture intake	Stocking rate	Milksolids cost	Supplements
Group A					
Farm 2	10,012	9,571	2.4	3.34	22
Farm 4	10,857	9,562	2.6	3.83	27
Farm 7	10,411	9,653	2.7	3.18	25
Farm 9	10,523	10,062	2.9	3.79	24
<i>Mean</i>	<i>10,451</i>	<i>9,712</i>	<i>2.6</i>	<i>3.53</i>	<i>25</i>
Group B					
Farm 1	12,839	10,668	2.7	3.45	28
Farm 3	12,883	11,200	2.7	3.77	26
Farm 5	12,962	12,070	2.8	3.37	22
Farm 8	12,232	11,262	3.0	3.68	26
<i>Mean</i>	<i>12,729</i>	<i>11,300</i>	<i>2.8</i>	<i>3.56</i>	<i>26</i>
<i>Overall mean</i>	<i>11,590</i>	<i>10,506</i>	<i>2.7</i>	<i>3.55</i>	<i>25</i>

As an example, Farm 2 and Farm 5 are compared. They used the same proportion of supplementary feed and had a very similar cost of milksolids production (Table 6.8). However, the annual milksolids production per hectare of Farm 2 (921 kg) was much lower than Farm 5 (1206 kg) (Table 5.4). The same applied to annual milksolids production per cow for Farm 2 and Farm 5 (390 and 424 kg, respectively) (Table 5.4). Therefore, the economic farm surplus per hectare of Farm 5 was 46% higher than Farm 2 (Table 5.10). These facts may be related to a better efficiency in pasture utilisation as revealed by the 26% higher pasture intake per hectare by milkers of Farm 5, when compared to Farm 2 (Table 6.8). Therefore, there is probably an opportunity to improve production per hectare and consequently farm profitability, through higher stocking rate in Farm 2, which is approximately 14% lower than Farm 5.

Farm 8 had the highest stocking rate (Table 6.8) the lowest annual total intake per hectare and the highest annual milksolids production per hectare, among farms from Group B (Figure 6.4). The combination of high annual milksolids production per hectare and low annual intake per hectare resulted in the highest feed conversion efficiency of all cows across all case study farms and highest feed conversion efficiency of milkers among farms of Group B (Figure 5.8). The financial key performance indicator values showed that Farm 8 had higher economic farm surplus per hectare and higher operating profit margin than Farm 1 and Farm 3 (Table 5.10). The opposite was true when comparing Farm 8 and Farm 5, where the latter had higher values of economic farm surplus per hectare and higher operating profit margin (Table 5.10). The reason is probably due to lower cost of milksolids production of Farm 5 (Figure 5.20), which could be a consequence of lower cost of dry matter and metabolisable energy (Figure 5.21) and/or lower quantity of supplementary feed associated with higher pasture intake (Table 6.8), which implies better utilisation of the fixed cost of land. Regarding annual milksolids production per cow, Farm 8 had the lowest value among

farms of Group B (Table 5.4), which was probably caused by the lower intake per animal by milkers (Appendix 5.8), as a consequence of higher stocking rate.

A concluding remark for this section is that higher performance of farms from Group A could be achieved through higher pasture and/or supplement intakes (Table 6.8). On the other hand, Farms from Group B (excluding Farm 8) could achieve higher performance through a more efficient feed utilisation, considering that they are included in the earlier Group one which has the lowest feed conversion efficiencies (see Section 6.3.6).

6.4.3. Comparisons between the case study farms and industry data

The average economic farm surplus per hectare (EFS/H) for all case study farms was higher than the mean for Manawatu (by 62%), Waikato (by 78%) and Taranaki (by 84%) regions (Table 6.9). Gross farm income per hectare was approximately 35% higher than the average for Manawatu region (Table 6.9). The average operating profit margin of 51% obtained by the case study farms means that for every NZ\$100 of gross farm income, NZ\$51 are retained as operating profit, which is higher than the NZ\$42 retained by the farms from Manawatu region (Table 6.9). The return on assets of 12.9% for the case study farms means that for every NZ\$100 of assets, approximately NZ\$13 is earned, which is higher than all industry averages and top 10% farms (Table 6.9). These values show that the case study farms are making good use of their assets.

The comparison with industry data shows that the case study farms can be classified as highly profitable dairy systems in New Zealand, at least under the conditions of 2000/2001 season.

Table 6.9 Gross farm income per hectare (GFI/H), economic farm surplus per hectare (EFS/H), return on assets and operating profit margin (EFS/GFI), for the case study farms and regional averages (LIC, 2001; MAF, 2001; Dexcel, 2002, personal communication).

	Manawatu region			Waikato region*	Taranaki region*			
	Case study farms			MAF	Economic survey			
	Mean	Max	Min	Mean	Mean	Top 10%	Mean	Top 10%
GFI/H (NZ\$)	6,062	6,813	5,127	4,501	-	-	-	-
EFS/H (NZ\$)	3,077	3,867	2,425	1,895	1,729	3,235	1,668	2,879
Return on assets (%)	12.9	14.4	10.0	11.6	8.5	11.8	9.3	12.8
EFS/GFI (%)	51	57	45	42	-	-	-	-

* Waikato and Taranaki data were used because data from Manawatu were unavailable.

CHAPTER 7

CONCLUSIONS

The results from the present case study among nine dairy farms in the Southern North Island of New Zealand showed that these systems, based on high production per hectare through high animal performance, were effective and profitable, at least under the conditions of 2000/2001 season. The average annual milksolids production per effective area (1,100 kg MS/ha/year) and per cow (411 kg MS/cow/year) for the case study farms were 49% higher than the national average (LIC, 2001) and also higher than the top 10% farms in Waikato and Taranaki region.

The average economic farm surplus per hectare for all case study farms (NZ\$3,077) was higher than the mean values for Manawatu (62%), Waikato (78%) and Taranaki (84%) regions. The mean value of 51% operating profit margin for the case study farms was also greater than the mean value of 42% for the Manawatu region. The mean return on assets (12.9%) for the case study farms was greater than the top 10% farms for the Waikato and Taranaki regions. On average, the case study farms can be classified as highly productive and profitable dairy systems in New Zealand.

Good pasture management based on the use of controlled pre and post grazing herbage mass targets, strategic use of supplementary feed to control pasture deficits and moderate stocking rates (overall mean 2.7 cows/ha), provided high allowances of high quality forage, creating the necessary conditions to achieve the objective of high performance per animal. The greater difficulty in pasture management during summer

and early autumn due to the onset of flowering and higher sward dry matter content, resulted in differences between the farmer's visual assessment and the adjusted data from plate meter readings during this period. This difference could be the result of underestimation of the available pasture dry matter by the farmers and/or overestimation by the rising plate meter which relied on standardised national monthly calibrations. The results suggest that herbage mass targets should be higher in summer than for other periods of the year.

The metabolisable energy intakes measured for the nine case study farms were higher than the calculated theoretical values. Again, this could be explained by the overestimation of dry matter offered to the animals. Alternatively, the case study farms could have been offering more feed to the animals than necessary, resulting in feed wastage. It was observed that the group of farms with the greatest difference between measured and theoretical values had the highest total metabolisable energy intake and in general, the highest milksolids production per animal, but the lowest feed conversion efficiency (average of 6.6 g MS/MJ ME intake by all cows and 8.0 g MS/MJ ME intake by milkers). The group of farms with the highest feed conversion efficiencies (average of 7.3 g MS/MJ ME intake by all cows and 9.0 g MS/MJ ME intake by milkers) had the lowest total measured intakes and in general, the lowest milksolids production per animal.

Pasture metabolisable energy (ME) intake had a high positive correlation with annual milksolids production per cow ($R^2 = 0.71$) and per hectare ($R^2 = 0.74$), probably because pasture represented 79% of total feed intake by milkers. On the other hand, supplement ME intake was not a statistically significant predictor variable to explain the variation of annual milksolids production per cow and per hectare. Supplementary feed was used in the case study farms to overcome pasture deficits, therefore, its effects were probably related to long term influences on pasture cover and body condition score.

For the price of NZ\$5.00/kg MS and a marginal input cost of NZ\$0.18/kg DM of supplements, the group production curve showed that the maximum input level, where the additional cost of input was marginally lower than the additional income received from an extra unit of input (NZ\$0.18/kg DM), was 11,800 kg DM/ha/year. This break-even point divided the farms into those with total intake lower (Group A) and higher (Group B) than 11,800 kg DM/ha/year. It was concluded that farms from Group A could achieve higher performance through higher pasture and/or supplement intakes. On the other hand, most farms from Group B could achieve higher performance through better feed utilisation, because they had the lowest feed conversion efficiencies. It is acknowledged that the sample size is small and that each farm has its own production curve, so care is needed in extrapolating from the group production curve. However, this is an useful tool to determine economic levels of efficiency for individual situations.

At the current milk payment of NZ\$5.00 per kg of milksolids, all case study farms had a good financial performance. However, this price is not likely to remain in the future. For the season 2002/2003, a value of NZ\$4.2/kg MS is expected, which is approximately 16% lower than the 2000/2001 season. Therefore, since farmers have little or no control over milk payments, control of production costs should receive more emphasis. This would be directly related to feed costs, therefore supplementary feed inputs, must be flexible in order to maintain a profitable system. Alternatively, more nitrogen could be applied in the case study farms, in order to control pasture deficits.

Finally, the accuracy of on-farm techniques used to measure feed intake, particularly pasture intake, require further improvement. The system of achieving higher production per hectare through a higher animal performance represents a new management strategy for these farmers and they need to improve their management skills regarding feed efficiency, mainly the systems achieving high levels of animal performance.

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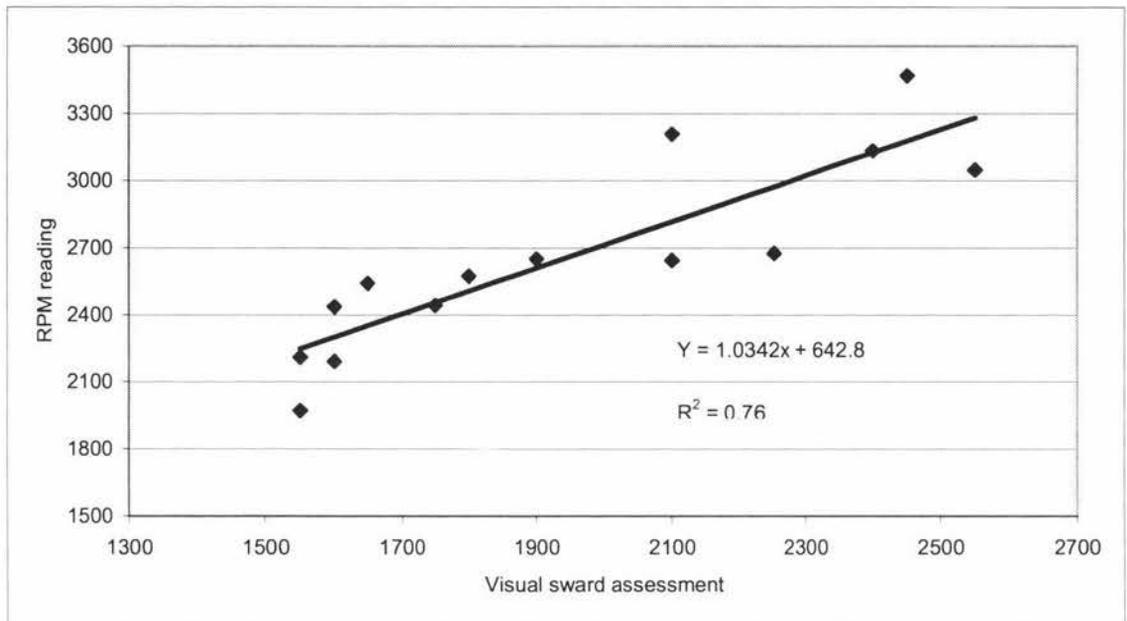
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APPENDICES

Appendix 4.1 Example of a monthly calibration regression between RPM reading (kg DM/ha) and visual sward assessment (kg DM/ha) for an individual farm (season 2000/2001).



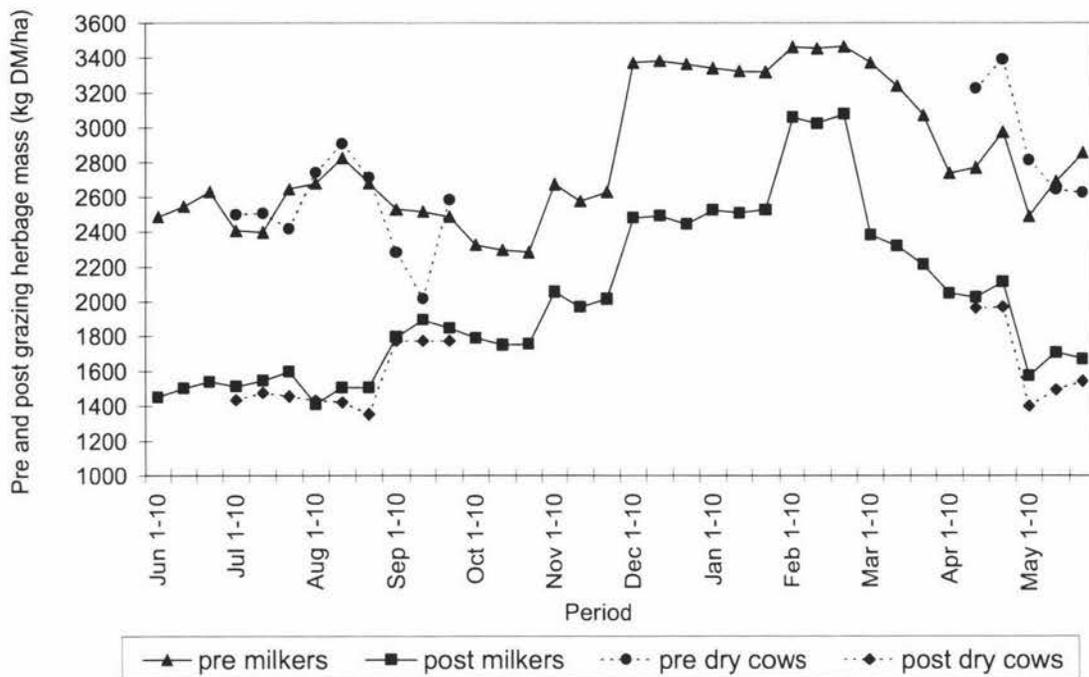
Appendix 4.2 Soil types and characteristics for all case study farms.

- Manawatu soils: well drained, Recent Soils from river alluvium, commonly on sand or gravel. They flood approximately every decade (Farms 4 and 6).
- Manawatu silt loam: Manawatu Soils with silt loam textured topsoil (Farms 2 and 8).
- Manawatu fine sand loam: Manawatu Soils with fine sand loam textured topsoils (Farm 5).
- Manawatu sand loam: Manawatu Soils with sand loam shallow topsoil. Drought prone (Farm 5).
- Manawatu sand loam gravelly phase: Manawatu Soils with gravel in the surface. Drought prone (Farm 5).
- Rangitikei soils: Recent Soils that normally flood every year and are well to excessively drained. Texture and depths vary considerably; tends to be drought prone (Farms 3, 4, 6 and 8).
- Rangitikei sand loam: Rangitikei Soils with sand loam topsoils (Farm 5).
- Parewanui soils: Recent Gley Soils that flood frequently and are poorly drained. May have sandy, silty or clayey texture (Farm 3).
- Kairanga soils: Recent Gley Soils that are poorly-imperfectly drained. They flood approximately every decade and are prone to pugging and compaction (Farms 2, 3 and 7).
- Kairanga fine sand loam: Kairanga Soils with sand loam topsoils (Farm 5).
- Kairanga silt loam: Kairanga Soils with silt loam textured topsoils (Farm 9).
- Kairanga peaty silt loam: Kairanga Soils with peaty silt loam textured topsoils (Farm 9).

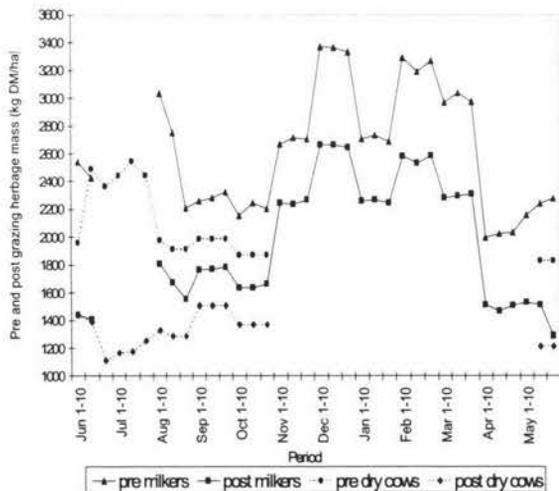
- Opiki soils: Recent Soils which flood approximately every decade. Imperfectly to moderately well drained. Alluvium interbedded with layers of peat (Farm 7).
- Matamau silt loam: generally imperfectly to poorly drained. Brown Soils that are developed in loess and other silt and clays with silt loam topsoils (Farms 1, 6 and 8).
- Matamau hill soils: generally imperfectly to poorly drained. Brown Soils that are developed in loess and other silt and clays on rolling to hilly slopes (15-25°) (Farms 1 and 8).
- Dannevirke silt loam: well drained Allophanic Brown Soils developed on loess and volcanic ash on terraces and gently rolling slopes. Excellent physical properties (Farm 6).
- Te Arakura soils: Gley Soils that do not normally flood. Poorly to imperfectly drained and found on river terraces that no longer flood (Farm 5).
- Puke puke soils: Gley Soils of the sand plains between dunes. Poorly drained with rising water table. Very sandy (Farm 3).
- Motuiti soils: Recent Soils of the dunes. Weakly developed topsoils and subsoils. Prone to wind erosion when disturbed (Farm 3).
- Foxton soils: Brown Soils of slightly older dunes. Thick topsoils and some B horizon development (Farm 3).
- Raumati soils: Gley Soils with poor drainage usually on colluvium (Farm 2).
- Himitangi soils: Recent Soils of the drier sand plains between dunes. Water table is not so high as in Puke Puke soils; soils are imperfectly drained. Very sandy (Farm 3).

Appendix 5.1 Adjusted pre and post grazing herbage mass (kg DM/ha) of milkers and dry cows, for each farm (season 2000/2001).

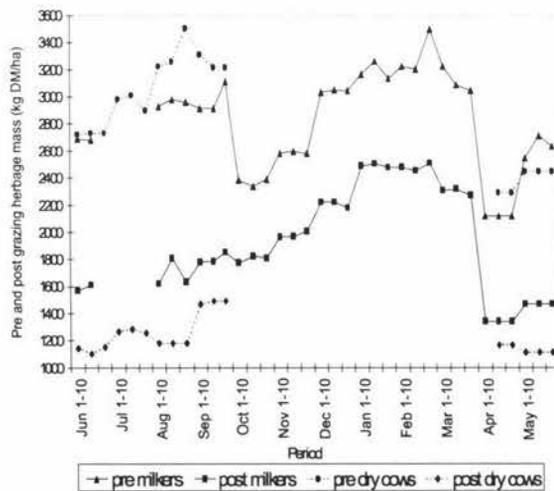
Farm 1



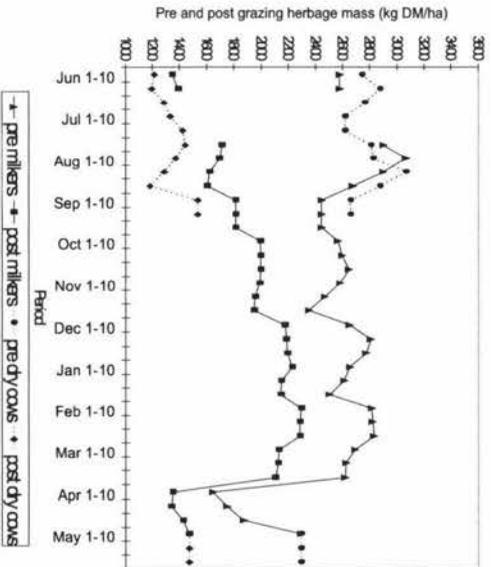
Farm 2



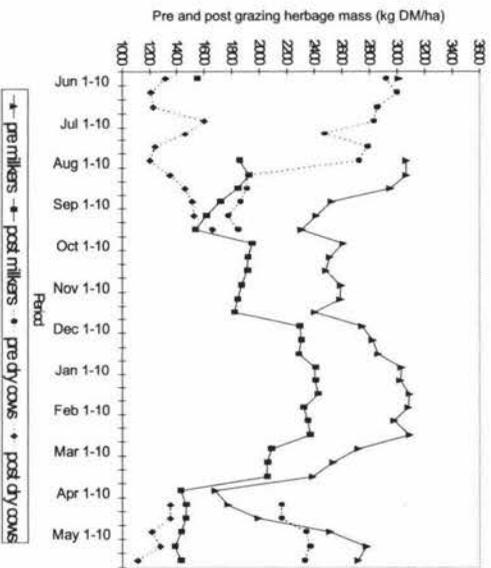
Farm 3



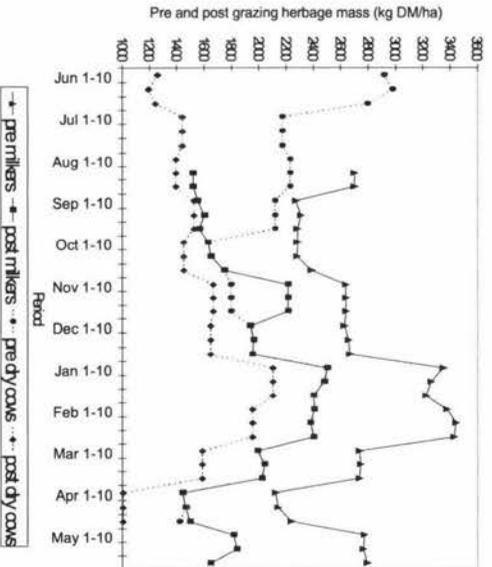
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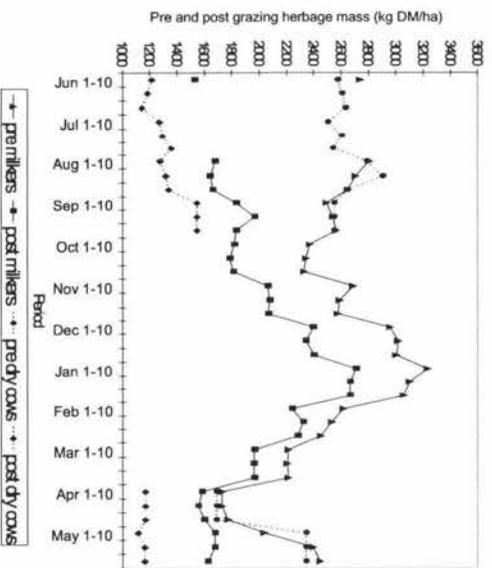
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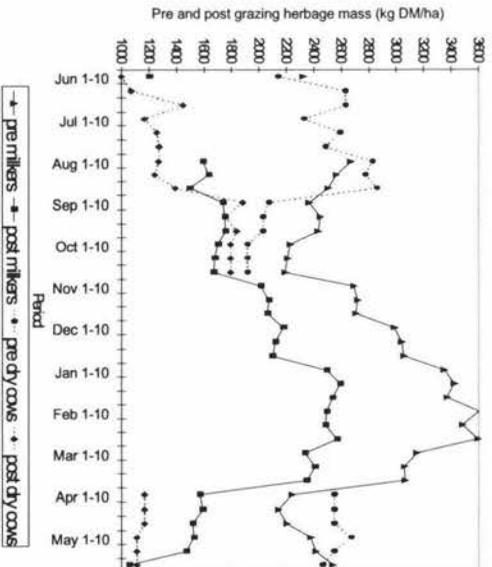
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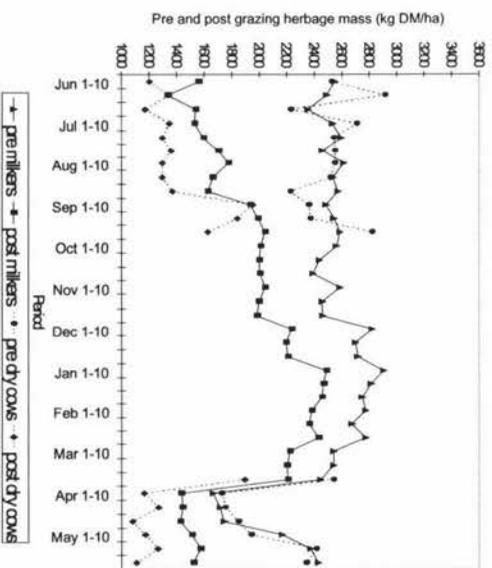
Farm 7



Farm 8

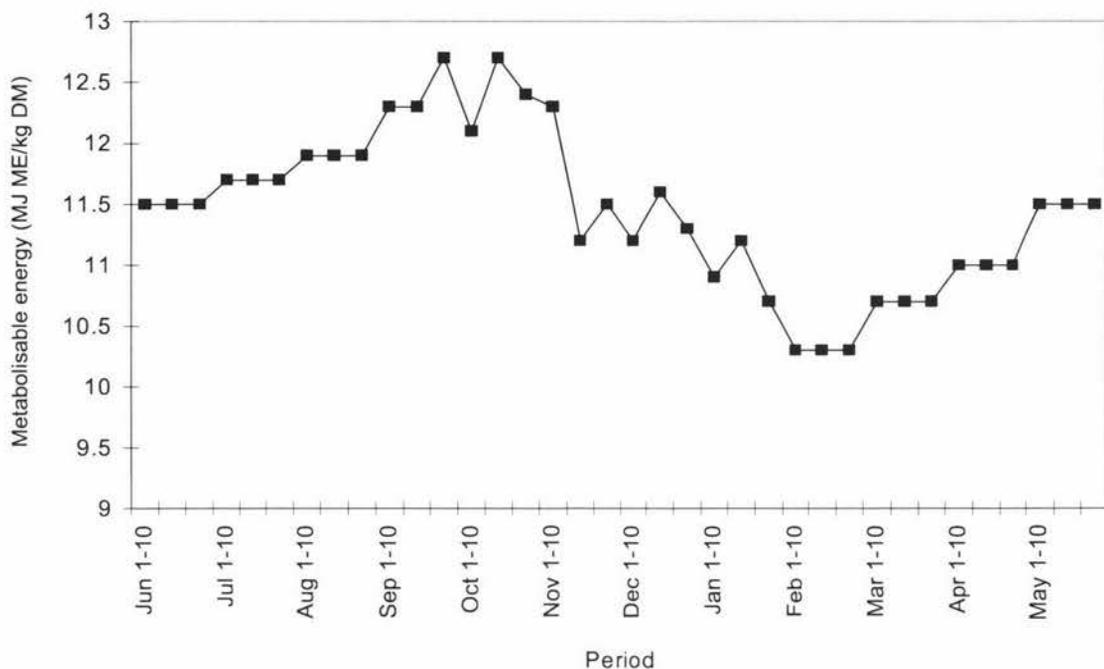


Farm 9

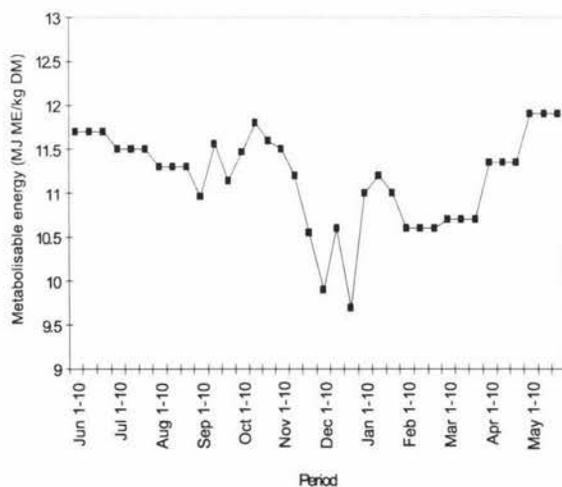


Appendix 5.2 Metabolisable energy concentration (MJ ME/kg DM) in pasture cut to grazing height, for each farm (season 2000/2001).

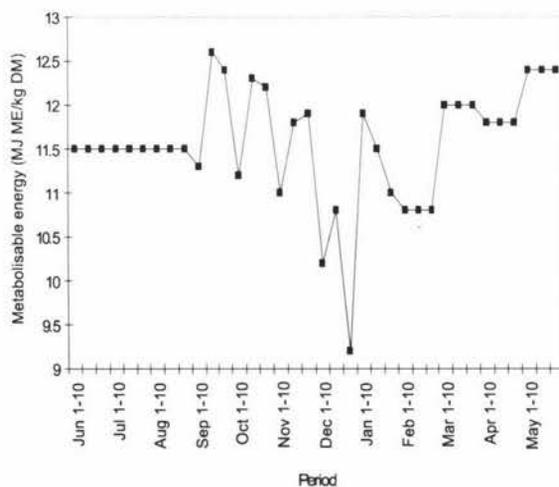
Farm 1

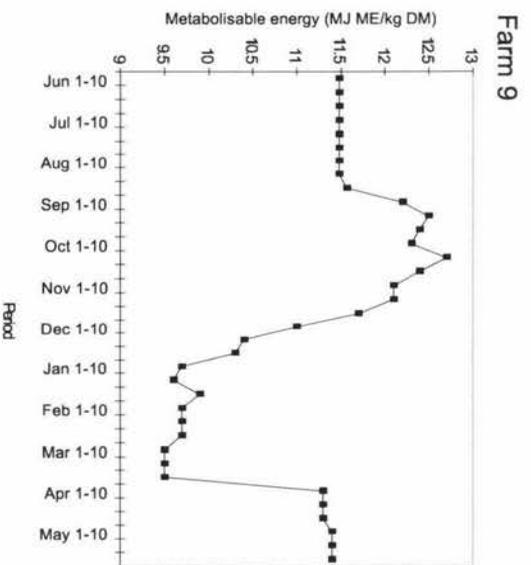
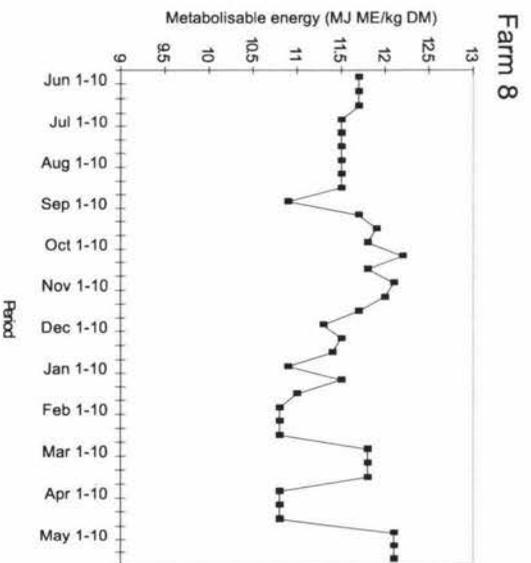
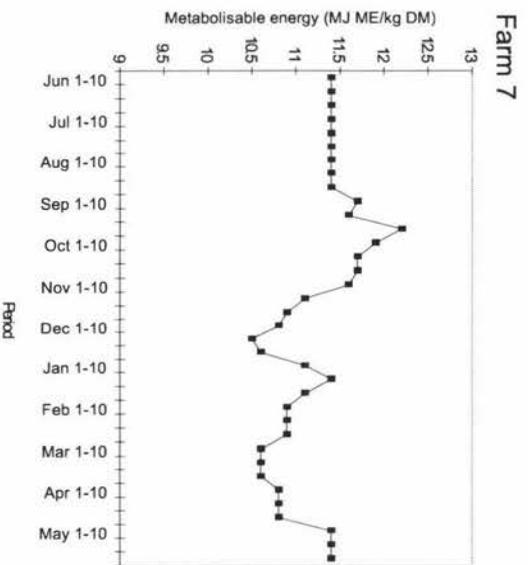
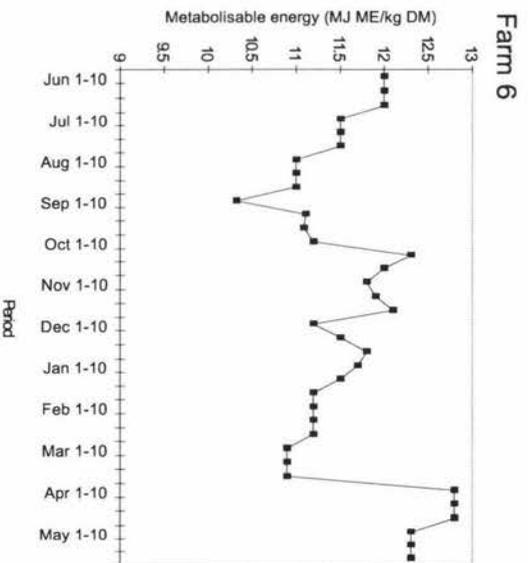
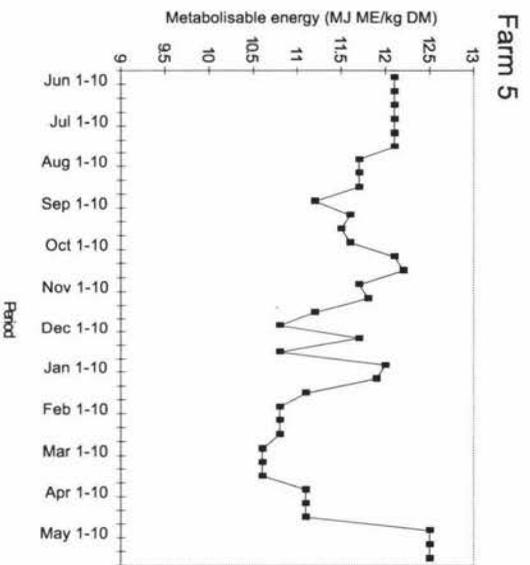
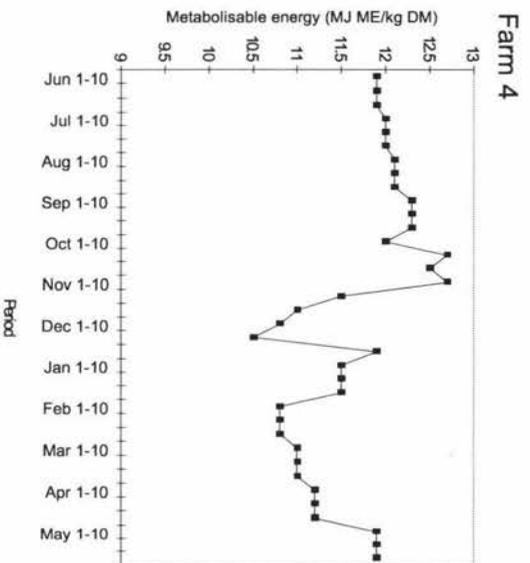


Farm 2



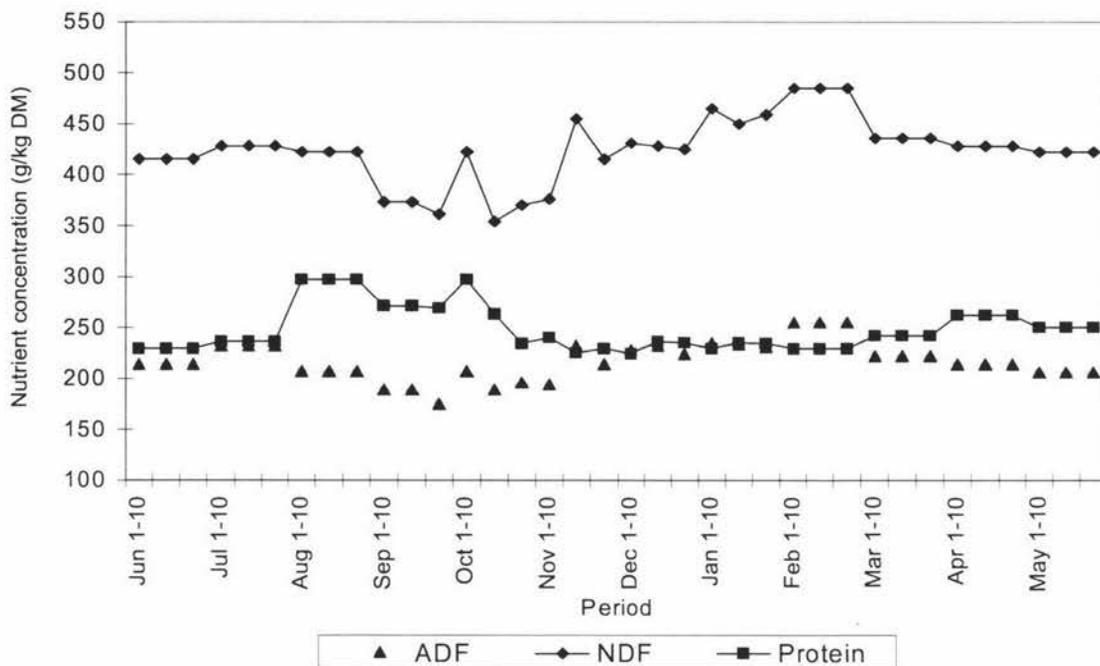
Farm 3



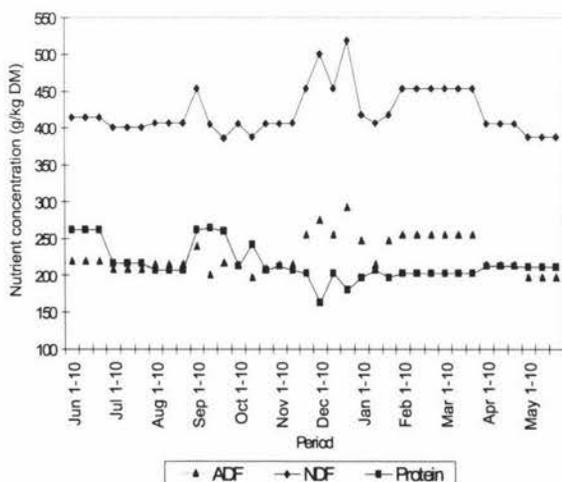


Appendix 5.3 Concentrations of crude protein, acid detergent fibre (ADF) and neutral detergent fibre (NDF) (g/kg DM) in pasture cut to grazing height, for each farm (season 2000/2001).

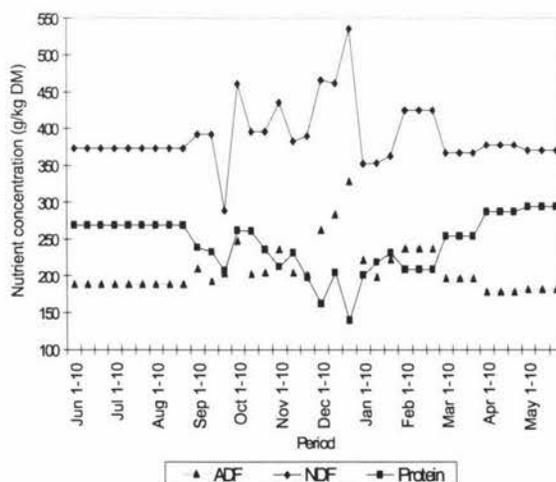
Farm 1



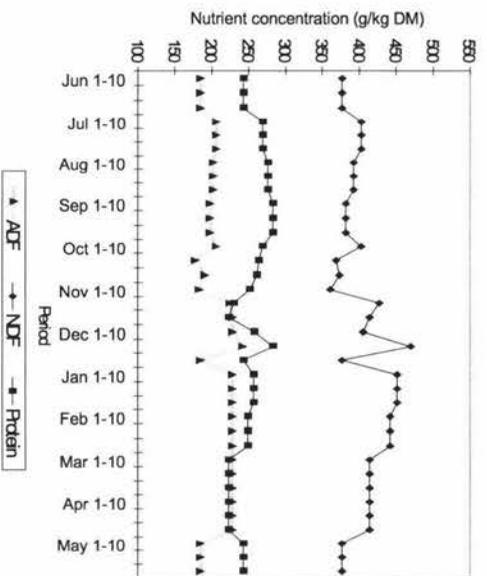
Farm 2



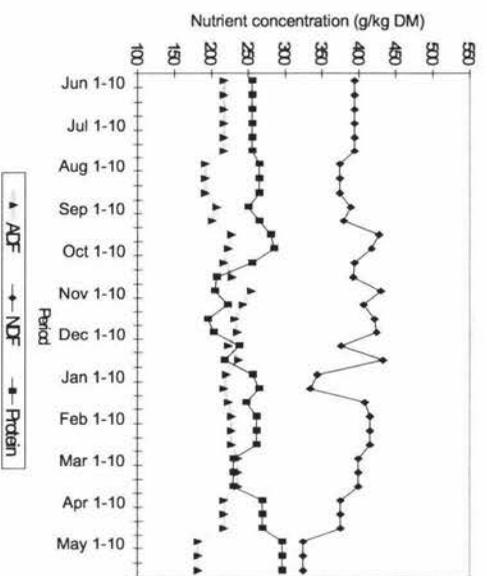
Farm 3



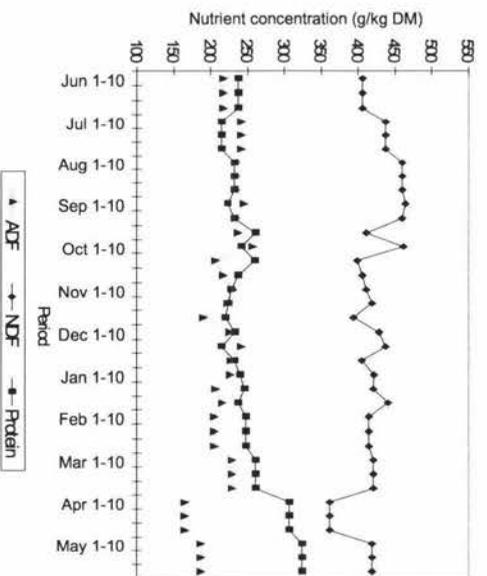
Farm 4



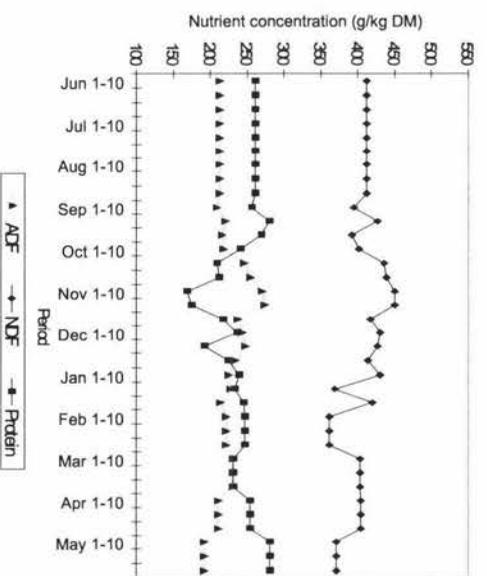
Farm 5



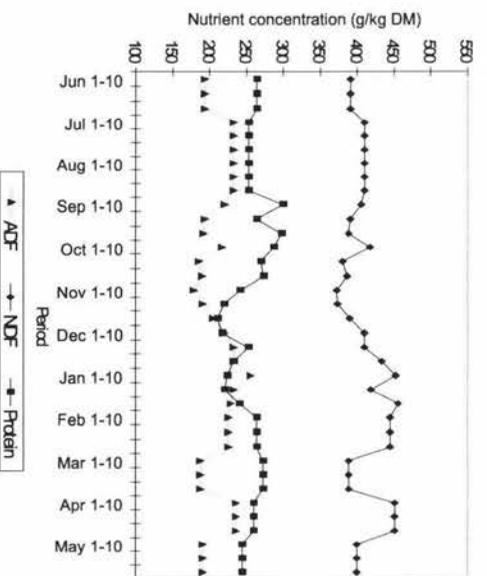
Farm 6



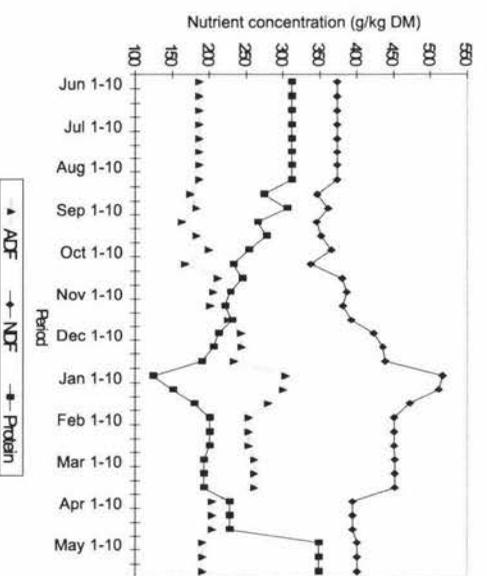
Farm 7



Farm 8

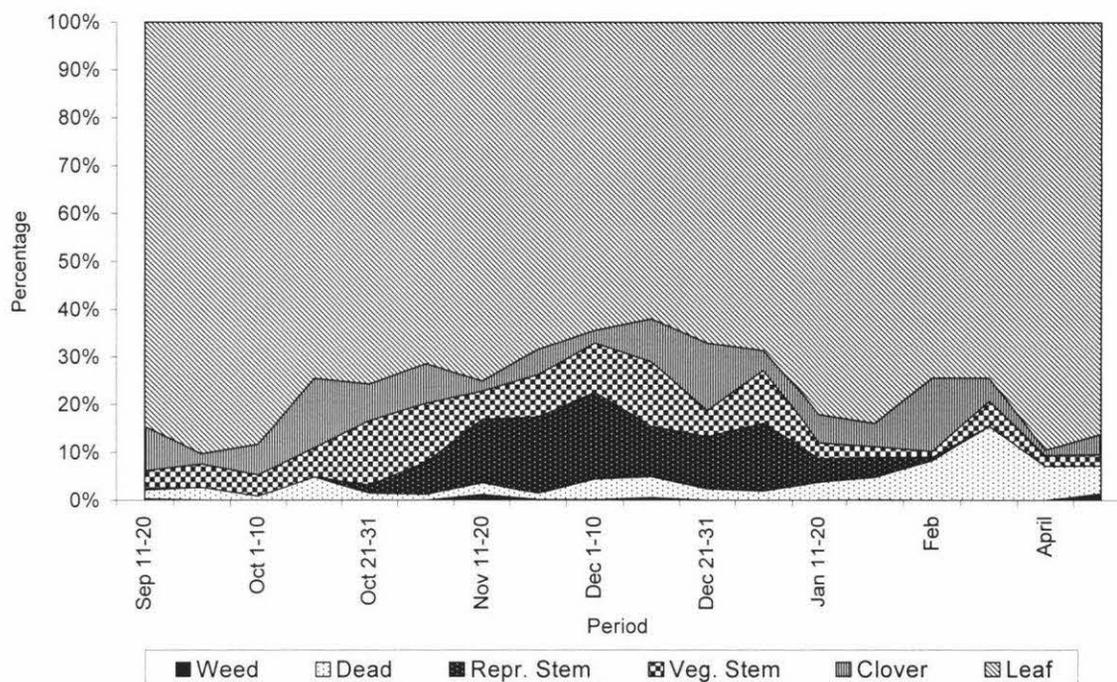


Farm 9

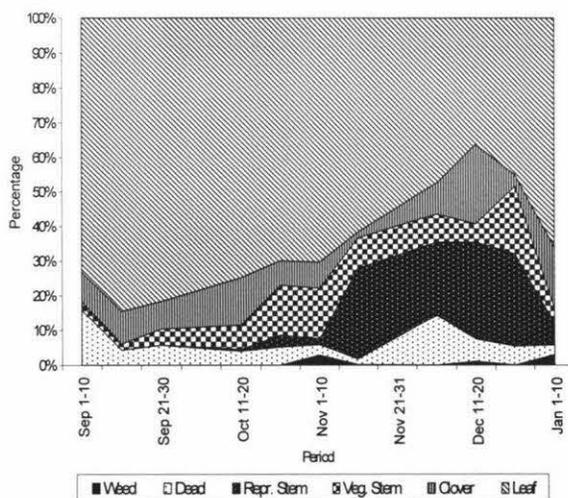


Appendix 5.4 Botanical composition of herbage cut to grazing height for each farm (season 2000/2001).

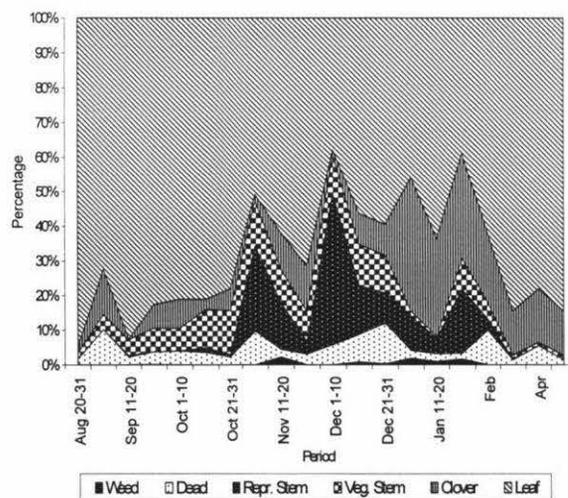
Farm 1



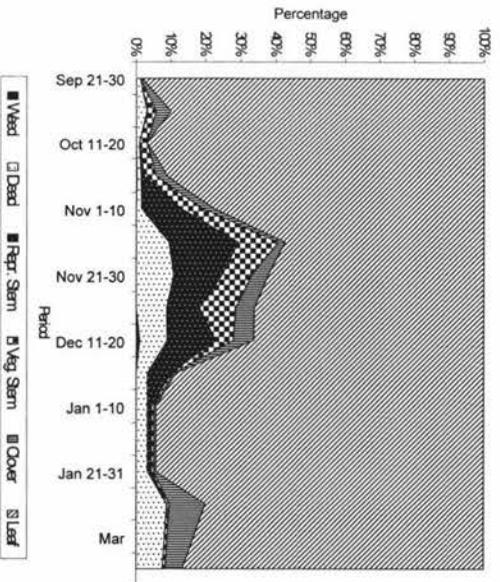
Farm 2



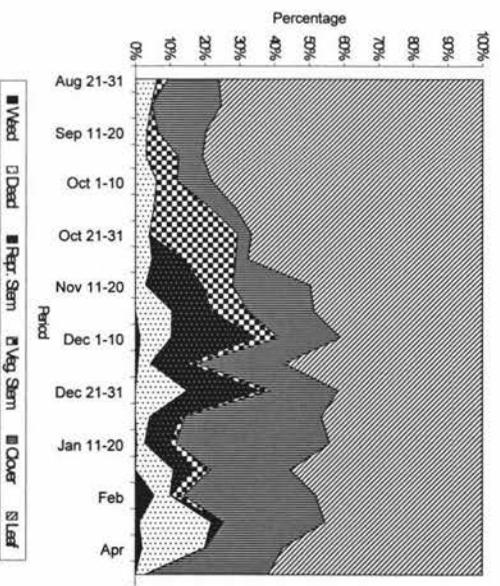
Farm 3



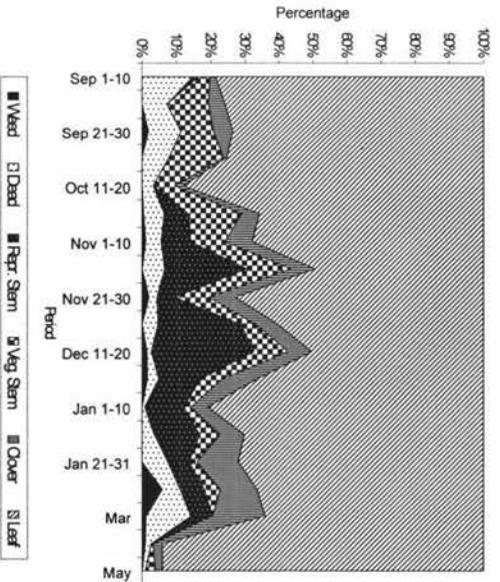
Farm 4



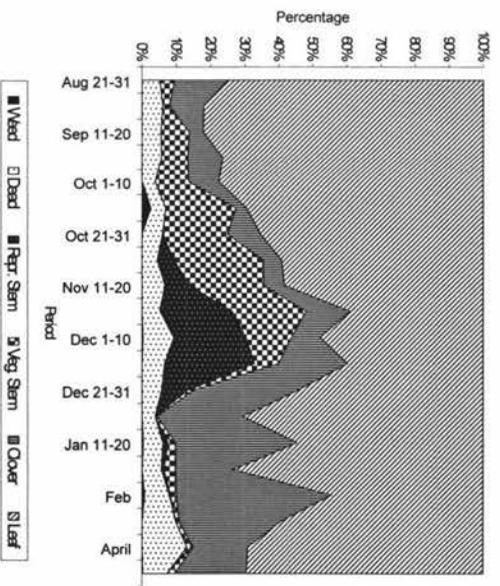
Farm 5



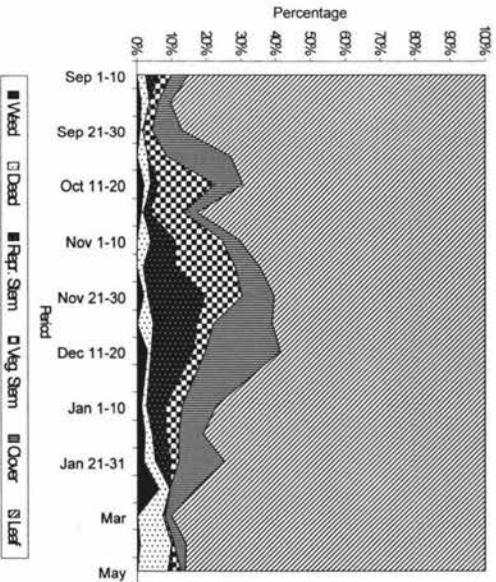
Farm 6



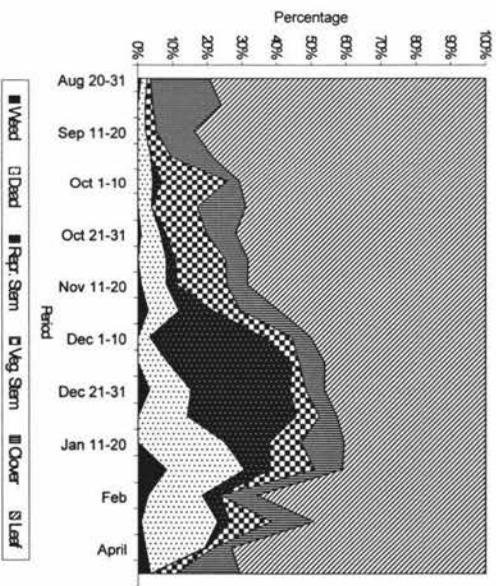
Farm 7



Farm 8

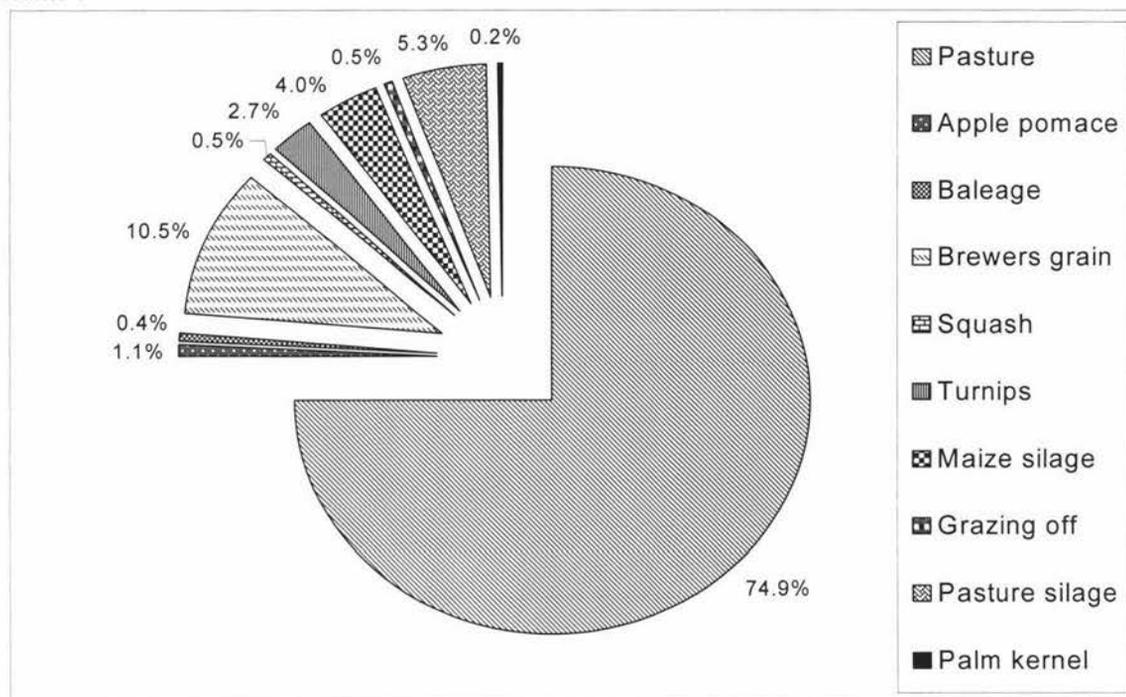


Farm 9

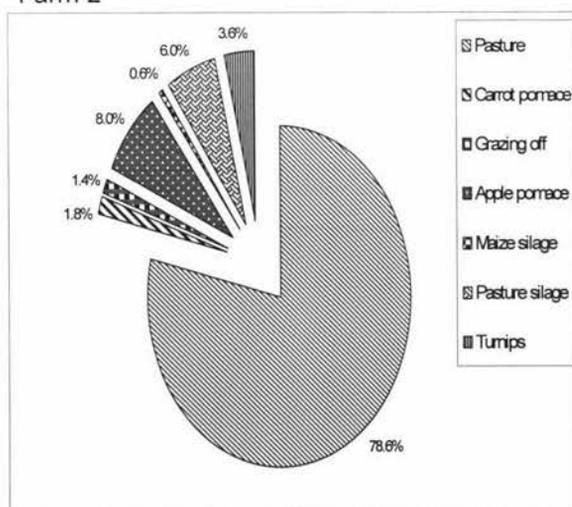


Appendix 5.5 Contribution of each feed to total feed intake (MJ ME) for the whole season (2000/2001), for individual farms. Some supplements used in particular farms were not plotted in the graphs, due to a very small proportion compared with total feed intake. They were: baleage (Farm 2, 0.1%), hay (Farms 2 and 5, 0.1% and 0.2%, respectively) and molasses (Farm 4, 0.05%).

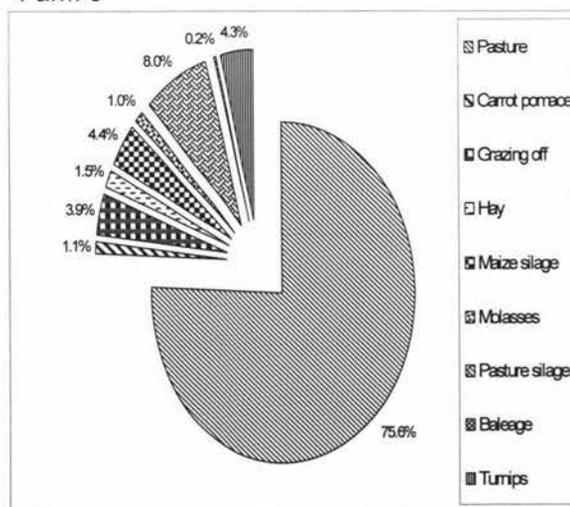
Farm 1



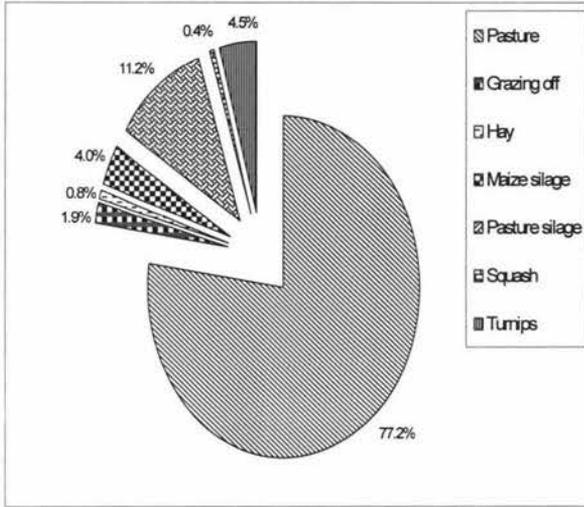
Farm 2



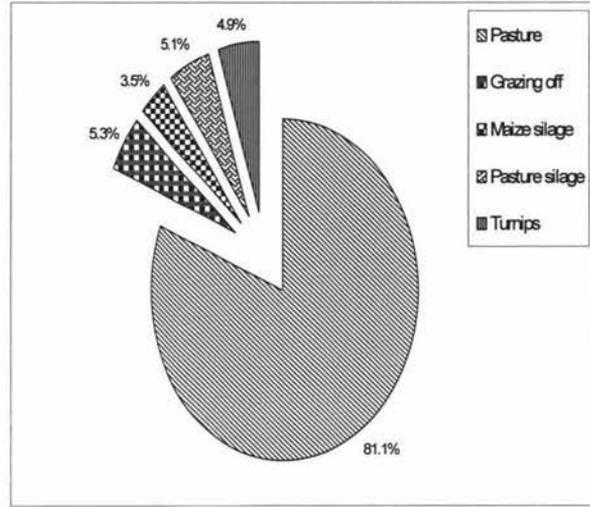
Farm 3



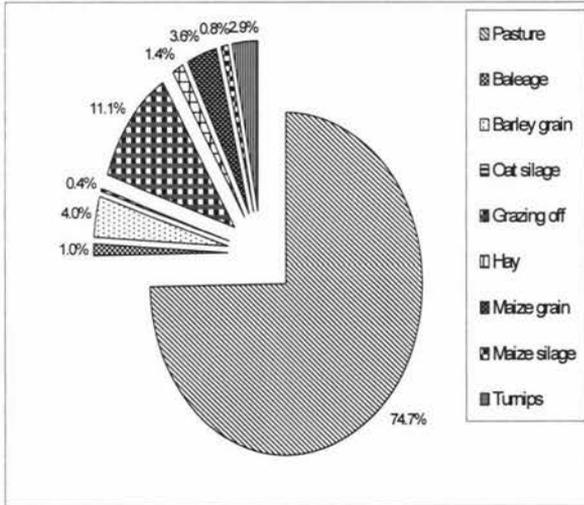
Farm 4



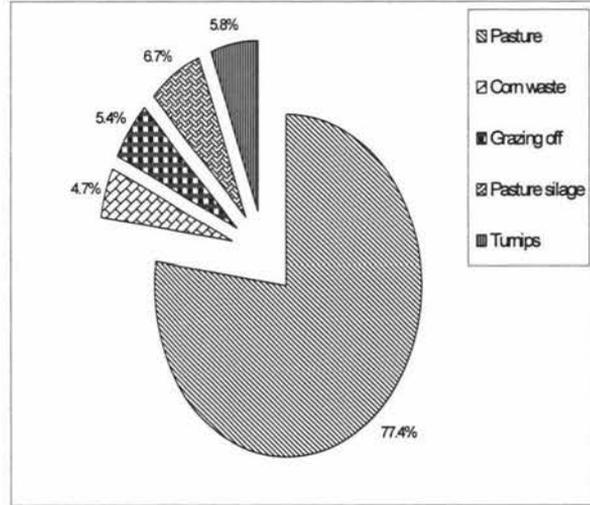
Farm 5



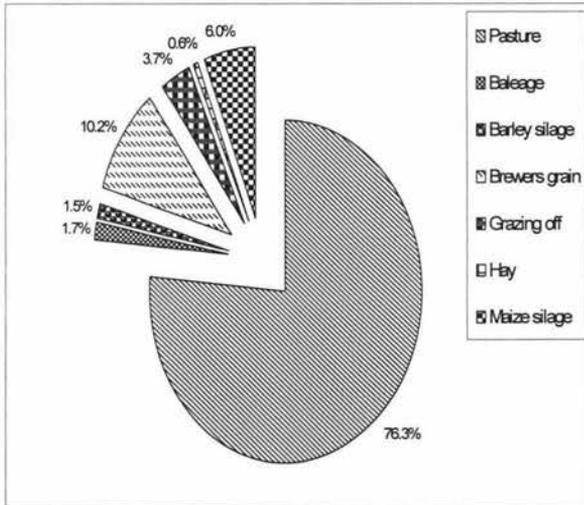
Farm 6



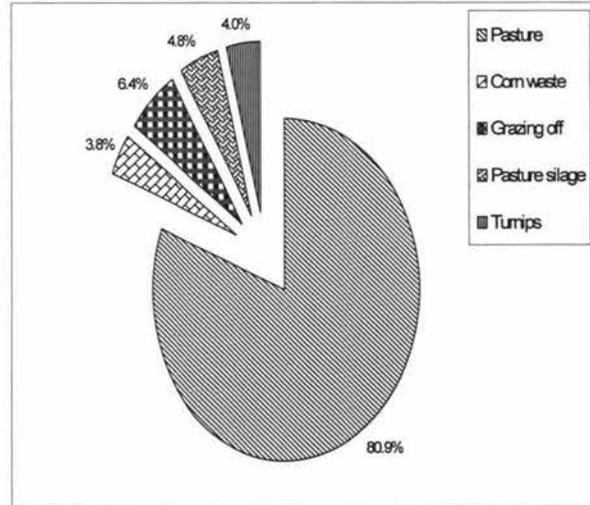
Farm 7



Farm 8

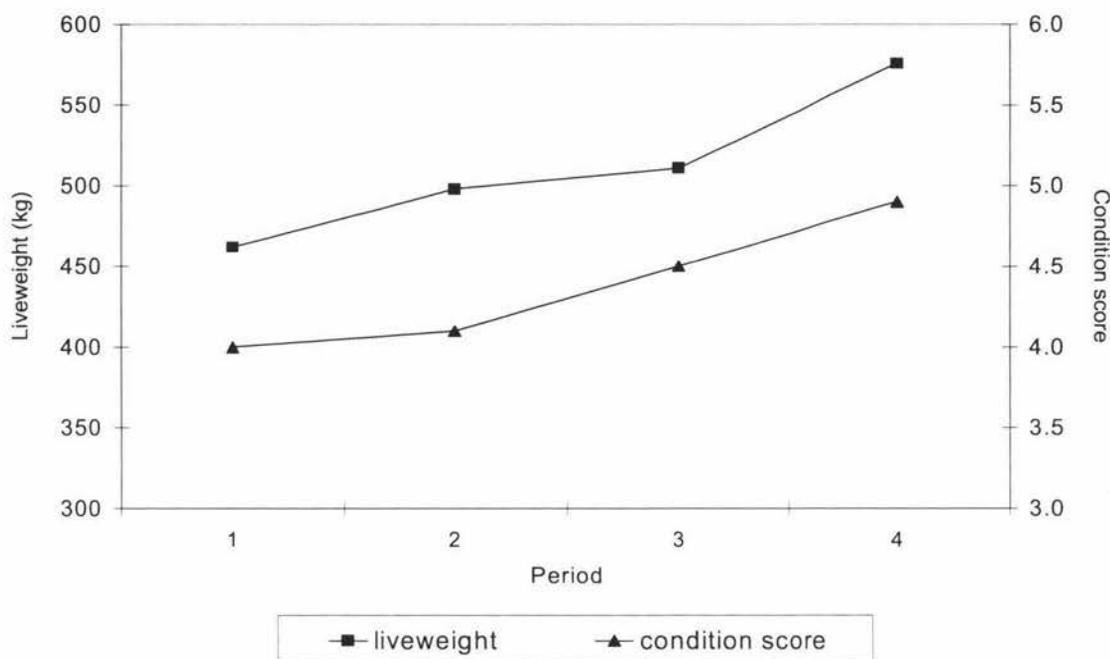


Farm 9

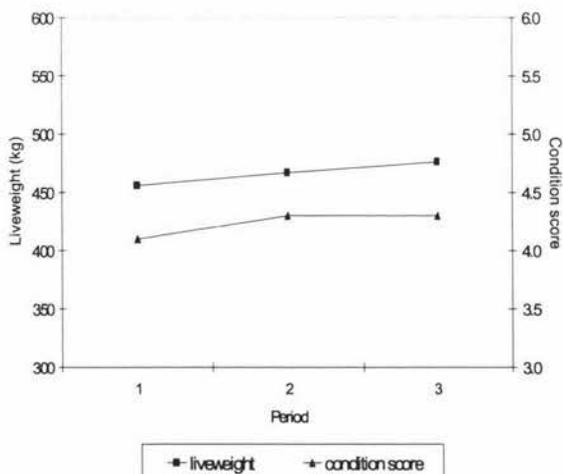


Appendix 5.6 Liveweight (kg) and condition score estimated from approximately 25% of the herd at four different periods (late September (1), late November (2), mid March (3) and late May/early June (4)), for each farm (season 2000/2001).

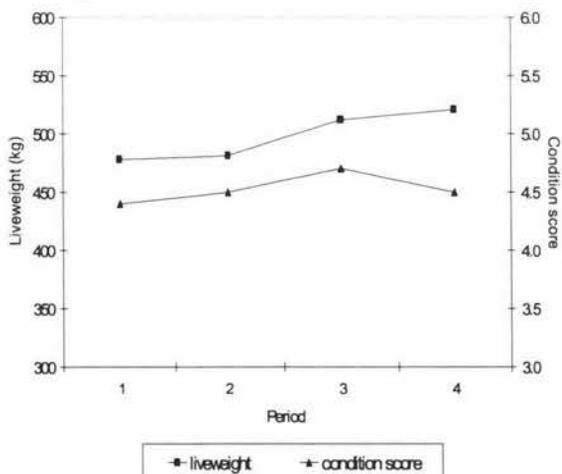
Farm 1



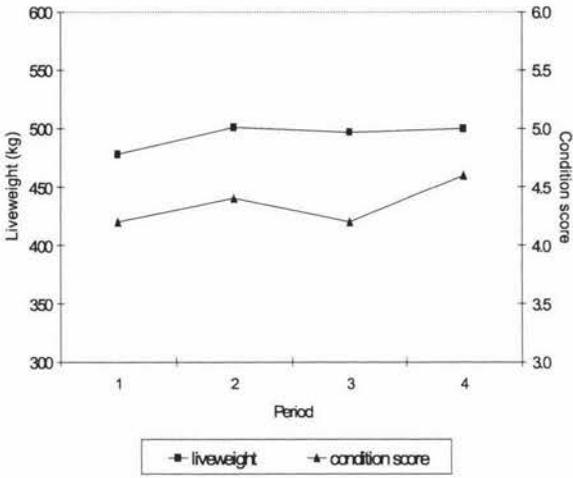
Farm 2



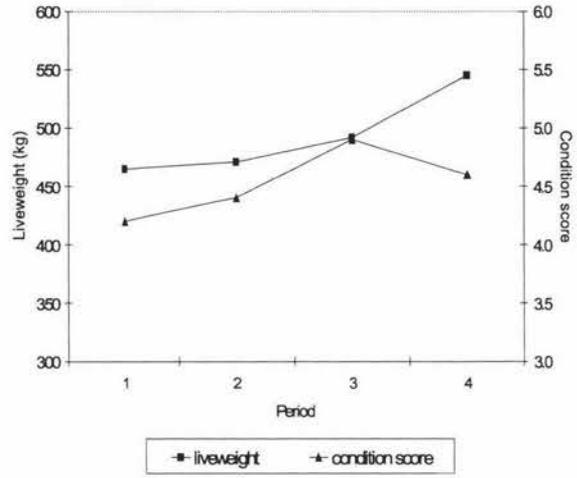
Farm 3



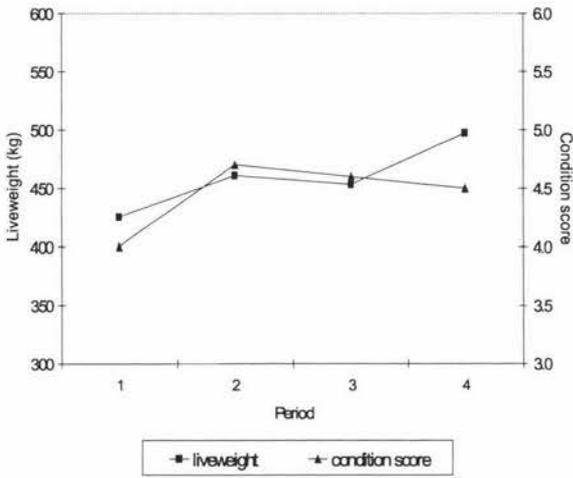
Farm 4



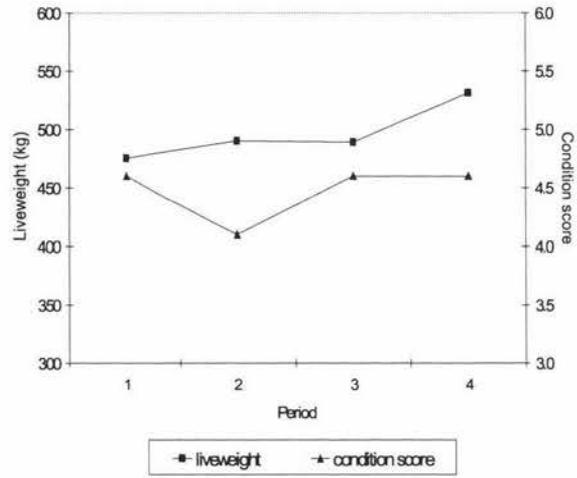
Farm 5



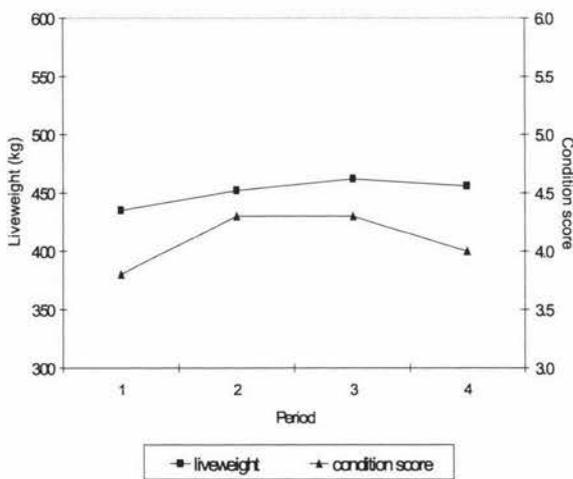
Farm 6



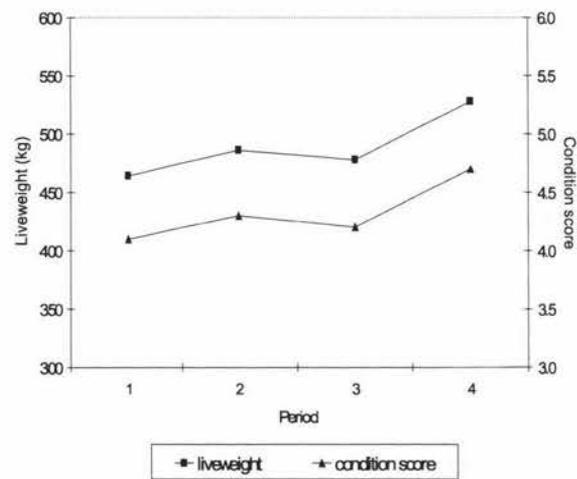
Farm 7



Farm 8

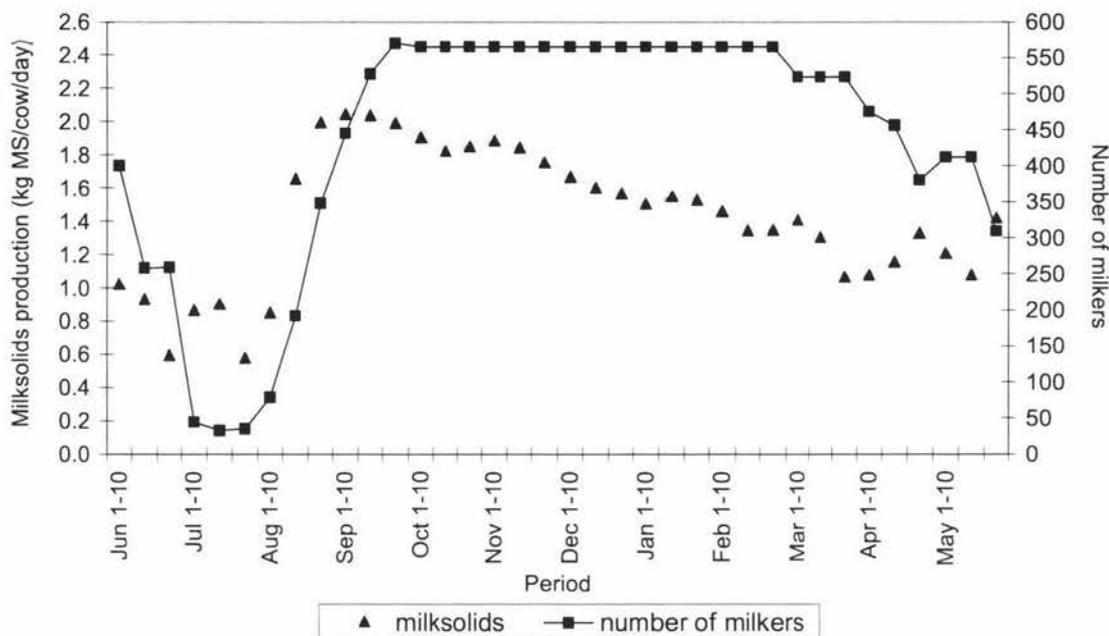


Farm 9

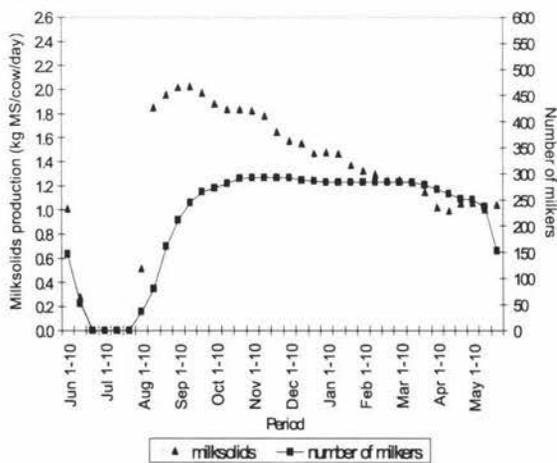


Appendix 5.7 Milksolids production per cow (kg MS/cow/day) and number of milkers for each farm (season 2000/2001) (averages of 10-day periods).

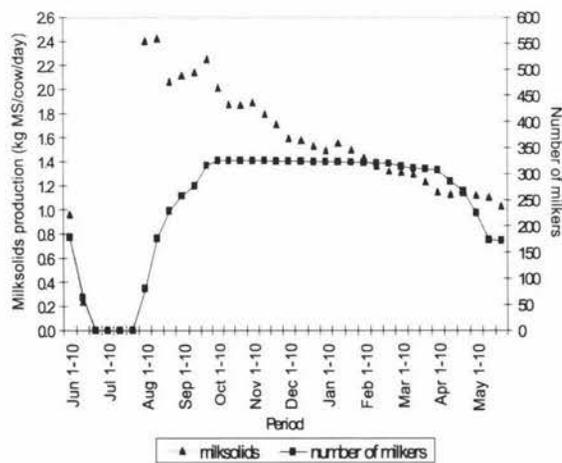
Farm 1



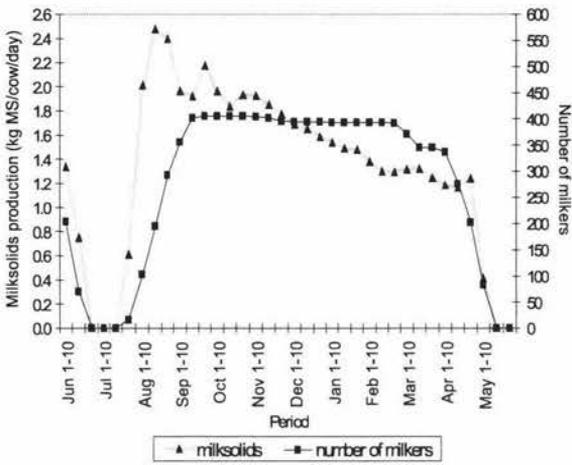
Farm 2



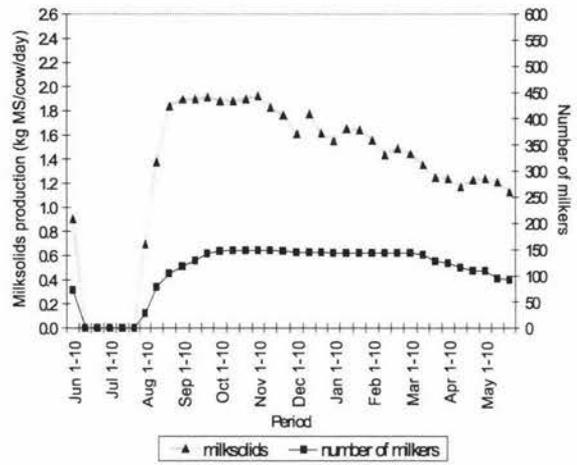
Farm 3



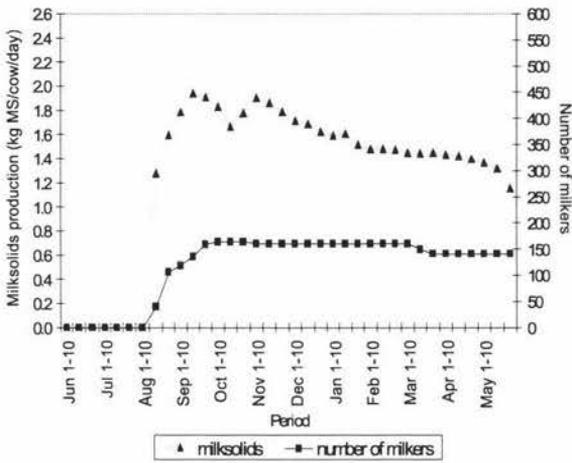
Farm 4



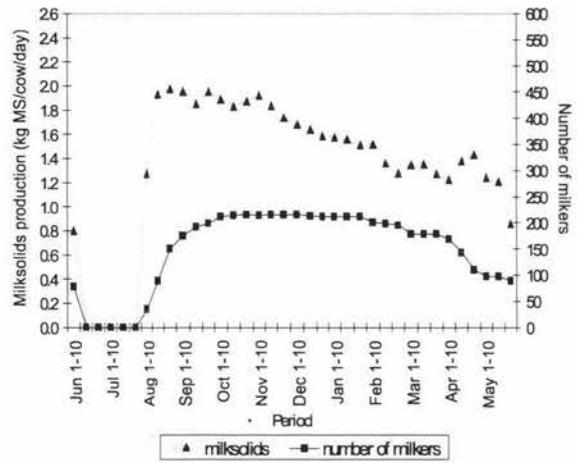
Farm 5



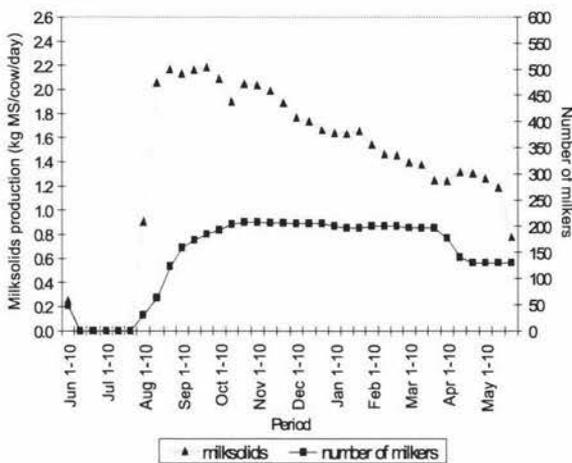
Farm 6



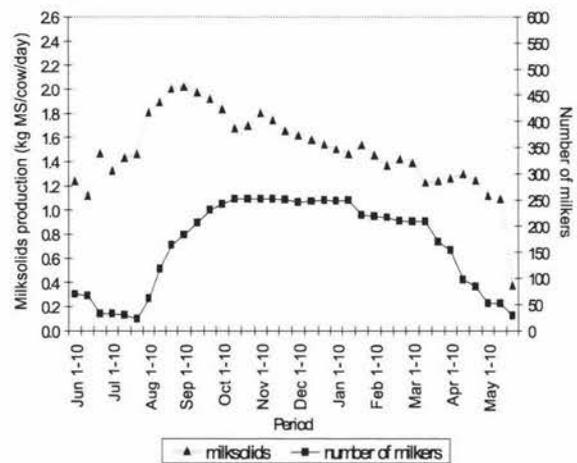
Farm 7



Farm 8

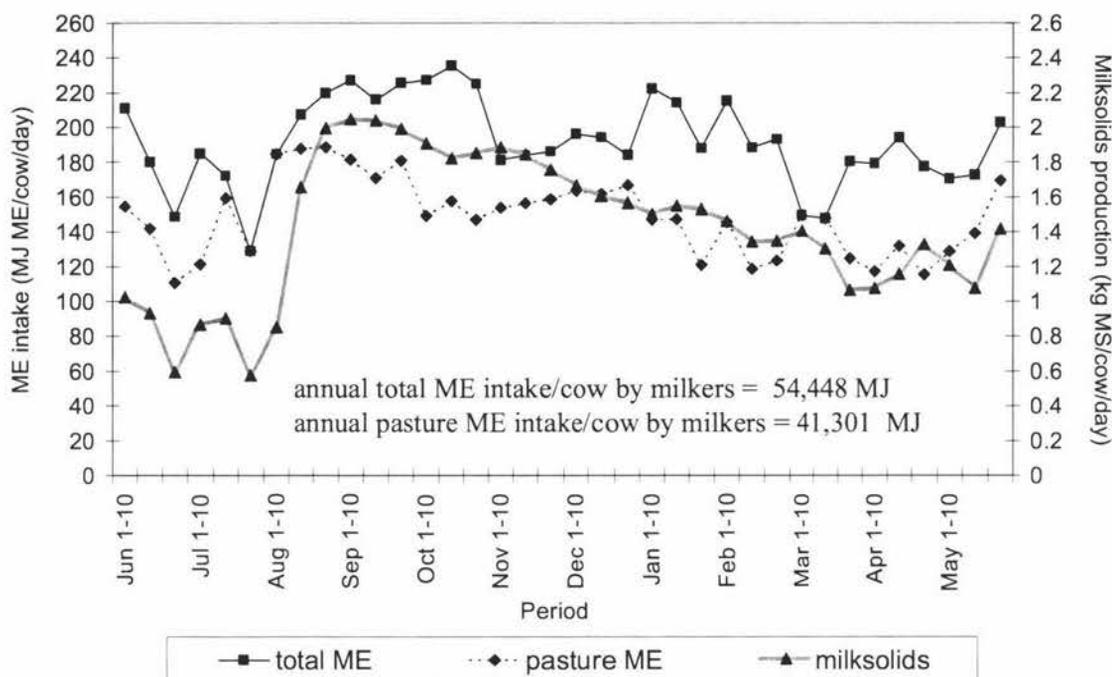


Farm 9

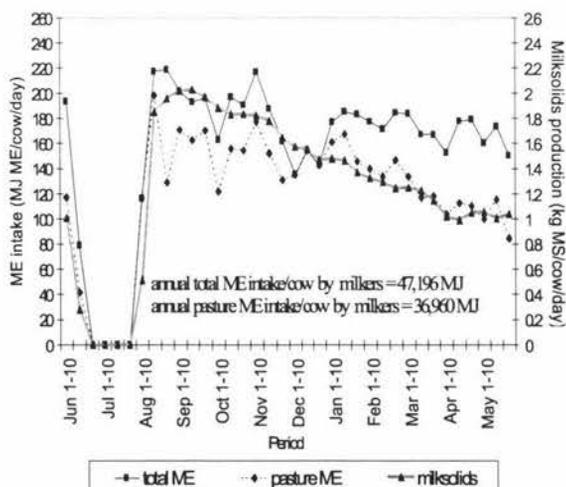


Appendix 5.8 Total feed intake (pasture plus supplement) per cow by milkers (MJ ME/cow/day), pasture intake per cow by milkers (MJ ME/cow/day) and milksolids production per cow (kg MS/cow/day), for each farm (season 2000/2001) (averages of 10-day periods).

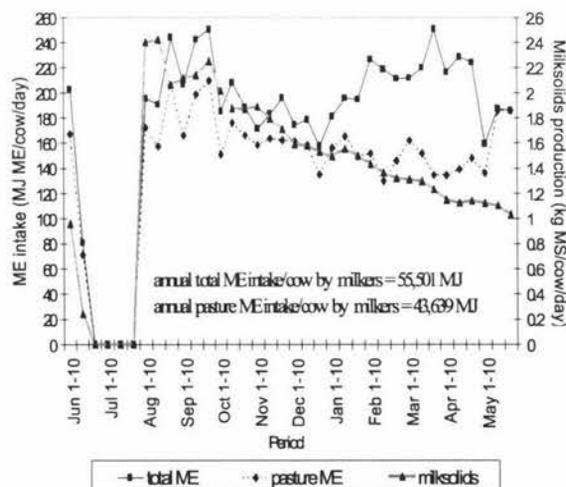
Farm 1



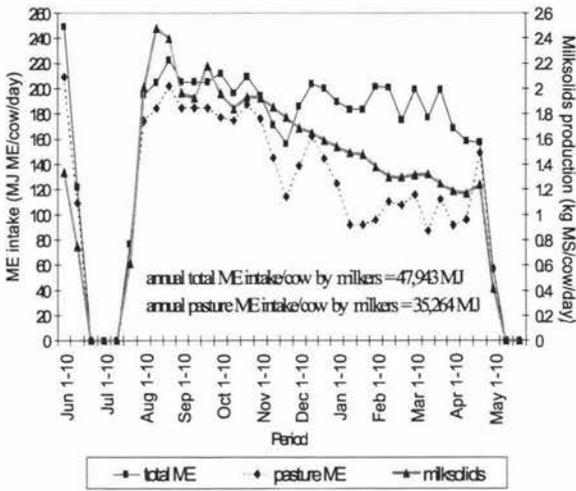
Farm 2



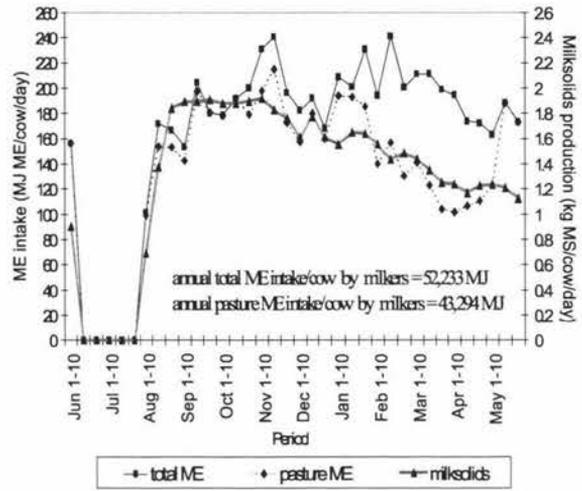
Farm 3



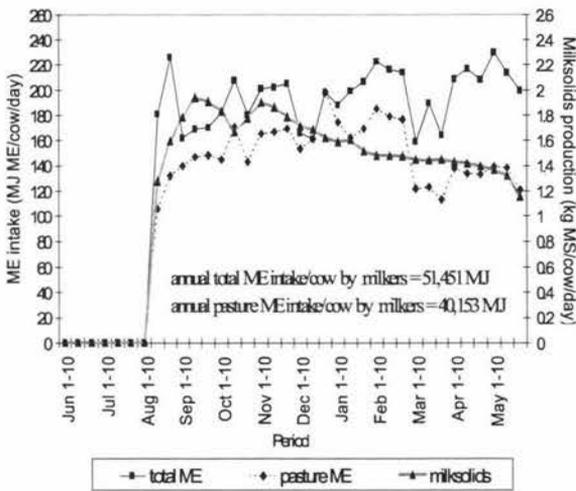
Farm 4



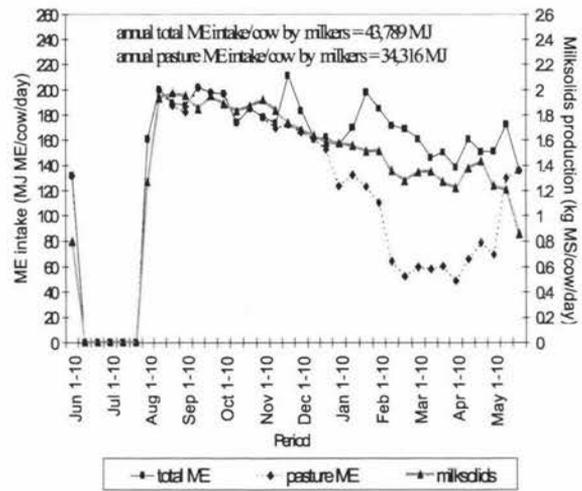
Farm 5



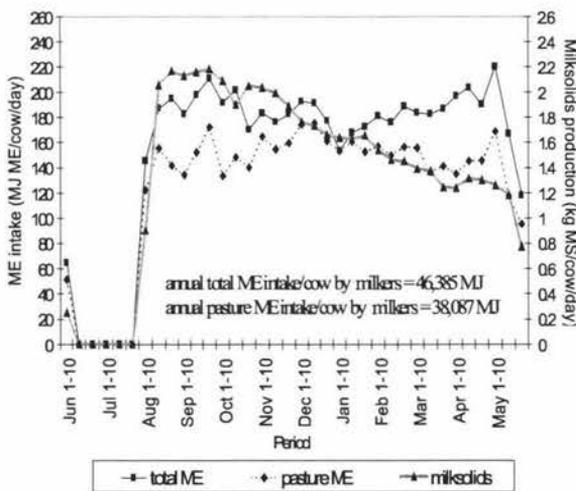
Farm 6



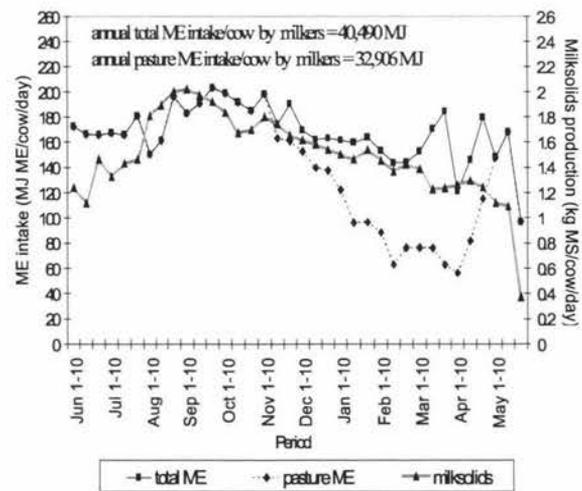
Farm 7



Farm 8



Farm 9



Appendix 5.9 Correlation matrix between pairs of general predictor variables (x).

	LD/C	LD/H	SR	PREHMm	POSHMm	PREHMd
LD/H	0.300					
SR	-0.371	0.768*				
PREHMm	0.811**	0.547	0.022			
POSHMm	0.365	0.067	-0.096	0.276		
PREHMd	0.180	0.481	0.348	0.365	0.016	
POSHMd	0.233	-0.059	-0.221	0.292	0.103	-0.290

* $p < 0.05$, ** $p < 0.01$. The Pearson correlation (r) value squared equals R^2 showed in the regression analysis.

Appendix 5.10 Correlation matrix between pairs of intake predictor variables (x).

	TME/Cmd	TME/Cm	TME/Hmd	TME/Hm	PME/Cmd	PME/Cm	PME/Hmd	PME/Hm	SME/Cmd	SME/Cm	SME/Hmd
TME/Cm	0.845**										
TME/Hmd	0.612	0.696*									
TME/Hm	0.418	0.735*	0.897**								
PME/Cmd	0.968***	0.812**	0.619	0.421							
PME/Cm	0.788*	0.931***	0.822**	0.819**	0.828**						
PME/Hmd	0.511	0.600	0.962***	0.865**	0.585	0.803**					
PME/Hm	0.319	0.590	0.898**	0.955***	0.381	0.778*	0.933***				
SME/Cmd	0.867**	0.745*	0.478	0.330	0.714*	0.554	0.263	0.134			
SME/Cm	0.579	0.689*	0.135	0.239	0.415	0.375	-0.072	-0.048	0.787*		
SME/Hmd	0.658	0.704*	0.781*	0.695*	0.507	0.614	0.581	0.542	0.825**	0.567	
SME/Hm	0.488	0.783*	0.584	0.743*	0.461	0.680*	0.521	0.573	0.446	0.636	0.548

*p < 0.05, **p < 0.01, ***p < 0.001. The Pearson correlation (r) value squared equals R² showed in the regression analysis

Appendix 5.11 Cost of production and income for individual farms (season 2000/2001). The values are expressed as totals per farm.

TOTAL FARM VALUES (NZ\$/farm)	Farms								
	Mean	1	2	3	4	5	7	8	9
Farm working expenses	201,040	395,963	209,510	217,611	267,322	70,452	118,117	136,404	192,937
Repair and maintenance	15,742	34,015	14,643	15,018	20,681	7,191	9,613	8,946	15,832
Vehicles expenses	13,719	25,951	9,998	14,077	18,031	7,787	11,245	5,287	17,376
Administration and standing charges	30,303	45,467	27,995	35,697	40,087	22,593	29,355	18,461	22,767
Rent	1,481	0	0	9,127	2,720	0	0	0	0
<i>Total cash operating expenses</i>	262,284	501,396	262,146	291,530	348,841	108,023	168,330	169,098	248,912
Depreciation	30,907	81,051	25,692	38,808	28,801	10,158	28,228	16,279	18,241
Value of family labour	47,945	82,500	51,300	58,140	61,700	35,000	24,500	35,000	35,420
Supplement inventory	-3,264	5,320	-28,330	-8,865	12,750	0	-5,190	-740	-1,058
<i>Total non-cash operating expenses</i>	75,588	168,871	48,662	88,084	103,251	45,158	47,538	50,539	52,604
<i>Total operating expenses</i>	337,873	670,267	310,808	379,614	452,092	153,181	215,868	219,637	301,516
Cost of Funds	154,450	279,304	137,152	143,595	117,449	98,795	121,211	107,159	170,937
TOTAL FARM COST	492,323	949,571	447,960	523,208	629,540	251,976	337,079	326,796	472,453
Total milk income	625,110	1,217,709	577,980	711,877	834,520	313,935	431,065	443,146	470,650
Non-milk income	47,997	115,740	62,867	-8,120	-6,521	40,320	63,083	921	115,685
GROSS FARM INCOME	673,107	1,333,449	640,847	703,757	827,999	354,255	494,148	444,067	586,335

Appendix 5.12 Cost of production and income for individual farms (season 2000/2001). The values are expressed per effective hectare.

VALUES PER HECTARE (NZ\$/ha)	Farms								
	Mean	1	2	3	4	5	7	8	9
Farm working expenses	1,753	1,859	1,676	1,784	1,725	1,355	1,458	1,949	2,218
Repair and maintenance	138	160	117	123	133	138	119	128	182
Vehicles expenses	125	122	80	115	116	150	139	76	200
Administration and standing charges	289	213	224	293	259	434	362	264	262
Rent	12	0	0	75	18	0	0	0	0
<i>Total cash operating expenses</i>	2,315	2,354	2,097	2,390	2,251	2,077	2,078	2,416	2,861
Depreciation	260	381	206	318	186	195	348	233	210
Value of family labour	444	387	410	477	398	673	302	500	407
Supplement inventory	-35	25	-227	-73	82	0	-64	-11	-12
<i>Total non-cash operating expenses</i>	669	793	389	722	666	868	587	722	605
<i>Total operating expenses</i>	2,984	3,147	2,486	3,112	2,917	2,946	2,665	3,138	3,466
Cost of Funds	1,453	1,311	1,097	1,177	1,145	1,900	1,496	1,531	1,965
TOTAL FARM COST	4,437	4,458	3,584	4,289	4,062	4,846	4,161	4,669	5,430
Total milk income	5,582	5,717	4,624	5,835	5,384	6,037	5,322	6,331	5,410
Non-milk income	479	543	503	-67	-42	775	779	13	1,330
GROSS FARM INCOME	6,062	6,260	5,127	5,769	5,342	6,813	6,101	6,344	6,739

Appendix 5.13 Input level of intake (kg DM/ha/year), total physical product (TPP, kg MS/ha/year), average physical product (APP), marginal physical product (MPP), total value product (TVP, NZ\$5.0/kg MS) and marginal value product (MVP).

Input level	TPP	APP	MPP	TVP (NZ\$)	MVP (NZ\$)
0	0	0	0	0	0
10,000	923	0.092	0.092	4,614	0.461
10,100	951	0.094	0.286	4,757	1.432
10,200	979	0.096	0.272	4,893	1.359
10,300	1,004	0.098	0.257	5,022	1.287
10,400	1,029	0.099	0.243	5,143	1.215
10,500	1,052	0.100	0.229	5,258	1.143
10,600	1,073	0.101	0.214	5,365	1.070
10,700	1,093	0.102	0.200	5,465	0.998
10,800	1,111	0.103	0.185	5,557	0.926
10,900	1,128	0.104	0.171	5,642	0.853
11,000	1,144	0.104	0.156	5,721	0.781
11,100	1,158	0.104	0.142	5,791	0.709
11,200	1,171	0.105	0.127	5,855	0.636
11,300	1,182	0.105	0.113	5,911	0.564
11,400	1,192	0.105	0.098	5,961	0.492
11,500	1,201	0.104	0.084	6,003	0.420
11,600	1,207	0.104	0.069	6,037	0.347
11,700	1,213	0.104	0.055	6,065	0.275
11,800	1,217	0.103	0.041	6,085	0.203
11,900	1,220	0.102	0.026	6,098	0.130
12,000	1,221	0.102	0.012	6,104	0.058
12,100	1,221	0.101	-0.003	6,103	-0.014
12,200	1,219	0.100	-0.0017	6,094	-0.087
12,300	1,216	0.099	-0.032	6,078	-0.159
12,400	1,211	0.098	-0.046	6,055	-0.231
12,500	1,205	0.096	-0.061	6,025	-0.303
12,600	1,197	0.095	-0.075	5,987	-0.376
12,700	1,188	0.094	-0.090	5,942	-0.448
12,800	1,178	0.092	-0.104	5,890	-0.520
12,900	1,166	0.090	-0.119	5,831	-0.593
13,000	1,153	0.089	-0.133	5,764	-0.665