Feeding of Conserved Forage - Implications to Grassland Management and Production

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IMPLICATIONS TO GRASSLAND MANAGEMENT AND PRODUCTION

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Introduction

This review will focus on the use of conserved forages in pastoral dairy farm systems; especially on their conservation as an aid to good grazing management during periods of rapid pasture growth, and on their consumption as an aid to good feeding management and grazing management during periods of slow pasture growth. Conservation of pasture, in order to move it from one time to another later time, always involves "costs", either financial expenditure or physical losses (of dry matter/quality) or both, which must be evaluated in the whole system.

Most of the data is drawn from New Zealand and Australia, with some from England and Ireland. The topic has been reviewed before (e.g. Rogers, 1984 and 1985; Leaver, 1985; Phillips, 1988; Mayne, 1991; Stockdale *et al.,* 1997), but the present review will put greater emphasis on the effects on pasture management and on the whole pastoral system, and on recent results, because the cows' ability to respond to supplementary feeds is now larger than it used to be, as a result of steady genetic improvement in milk producing capacities. In recent years there has been marked increase in supplement use on pasture based dairy farming systems in New Zealand often driven by perceived limitations to production increases in existing systems rather than profit (Attrill and Miller 1996). This review attempts to identify, and discuss, the factors involved in supplementary feeding (i.e. the responses of cows and farming systems to extra feed) to enable sustainable increases in productivity and profitability on pastoral based systems.

Grazed pasture, the basal ration, is a living source of feed; its supply varies with season and climate, and its future growth can be influenced by its present grazing management. A key feature of the interaction between the cow and the pasture is the fact that an increase in the level of feeding, either from added pasture or added supplements, will always cause an increase in the residual herbage mass left after grazing. This, in turn, will affect the future growth and composition of the pasture. The pastoral dairy systems must achieve close synchrony and balance between feed demand and pasture supply at all times. In these intensive pastoral systems, used mainly in the Southern Hemisphere, including New Zealand, Australia (Victoria and Tasmania) and parts of South America and South Africa, conserved forages are used as a supplement to the basal ration of grazed pasture to help achieve the balance with feed demand when pasture growth is limiting. The conserved forages are almost never used as the basal ration, as is commonly the case in many Northern Hemisphere regions, at least in winter (Thomas and Thomas, 1989).

Milk Production on NZ Dairy Farms; An Example of Intensive Pastoral Systems

There are 3.3 million cows and 3.8 million people in New Zealand; consequently 90% of milk is exported, without subsidies or incentives, at the "world market price". Currently this is about NZ$3.50/kg milksolids (fat plus protein), or 29c/L, with 4.7% fat and 3.8% protein.

The costs (c/kg DM) of various feeds are: - Pasture silage, 10 to 15c; maize silage, 14 to 20c; grains, 25 to 40c; concentrates, 40 to 50c; grazed pasture (variable costs), 3 to 5c. Consequently grazed pasture is the only high-quality feed that can be used as the basal ration for cows, although silages can be fed strategically, and grain can be fed occasionally in the grain-growing districts. This financial need to use grazed pasture as the basal ration is made physically possible as the temperate climate allowing pastures to grow and to be grazed throughout the whole year. These pastures contain high concentrations of metabolisable energy and crude protein (10 to 12 MJME/kg DM; 17 to 27% CP; Moller *et al.,* 1996).

Ninety percent of all the cows calve in early spring, in order to synchronise their increased feed requirements of early lactation with the increased pasture growth in spring-time. They are later dried-off after relatively short lactations (220 to 240 days), before the following winter, in order to balance their reduced feed requirements, when non-lactating, with the reduced pasture growth in winter (see Figure 1). The remaining 10% of cows are milked through the winter, usually after calving in autumn, either by feeding a high proportion of silage in their winter ration, or by operating with a low stocking rate during winter (Garcia and Holmes, 1999). The small local market for short shelf-live products is a key feature allowing the milk production pattern to follow the seasonality of pasture growth rather the seasonality of consumer demand.

For the spring calved herd with a moderate stocking rate, a temporary pasture surplus (growth faster than consumption) occurs during October to December. This can be conserved, and fed during later periods of pasture deficit (summer, winter or early spring), which may in turn allow earlier calving or later drying-off. However for the spring-calved herd with a higher stocking rate, there may be little or no pasture surplus at anytime of year, but there will be large pasture deficits in summer, winter and autumn (Figure 2). Supplementary feeds must be imported on to the higher stocked farm to fill periods of deficit.

Average stocking rates have increased from about 1 cow/ha in 1950 to 2.7 cows/ha in 2000; this combined with increased milk yield/cow has created much higher feed demands per hectare. Therefore most dairy farms now import feed in one form or another, whereas most farms were self-contained for feeds prior to 1975. With the increased use of supplementary feeds in New Zealand dairy farming systems farmers must take into account the likely responses (productive and financial) to the extra feed as well as the short and long term consequences of this extra feed to the grazing system (grazing management and sward conditions).

The Response by Cows to the Feeding of Conserved Supplements

In all feeding systems, the cow's responses to supplementary feed are determined by:

- The amount by which her intake from her basal ration is decreased (the substitution effect).
- The net amount by which her total nutrient intake is increased.
- The proportion if this net increase which is partitioned into extra milk synthesis.

These factors also apply to grazing conditions, but in addition, grazing cows always respond to an increase in feeding level (either from extra pasture or from extra supplement) by leaving a higher post-grazing residual herbage mass (RHM) (Dalley *et al.,* 1999). As discussed elsewhere, in this review, this increase in RHM will have important subsequent effects on sward characteristics through changes in the growth, senescence and composition of the pasture.

The immediate and long term effects of supplementary feed in a grazing system are illustrated Figure 3. In theory, if all of the metabolisable energy in the extra feed eaten was absorbed by the udder and converted into milk then an extra 10 MJME in total intake would produce an extra 6.5 MJ net energy in milk, equivalent to about 0.15 kg milksolids (milksolids = fat plus protein).

In fact, consumption of 10 MJME as supplementary feed usually causes some decrease in pasture consumption, and some increase in liveweight gain. Therefore the actual, immediate response in extra milk production is always smaller than the theoretically possible 0.15 kg MS given above.

The pasture not eaten, and the extra liveweight, may subsequently contribute to the production of extra milk in carry over, long-term responses (Figure 3). When the immediate and the long-term effects of adding supplements to a pastoral system are added together, the total response to extra feed in a grazing system will almost always be smaller than this theoretical value. Some of the extra nutrients are "lost" from the system in the form of wasted pasture, which decays, and/or extra liveweight which is never converted into milk.

The size of the response to extra feed depends mainly on the "need" for extra feed, by the cow or by the system. Large responses will be achieved only if the current performance of the cows or the system is being severely limited by the lack of feed. These situations represent "potential deficits", where the actual levels of intake and production by the cow or the system are well below their potential levels.

The immediate effect of supplementary pasture silage was illustrated by Bryant and Trigg (1982), for cows given a restricted daily allowance of pasture, with or without silage. Consumption of 4 kg silage DM/day caused a 1.7 kg DM decrease in pasture consumption (substitution rate 0.43) and consequently an increase in residual herbage mass, and increases in milk production and in liveweight gain. The immediate milk response was 0.15 kg MS from 4 kg silage DM, or 38 kg MS/kg DM, while the final, total response would depend on the final fate of the extra liveweight and the extra residual herbage mass.

Substitution Rate

The substitution rate is affected by many factors including pregrazing herbage mass, and quality of the herbage and the supplement (Stockdale *et al.*, 1997). However the main factor is the cow's overall level of feeding (and production) relative to her potential intake (and production), described mainly as the quantity of supplement fed and the quantity of pasture offered (Grainger and Matthews, 1989).

For example, for forages: -

Substitution Rate = 0.01 + 0.16 x unsupplemented pasture intake.

$$\text{Where substitution rate} = \left(\frac{\text{Decrease in pasture intake}}{\text{Supplement eaten}} \right)$$

$$\text{And unsupplemented pasture intake} = \left(\frac{\text{Kg DM eaten/cow daily} \times 100}{\text{Kg LWT of the cow}} \right)$$

(Larcombe, 1989; cited by Stockdale *et al.*, 1997).

Substitution rates usually range from 0.3 to 0.7, with even higher values recorded for cows given generous pasture allowances and large quantities of supplement (e.g. Phillips, 1988).

The substitution effect has obvious negative effects on the cows' immediate response to the extra supplementary feed. It will also have negative effects on the long-term responses by the whole system, if the pasture which is spared by the supplement (substituted) is wasted and not eaten later.

"Managed substitution" is widely used in commercial and experimental farming systems, in order to meet targeted levels of management for the cows and the pastures. Some of these are illustrated by the management decision rules and targets explained by MacDonald and Penno (1998); and Phillips and Matthews (1994).

Grazing pasture is a relatively slow method of feed consumption, and it requires long periods of grazing each day (e.g. 9 to 10 hours grazed per day; Watson, 1999). These long periods are in marked contrast to the time taken to eat diets of silage and concentrates; 3.5 to 4.0 hours per 24 hours (Jackson *et al.*,1991). Cows presumably prefer to consume feeds which can be ingested at faster rates, and thus be able to spend less time per day in the activity of feed consumption.

Rates of feed consumption are:

Pasture	20 to 40 g DM/min
Hay/Silage	50 to 70 g DM/min
Concentrates	250 g DM/min meal
	350 g DM/min pellets

(Phillips, 1988; Mayne, 1991; Bramley *et al.,* 1992)

Consumption of supplementary feeds generally cause decreases in total grazing times, ranging from 22 to 26 minutes per kg DM eaten as concentrates or maize silage (Sarker and Holmes, 1974; Watson, 1999); up to 30 to 40 mins/kg DM eaten as hay or silage (Phillips and Leaver, 1985; Mayne, 1991). The decrease in grazing time is probably linked to the rate at which the supplement can be eaten. However time is rarely the factor which limits the cows' response to supplements, because the main factor is usually her "potential deficit".

It is tempting to suggest that forage supplements will cause larger substitution rates than concentrates, because the forages are eaten more slowly, and cause larger decreases in grazing time. However there is no clear evidence that this is true (Stockdale *et al.,* 1997), probably because so many other factors also influence the substitution rate.

Partitioning

The ability of the cow to utilise a high proportion of the extra nutrients, derived from supplements, into the synthesis of extra milk is another key determinant of her immediate response to extra feed (Figure 4). A high proportion will be partitioned into extra milk only if the cow's potential milk yield is much higher than her current, actual milk yield because of a relative feed deficit.

Calculations from the data reported and cited by Grainger (1990) and Stockdale and Trigg (1989) provide estimates for the percentage of extra metabolisable energy partitioned towards the synthesis of extra milk: -

- Early lactation, and current milk yield which is much lower than potential milk yield because of severe feed restriction: 70%
- Early lactation, and only moderate feed restriction: 40%
- Late lactation: 35%
- No feed restriction at all: 0%

These values will be higher for cows with high genetic merit for milk production than for cows with lower genetic merit (Fulkerson, 1997; Ferris *et al.,* 1999), because these high merit cows have very high potential milk yields, and therefore usually exist in a state of energy deficit. Logic indicates that these high merit cows will also show smaller substitution rates, but there is no evidence to justify this belief. Genetic improvements in milk production capacity have and will continue to make important contributions to increasing responses to extra feed.

The energy which is eaten but not used by the udder must be converted into extra liveweight gain, which can contribute later to improved fertility (Garnsworth and Webb, 1999), or to increased milk production (Grainger and Wilhelms, 1982). Under conditions of continued feed restriction after the period of supplementary feeding, the carry-over effect is likely to be about 0.5 times the immediate response to the extra feed (Broster and Broster, 1984; Bryant and Trigg, 1982; Rogers, 1985).

The Response by the Farming System to the Feeding of Conserved Supplements

Introduction

Successful grazing systems are planned. From the setting of production and financial objectives and systems planning through to grazing management, monitoring and evaluation. Grazing management can be defined as the manipulation, within a grazing system, of the feed supply (pasture and other supplementary forages) and animal feed demand to achieve planned pasture and animal production targets. Although farmers are likely to have different grazing management objectives and each system unique, grazing systems in New Zealand have, in general, been based on high stocking rates, to achieve high levels of pasture utilisation and per hectare production. These systems have resulted in low average cow production and short lactation length to enable the animal feed demand profile to closely match that of pasture growth with little or no reliance on additional supplementary forages. A grazing system can be represented as a model of feed flow from pasture production through to animal product (Figure 4). The average pasture cover and the level of animal performance achieved are used to balance any variation between pasture production and intake per animal. The system is controlled through the farmers control over animal intakes through stock policy decisions. For this model to work successfully farmers must be willing to control the herbage intake of grazing animals even though at times this will result in reduced intakes and lower levels of animal production (Matthews 1994).

Currently there is considerable debate between the merits of this traditional mainly pasture based system and alternative systems based on improved animal performance and the increased use of supplements (e.g Penno *et al*., 1996, 1998, 1999, Brander and Matthews 1997, Cassells and Matthews 1995, Matthews 1997). If increased levels of production per animal are to be achieved this effectively reduces the control of the grazing system through controlling intake levels within the grazing system, and requires increased use of supplements and/or reducing stocking rate to balance animal demand with pasture growth (Matthews 1994). The following are examples of the grazing objectives for a number of leading New Zealand dairy farmers attempting to make effective use of additional forage inputs to achieve a high per cow and per hectare productivity (Matthews 1995):

- To maximise pasture production.
- To make efficient use of the pasture grown.
- To exploit the production potential of the herd.
- To achieve a high per hectare production through high per cow performance.

To plan, manage and monitor grazing systems involves an understanding of the factors affecting pasture production, average pasture cover, feed intake (requirements) per animal, animal production and animal responses to supplementary feeding as well as the ability to quantify and measure each of these components at the farm level. Grazing management also requires an understanding of the interactions that take place between pastures and grazing animals. Increased emphasis on system performance will require a clearer understanding of the responses of both the animals and the farming system to supplementary forages to enable economic responses to be captured.

Short Term Experiments

The average results from trials in which grass silage was fed with grazed pasture (Table 1) show the major effects of the initial feeding level on the responses to supplementary feeding and that that it can in fact reduce milk production (Phillips, 1988).

Average results (per kg DM fed) from 12 studies in which pasture silage was fed during periods of pasture deficit (Rogers, 1985) were: -

- + 30 gm MS (+ 0.5 litre milk)
- + 150 gm liveweight
- - 0.4 to 0.6 kg pasture DM eaten per kg DM eaten as silage.

More recently an extra 20 to 40 gm MS/kg silage DM were produced by cows at a high stocking rate, fed 5 kg silage/day in spring or summer (Clark, 1993) with the long-term, results almost twice as big (Table 2). An extra 0.6 to 0.9 kg extra milk was produced per kg maize silage DM by cows eating restricted quantities of moderate quality pastures (Stockdale, 1995). These responses decreased sharply in conditions where the total diet contained less than about 14% crude protein, either because the diet contained a high proportion of maize silage (CP% about 7 to 9%) or because the grazed pasture contained a low crude protein concentration. Milk yield was increased by the inclusion of extra protein (fish, soya bean or cotton seed meals) with the maize silage when it was fed with summer pasture in New Zealand (MacDonald *et al.*, 1998) or in Australia (Moran and Stockdale, 1992).

Chopped green maize can also be used to supply about half of the total ration for grazing cows (Moran, 1992), and whole-crop silages (e.g. from conserved wheat) can also be used successfully as a supplement for grazing cows (Waugh, 1997).

An extra 50 to 60 g MS were produced per kg DM grazed as turnips or as sorghum (at 3 to 4 kg DM/cow daily), by cows given a daily pasture allowance of 25 kg DM in summer (Harris *et al.*, 1998).

High quality supplements generally produce larger responses (Stockdale *et al.*, 1997). For example responses to hay, maize silage or concentrates were about 0.45, 0.8 or 1.3 kg extra milk per kg extra DM. The benefits of silage with higher digestibility were illustrated by Rogers (1984) and by MacDonald *et al.*, (2000). The high quality of turnips and sorghum (12 and 11 MJME/kg DM respectively) probably contributed to the relatively high immediate responses reported above for these feeds.

Self Contained Systems; Forage Conserved on the Farm

The interaction between stocking rate and date of silage conservation was studied in Taranaki, New Zealand, (Thomson *et al*., 1984). Early conservation had an adverse effect at the higher stocking rate, reducing milk produced per cow prior to 1st December because conservation induced a feed deficit in early lactation. However, at the lower stocking rate, early conservation had a beneficial effect, increasing milk produced per cow after 1st December, because of decreased dead matter concentration in the pasture during summer.

Another Taranaki experiment measured the productivity of farmlets on which surplus pasture in spring was either harvested and conserved as silage, or carried through on the paddock as “deferred grazing” to be grazed in late December and January (Thomson *et al*., 1989). There were only small differences in milk yield between the two systems at both stocking rates, except in one year when, at the higher stocking rate, the silage farmlet produced 165kg milk solids per hectare more than the deferred grazing farmlet, due entirely to extra milk produced after December 10, from 50 extra days in milk. The results suggest that conservation as silage will reduce the variability of milk production between years at higher stocking rates, but it was not "profitable" every year even at the higher stocking rate.

An experiment in Victoria, Australia, compared two conservation systems, one with hay and the other with silage, both at 2 cows/hectare (Thomas & Matthews, 1991). The silage was conserved at earlier dates and was of higher digestibility, (68% v 61%) than the hay. The herd on the silage farmlet produced more milk per cow (4380 v 4049 litres) than the herd on the hay farmlet, mainly due to differences while the supplement was fed during the summer. However there was no difference between the two farmlets in economic surplus because the silage farmlet incurred greater costs, because it was forced to purchase extra silage, whereas the hay farmlet sold surplus hay. The loss of DM in the silage stack was 25%, which was one reason for the need to purchase extra silage.

a - Dry Matter losses

Mowing, wilting and chopping resulted in slightly higher quality silage than silage direct cut with a forage harvester (+ 3% milk per cow). However direct cutting caused smaller losses of DM in the paddock and in the stack, and thereby produced 20% more milk per hectare of silage (Small & Gordon, 1988). This experiment, and that by Thomas and Matthews (1991) above, emphasises the important consequences of the losses of DM which can occur during the conservation process, on the productivity of the whole farm. These losses extend into the management of the silage face, especially for maize silage, and to the feeding methods, which can be over 20% if silage is fed in the field (Phillips, 1988).

b - Growing Forage Crops

The total supply of feed was increased by growing 18 t DM/ha as maize on 20% or 50% of the farm, harvesting it as silage and feeding it to the cows as required (Campbell *et al.,* 1978). Milk production per hectare was increased, but, with the yields costs and prices in the 1970's, the gross margin per hectare was reduced. A more recent experiment showed benefits from growing maize on 12% of the farm's area in only 1 year out of two (Thomson *et al.,* 1998). A theoretical study of the incorporation of maize silage on dairy farms in Southern England assumed yields of 12 to 18 t DM/hectare from maize and 10 t DM from pasture (Doyle & Phipps, 1987). The model predicted increases in profit due to inclusion of maize on up to 100% of the farm area, although the biggest increase was from 0% to 25% of the area as maize. Obviously the results of such experiments will be very dependent on the yields of DM from the maize, and the costs and prices involved.

Turnips can provide a large supply of "grazeable", high quality feed (12 MJME/kg DM) in summer when pasture growth and quality can both be low, and the relatively high immediate responses (50 to 60g extra milksolids per kg extra DM) were described above. However in the whole system, growing the crop reduces the area of pasture which causes a temporary increase in stocking rate. This resulted in the conservation of less silage, and in lower average body condition and daily milk yield of the cows by the time when consumption of the turnips could begin (Thompson *et al.,* 1997). The overall net effects of the turnip crop on the whole farm's productivity will depend on the size of the adverse effects while the crop is growing and the size of the benefits while the crop is eaten. There is unlikely to be much net benefit unless the turnip yield exceeds about 12 t DM/ha and the crop allows the dry-off date to be delayed, giving extra days in milk.

c - The use Of Nitrogen fertiliser to Conserve extra silage

Extra silage can be conserved if extra nitrogen is applied, and this can result in extra milk provided that the extra feed is needed by the cows and by the system. However, with present cost and prices (1 kg N costs $1; 1 kg MS worth $3.5), this strategy will result in only small increases in profit.

The application of 428 kg N/ha produced an extra 3.3 t pasture DM/ha, which allowed the conservation of an extra 1.6 t silage DM with 3.3 cows/ha (McGrath et al, 1998b). An extra 69kg MS were produced per cow, with an extra 27 days of lactation (mainly due to feeding of silage to allow drying-off to be delayed). However profit was not increased. A combination of 100kg N/ha plus conservation of extra silage plus earlier calving, produced small increases in milk per cow and per hectare (Thomson *et al.,* 1991).

d - In-situ Conservation of Forage

Pasture can be stored in situ, without being harvested, by simply shutting the gate to exclude grazing cattle, and allowing the herbage to accumulate until needed for grazing at a later date. Autumn-saved pasture and foggage are examples of this (Wallace 1958, Holmes, 1989), and the practice is common in tropical systems (Butterworth, 1985). Prolonged in situ storage is associated with increased senescence and other changes in composition and quality, and these are larger if storage occurs in spring/summer when the grass is going through its reproductive phase and temperatures are high, than if storage occurs during winter with lower temperatures and light intensity (L'Huillier, 1988; Holmes, *et al.,* 1992).

Pasture can be stored from late spring until summer by "deferred grazing" (McCallum *et al.,* 1991; L'Huillier, 1988), a low-cost technique which has some application in intensive pastoral systems. The stored herbage is of relatively low quality, but it can contribute to reseeding and to a fallowing effect on the soils.

Pasture can be stored until early spring by storage from autumn (Wallace, 1958) or by gradual accumulation over the winter period (Bryant and MacDonald, 1983). In the latter case, an extra 200 kg DM accumulated/ha in July to September resulted in the production of an extra 3 to 8 kg milksolids/cow, or 12 to 24 kg milksolids/ha, in early lactation by highly-stocked farmlets which experienced a pasture deficit in early lactation. These responses are equivalent to very efficient conversion of the extra feed into milk in these intensive systems.

However the changes in herbage composition and in pasture structure which are associated with winter storage of pasture (Holmes *et al.,* 1992), can also cause subsequent problems in pasture production and quality, and ultimately in milk production (Clark *et al.,* 1994). Accumulation of excessive herbage masses in early spring must be avoided.

Growth of grazeable crops (e.g. turnips; green-feed maize) on part of the farm represent a form of *in situ* conservation of feed. These incur costs of growing the crop, but do not suffer from deterioration in quality, and may also result in improved pastures subsequently after reseeding back into grass.

Shorter term conservation is achieved through the use of rotational grazing with forage being accumulated between grazings. This is one reason for the common practice of lengthening rotations as the system is moving from a period of feed surplus to deficit, or fast to slower pasture growth rates (Matthews 1994). In most instances this represents a feed transfer and intake rationing strategy to reduce the impact of lower pasture growth rates rather than the addition of extra feed into the system.

Long-term System Studies, With Imported Supplements

Pasture silage (5 kg DM/cow daily, with 10.8 MJ ME/kg DM) was fed for 30 days in either spring, summer or autumn or at all 3 times (90 days) and these four systems were compared with a fifth system which received no silage (Clark, 1993). All five systems carried a relatively high stocking, 3.8 cows/Ha. Some results are shown in Table 2, relative to the system that fed no silage.

Feeding silage in autumn also allowed the cows to be milked for an extra week, which contributed to their bigger response. The farmlet on which silage was fed at all three times also had an additional 450kg DM/Ha average herbage mass at the end of the lactation. The high stocking rate used in this experiment ensured that pasture deficits did occur, but a rigid design of this sort does not allow for the exact matching, in time and quantity, between pasture deficits and silage fed which can be achieved on the best farms.

Maize silage was fed to cows, grazed at two stocking rates (MacDonald, 1999) and some results for 3 years are shown in Table 3. An increase in feed demand, by increasing stocking rate, with no increase in feed supply caused decreases in feed available per cow, and consequent decreases in milk yield per cow and even per hectare, plus reduced fertility. However, when the increase in feed demand was associated with an increase in feed supply (as maize silage), the adverse effects on performance per cow were overcome, and milk production per hectare was increased considerably.

In two other treatments, with 4.42 cows/Ha, the extra feed was supplied either as maize grain or as a balanced ration including maize silage and concentrates. The responses per cow and per hectare were greater than from maize silage, mainly due to the higher concentrations of ME/kg DM in the other two feeds, but the responses were similar if expressed per MJME.(Penno et al, 1998).

Of the three systems shown above, only that at 3.34 cows/Ha without maize silage and that at 4.42 cows/Ha with maize silage are sustainable, and sensible. The response by the whole system can be expressed as an extra 398 kg MS/ha, from a combination of an extra 5.8t DM/ha plus an extra 1.08 cow/ha plus an extra 11 days in milk per cow.

In an earlier stage of the experiment, maize silage was also fed at the lower stocking rate (3.34 cows/Ha), but the productivity of this system was limited by its low feed demand (Penno et al, 1996).

Best responses from whole systems are usually obtained from several integrated inputs that affect both feed demand and feed supply.

In another study, imported maize silage was fed in either Spring, Summer or Autumn (Thomson et al, 1998). In both years the responses were lowest in summer, possibly due to its relatively low protein concentration (see Stockdale 1995). When fed in Spring or in Autumn, the response to maize silage was about 70g and 165g extra milksolids per kg maize silage DM in Year 1 and Year 2 respectively, with much lower milk yields achieved in Year 2. There were no obvious reasons for the differences between years; but they illustrate the risk attached to the achievement of high responses (Thomson *et al.*, 1998).

The latter study is being continued, with the feeding of maize silage targeted at specific periods of pasture deficit, including deficits caused by early calving, late drying off at a higher stocking rate.

A similar experiment to that described by Macdonald (1999), was carried out in Victoria, Australia, but concentrates were fed instead of maize silage (Grainger, 1995; cited by Stockdale *et al.*, 1997). A combination of extra feed demand (higher stocking rate) and extra feed supply, produced extra milk in all years, up to 1200 to 1800 kg milksolids/Ha with 3.5 to 4.7 cows/ha and 0.8 to 1.7 t concentrates fed/cow. However the extra concentrates were profitable only in the 2 years when the concentrates cost 13c/kg, and not in the 3rd year when they cost 24c/kg, with $5.4/kg received per kg milkfat.

Results from Commercial Farms

Data for the top quartile and the bottom quartile of farms (classified on the basis of profit per hectare) are presented in Table 4 (Howse and Leslie, 1997). The top farms successfully combined extra feed demand/ha (extra cows producing higher yields per cow) with extra feed supplied in order to produce more milk and profit. Attrill and Miller (1996) concluded, however, that the increased use of supplementary feeds on dairy farms in New Zealand had, on average, increased production but not profitability.

In the traditional highly stocked grazing system in New Zealand supplementary forages have been used either to enable the system to a) survive crisis situations (e.g. droughts) and b) maintain the high stock numbers over the non-productive winter period when pasture growth rates are low. For most seasonal supply dairyfarming systems in New Zealand the summer is the most climatically variable time of the year. Research carried out in the area of summer management (MacDonald 1987, Gray et al, 1992) has mostly focused on survival tactics, with decision rules over the summer autumn period aimed at protecting the new season often resulting in the farmer relenting control and short term production losses.

Increased profitability to added supplement is most likely to occur when it is used in a more productive capacity during the lactation period (Brander and Matthews 1997, Matthews 1997) through either increasing the number of lactation days (Penno *et al*., 1999, 2000) or the average production per lactation day (Cassells and Matthews 1995). This change is illustrated by the change in total supplement use (forage supplements and off-farm grazing) in a high producing dairy farm (Table 5) as the emphasis changed from high production per hectare based on a high stocking rate to one based achieving a high production per hectare through increased per cow performance (Cassells and Matthews 1995).

Brief details are given in Table 6 of two more extreme examples of farms using supplementary feeds in very intensive pastoral systems in New Zealand. Again both systems have combined extra feed demand plus extra feed supply to produce large quantities of milk per cow and per hectare, profitably.

Summary of the Factors Affecting Short and Long-term Responses to Supplementary Forages

Two simple lists (shown in Table 7) illustrate the size of probable responses to supplementary forages and the factors that will contribute to them. The largest responses will be achieved by cows and systems with the highest potential feed demands and milk production, from high quality supplements given at the right times and in the right quantities.

Appropriate use of supplements in efficiently planned and integrated systems can probably achieve the highest responses because of the "long-term" benefits of good feeding. e.g. through effects on body condition as shown by Stockdale (1999) and sward conditions (Benson and Matthews 2001).

This will involve the positive attributes of feed substitution or managed substitution. In the efficient intensive grazing system, the substitution effect is used deliberately to "save" pasture during a pasture deficit, while simultaneously maintaining the cow's level of feeding. In this case the substitution is done by the farm manager and not by the cow. For example, the cow's total required feeding level is 15 kg DM/day; with pasture only this would require a daily allowance of about 35 kg DM/cow daily. During a period of slow pasture growth (e.g. dry summer), the cows pasture intake can be reduced to 10 kg DM/day by reducing the pasture allowance (by reducing the area grazed each day) to about 20 kg DM / cow daily while simultaneously feeding 5 kg DM/cow daily as silage. This combination of reduced pasture intake and consumption of supplementary feed can ensure that the cows' total feeding level, and the postgrazing residual herbage mass are both maintained.

The overall objectives of this managed substitution are to: -

- Maintain the cow's total level of feeding.
- Decrease the daily rate at which pasture is consumed, so that it is equal to the daily rate of pasture growth.
- Maintained the pre and post grazing herbage masses at the required, target, levels.

"Managed substitution" is illustrated by the experimental data for cows given either a pasture allowance of 45-kg DM/cow daily with no supplements, or a pasture allowance of 30 kg DM/cow daily plus 8 kg DM/day as maize silage and cotton seed meal (Moran and Stockdale, 1992). Both feeding combinations resulted in similar levels of intake, milk yield and postgrazing residual herbage mass, and pasture consumption was reduced by the addition of maize silage without increased wastage of pasture.

The relations between pasture allowance, pasture intake and residual herbage mass at different levels of supplement intake, and the ability to manage substitution have not been studied in detail. However, there will probably be a close relationship between total allowance of feed (pasture plus supplement) and total feed intake (pasture plus supplement).

The increasing emphasis being given to supplement use in grazing systems will require the establishment and management of sward conditions to enable pasture growth to be maximised and used efficiently (Matthews 1995). An example of appropriate sward targets is given in Table 7. There needs to be increased emphasis on pre-grazing and post-grazing sward conditions rather than average pasture cover as these control both pasture quality and animal intake. Phillips and Matthews (1994) suggested that in a dairy farm system there were few occasions when average cover should be outside the range of 1900 to 2100 kg DM/ha (Table 7). The net effect is to limit the ability to buffer differences in pasture growth and animal demand through building up and running down cover. This means that average pasture cover cannot act as a large feed reserve in the grazing system. To do this would then force pre-grazing levels outside the desirable range as average cover increased and also post-grazing residuals outside this desirable range as pasture cover was decreased.

While manipulating grazing rotation lengths has been one of the key grazing management decisions made by New Zealand farmers (Figure 4) Matthews (1997) suggests that as farmers make increased use of supplements to buffer the variability in pasture growth rate rotation length will become less important for transferring feed but geared more to the replacement rate of pasture in the sward. It is also suggested that stock numbers rather than intake (production) per animal will in future be used to buffer the system along with an increased use of supplementary forages.

To gain maximum benefit (both production and financial) supplementary feed will be used not only to meet animal requirements on the short term but also for the maintenance of appropriate sward conditions to ensure long term production responses are achieved.

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Table 1 - The effect of pasture allowance on the response to additional supplement (Phillips 1988)

	Silage Fed (kg DM/cow/day)	Substitution Rate	Extra Milksolids (gm/cow/day)
Fed with generous pasture	5.0	1.1	- 31
Fed with restricted pasture	4.9	0.3	+ 105

Table 2 - Production responses (kg milksolids/cow) to pasture silage fed at different stages of lactation Clark, 1993)

	Spring	Summer	Autumn	Spring, Summer & Autumn
During the feeding period	5.7	3.6	12.0	
During the whole lactation	10.1	10.0		28
Responses to the extra feed (gm extra MS/kg extra DM)	69	67	79	62

Table 3 - Systems response to increased stocking rate with or without the addition of maize silage (MacDonald, 1999)

	Stocking Rate (Cows/Ha)		
	3.34	4.42	4.42
Maize silage fed (t DM/Ha)	0	0	5.8
Days in milk:	266	217	277
Milk produced (kg MS)			
Per cow::	362	269	364
Per hectare:	1208	1190	1606
Percentage of cows anoestrous at start of mating:	11	35	13

Table 4 - The use of supplementary feeds on commercial dairy farms in New Zealand (Howse and Leslie, 1997)

	Quartile	
	Top	Bottom
Profit ($/ha)	2280	1130
Cows/ha	3.3	2.8
Milksolids produced		
kg/cow	334	267
kg/ha	1100	742
Feed purchased (t DM/ha):	1.1	0.3

Table 5 - The effect of changes in stocking rate and supplement use on per cow and per hectare production (adapted from Cassells and Matthews 1995)

	1980-1988	1989-1993	1994-1995
Stocking rate (cows/ha)	3.93	3.47	3.03
Production			
(kg milksolids/cow/year)	265	318	409
(kg milksolids/ha/year)	1035	1107	1239
Feed Inputs			
Supplement (kg DM/ha/year)	1433	551	2455
Grazing (kg DM/ha/year)	1060	605	924
Total (kg DM/ha/year)	2493	1156	3379

Table 6 - An example of two New Zealand dairy farms using high levels of supplements

	J and S Van Der Poel	G and F Edgecombe
Cows/ha	4.15	4.1
Milksolids produced		
kg/cow	430	540 (in 315 days)
kg/ha	1790	2200
Supplements fed t DM/ha	4.9	6.0
Main Supplement used	Maize silage	Cannery byproducts

Table 7 - Factors affecting the likely level of response to additional feeds
(a) Immediate, short-term responses:

Low Response 30 g MS/kg DM	High Response 60 g MS/kg DM	Very High Response 100 g MS/kg DM
Moderate initial level of feeding	Low initial level of feeding	Very low initial level of feeding
Cows with low potential feed demand and milk yield. e.g. mid to late lactation e.g. moderate genetic merit e.g. some disease problems e.g. thin cows	Cows with high potential feed demand and milk yield. e.g. early lactation e.g. high genetic merit e.g. healthy cows e.g. adequate body condition	ONLY by high potential cows in early lactation, and high quality supplement
Low quality supplement (<9 MJME/kg DM)	High quality supplement (>11 MJME/kg DM)	
Grazing on high quality pastures.	Grazing on low quality pastures.	

(b) Total, long-term response (including carry-over effect)

Low Response 50 g MS/kg DM	High Response 100 g MS/kg DM
Low immediate response (30 g MS/kg DM)	High immediate response (60 g MS/kg DM)
Moderate feed demand /ha	High feed demand/ha
No extra days in milk achieved from extra feed	Extra days in milk achieved from the extra feed (from earlier calving and/or later dry-off)

Table 8 - Seasonal pasture targets for a seasonal supply dairy farm (adapted from Phillips and Matthews 1994)

Season	Average Pasture Cover (kg DM/ha)	Pre-grazing herbage mass (kg DM/ha)	Post-grazing herbage mass (kg DM/ha)
Late-autumn	1750-2000	2400-2700	1200-1400
Winter	1900-2100	2500-2700	800-1000
Early-spring	1900-2000	2500-2700	1300-1400
Late-spring	2000-2200	2500-2700	1500-1600

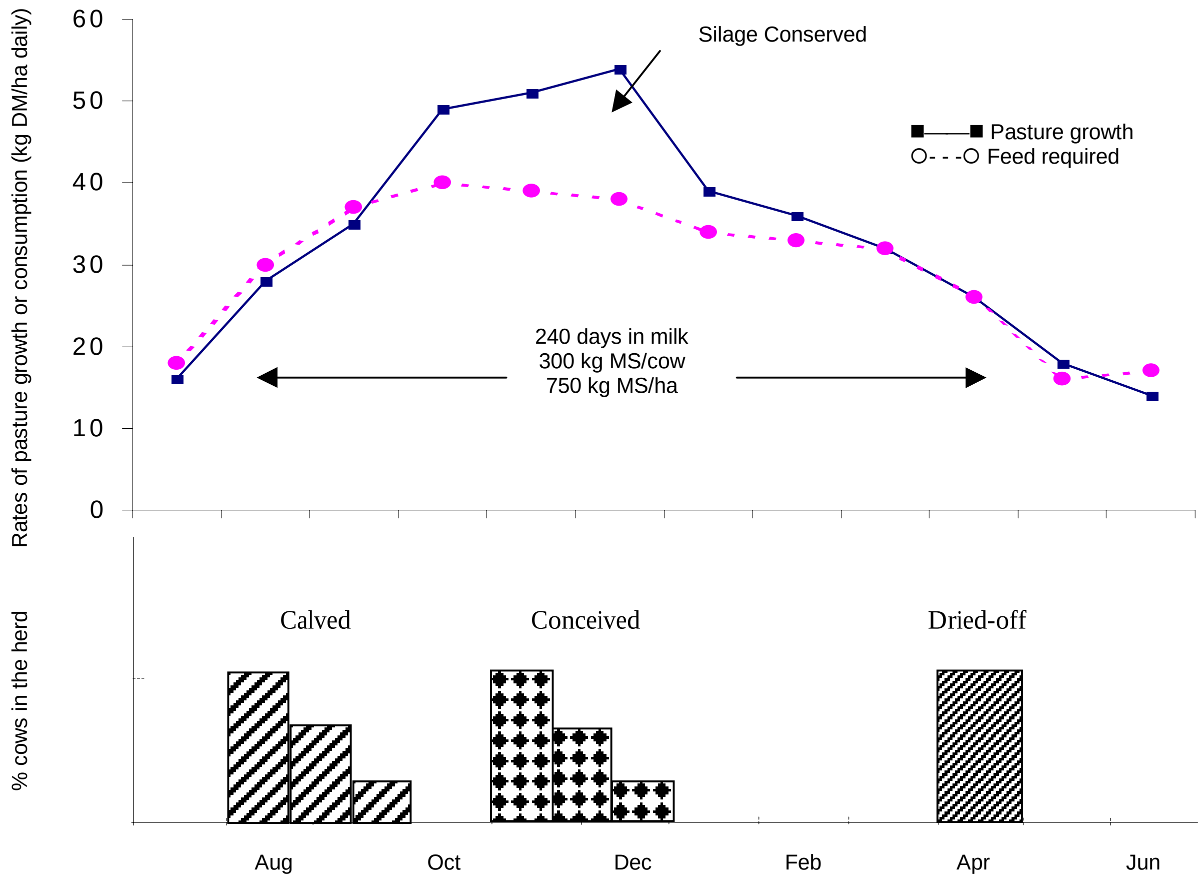

Figure 1 - Moist Summer/Cool Winter: 2.5 cows/ha : No Supplements

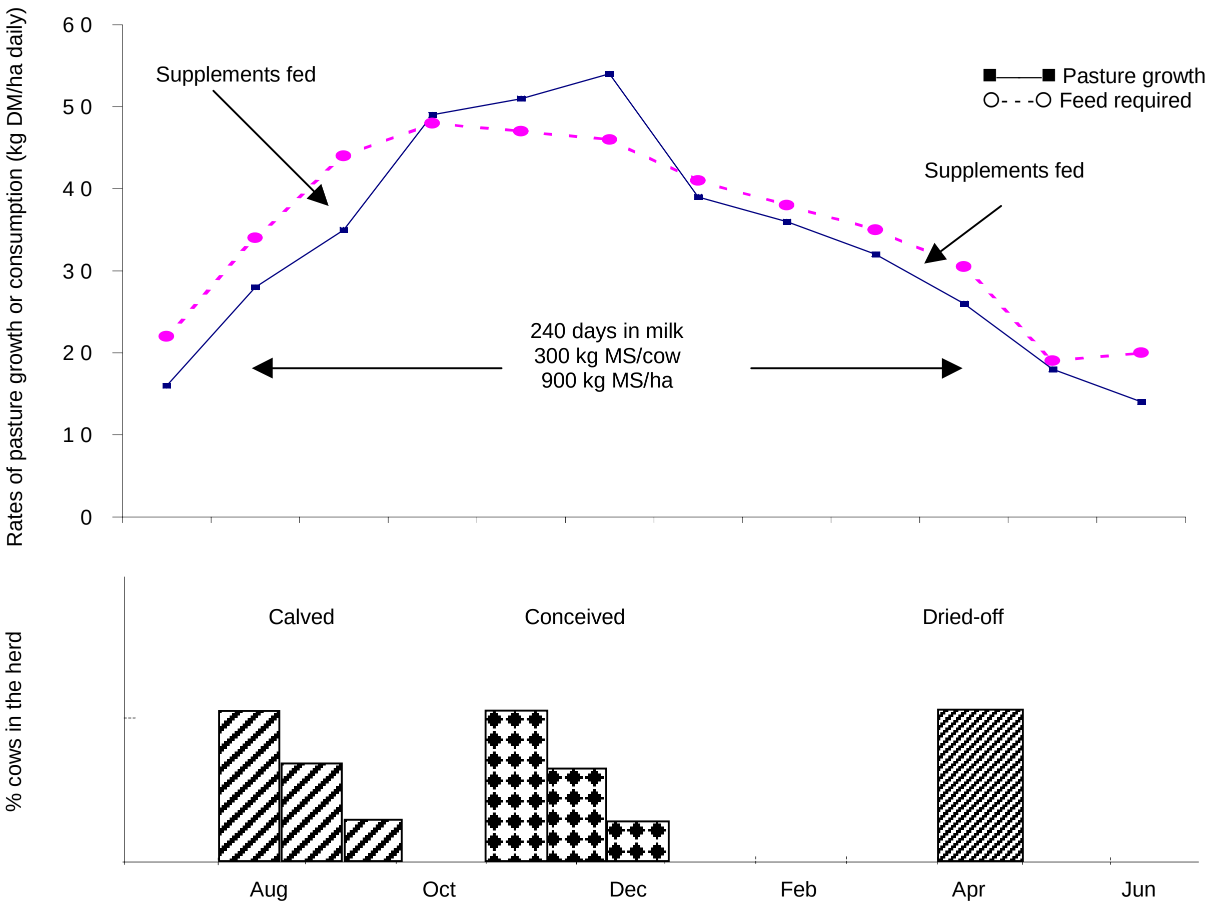

Figure 2 - Moist Summer/Cool Winter: 3 cows/ha: Supplements Fed Spring and Autumn

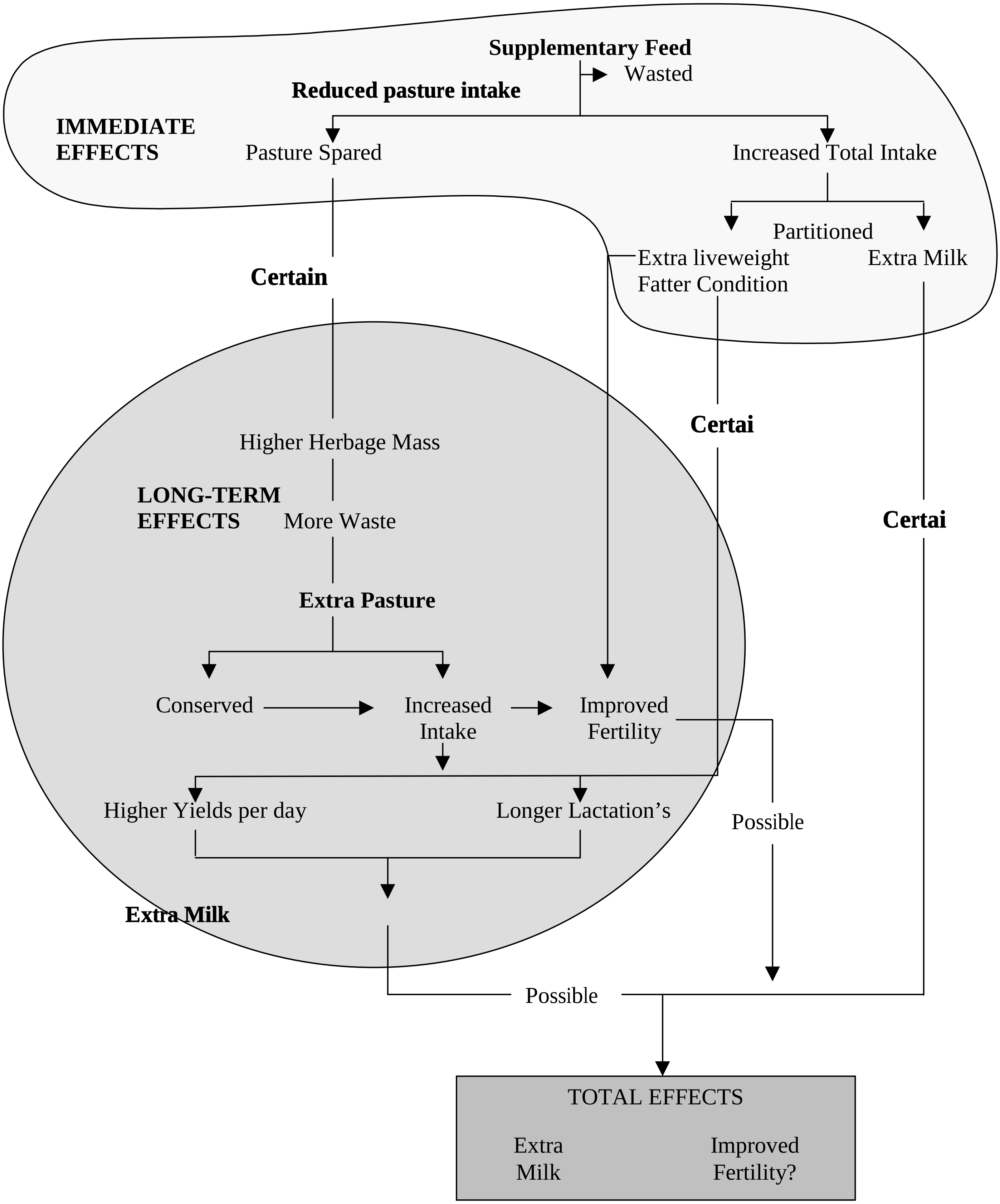

Figure 3 - Immediate and long-term, or carry-over, responses of cows to supplementary feeding (Modified from Brookes 1996)

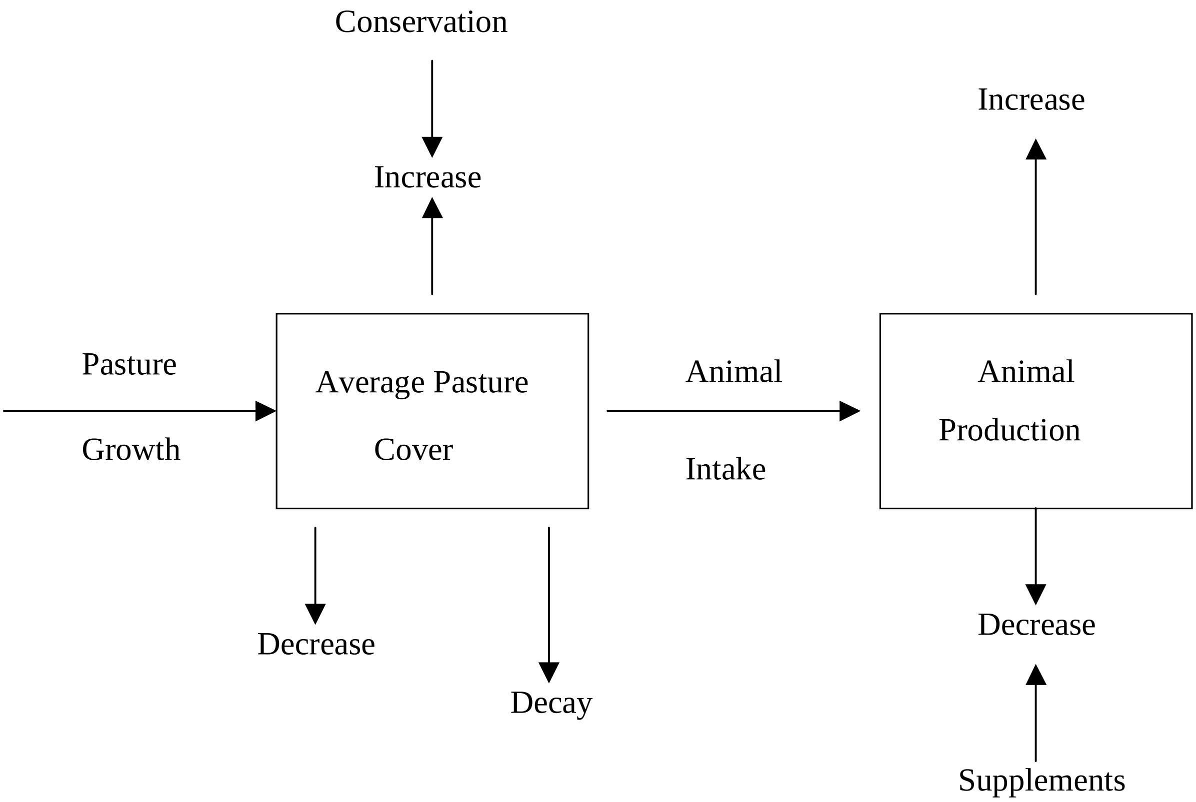

Figure 4 - Feed Flow Model of a Grazing System (adapted from Matthews 1994)