# Trends in feeding systems for dairy production in the subtropics of Australia

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## Summary

There is continuing discussion as to the efficiency and competitiveness of dairy production in the subtropics. The example of northern Australia is used to describe the historical development of a commercial dairy industry in the subtropics, the complexity and productivity of present day systems, and projections for the future. The present farms have substantial capability to increase productivity, based on substantial increases in stocking rate, which is in turn supported by increases in irrigation, and in inputs of conserved fodder, cereal grains and by-products. The capacity of the farm to grow forage forms the basis of the feeding system, and the business can be further expanded on the base by substantial use of purchased feeds. Efficiency measures, in terms of milk production per cow and per hectare, and in use of natural resources, labour and capital, can all be increased through these means.

It is important to give more emphasis to evaluating feeding systems within the wider context of the whole farm. The system must be efficient in use of land labour and capital, and acceptable to the modern community. Future developments are likely to be in methods of doing this, particularly in assessing the impacts of feeding systems on farm business management and whole farm planning. New technology has the potential to benefit subtropical dairy farming through assisting in building feeding systems which use the natural advantages of the subtropics, and in making more rapid improvements in the genetic potential of plants and animals than has been possible in the past. We need to remain aware that the future feeding systems in the subtropics may look quite different to those in present use.

## Introduction

The potential for dairy production in the subtropics and tropics has remained a point of debate over many years. Some 40 years ago Payne (1963) considered the potential for milk production from tropical pastures to be high, while Hardison (1966) considered the potential for milk production from these grasses to be very low. There have been many developments in subtropical dairy production since then (Chamberlain & Cowan, 1999), but we are still faced with the question as to whether production in the subtropics can be competitive with that in the temperate zone. The more successful dairy industries in the subtropics have based their operations on temperate technology, made possible by modifications of the environment. It can be questioned whether such a trend will result in a competitive industry in the subtropics in the longer term.

The dairy industry continues to undergo rapid change (Parker *et al*., 2000). The globalisation of the industry has major implications for producers, processors and consumers. A key point is that in a global environment there is much less commitment to maintaining a regional industry if it is inefficient compared with alternative sources of product. In addition the dairy industries of many countries are being deregulated, allowing the free flow of milk products into and out of regions, and exposing local industry to international price signals. There is also a necessity for the industry to demonstrate that it is not likely to degrade the natural resource base. In the presence of all this change, there must be a competitive advantage for an industry to remain and grow.

A major factor contributing to a competitive advantage in the dairy industry is a low cost feeding system. In the subtropical zone of Australia there have been rapid developments in feeding systems, resulting in large increases in productivity, but the region is still poorly equipped to compete on an international market. Australia is at the moment going through a major restructure as a result of globalisation and deregulation occurring concurrently, and this has brought the competitive bases of subtropical and temperate feeding systems into sharp focus. In my talk I will rely heavily on our Australian experience to review how changes have developed in subtropical feeding systems, and make comments on some of the choices that challenge us in the future. References to currency are in Australian dollars.

## A feeding system

A feeding system is the result of management decisions that bring together animal, feed and natural resources; to produce a yield and quality of animal product consistent with market needs and community expectations, and to enable profitable use of capital, labour and time. The managers' expertise is an important part of the feeding system, and the system has objectives well beyond production, such as efficient use of labour and capital, and sustainable resource management. The optimum feeding system can only be determined from a whole farm analysis.

## Historical development

In northern Australia native pastures (*Heteropogon contortus*, *Themeda australis*, *Erichloa* spp., *Dicanthium* spp.) were the traditional feed source for cows on farms, and these still occupy an average of half the farm area (Kerr *et al*.,. 1996). It has been necessary to replace the remaining area with more productive forages, in particular introduced tropical grasses (*Chloris gayana*, *Pennisetum clandestinum*, *Setaria* spp., *Panicum* spp., Table 1). Though average farm area is relatively high at 218 ha, carrying capacity is low at 0.5 cows/ha (Kerr *et al.*, 1996). A primary limitation is water supply for plant growth (Minson *et al.*, 1993), and on the 53% of farms which have developed irrigation an average area of 24 ha is irrigated (Kerr *et al.*, 1996). Increasing interest has also been shown in utilising off-farm feed resources for milk production, particularly cereal grains, maize silage and by-products such as molasses, whole cotton seed and pineapple skins. The ratio of price received for milk to feed cost has fallen from 2.5 to approximately 2.0 over 20 years, and in July 2000 fell overnight to 1.3. The proportion of gross income available for labour and return to operator has decreased from 60 to 34% (Busby & Lake, 1996), though the situation from July 2000 is unknown. There has been a three-fold increase in total farm milk output (NSWA, 1997).

**Table 1** Chronological development of dairy pasture systems in subtropical Australia

| Date | Summer pastures | Winter forages | Concentrate level (t/cow) |
|---|---|---|---|
| 1960 | native pastures | oats (dryland) | 0.5 |
| 1970 | introduced grass-legume pastures | oats (dryland) | 0.5 |
| 1980 | introduced grass + nitrogen fertiliser | ryegrass (irrigated) | 0.8 |
| 1990 | crops (maize silage; lucerne) | clover-ryegrass (irrigated) | 1.5 |
| 1999 | crops (maize and grain sorghum silage; lucerne) | clover-ryegrass (irrigated) | 2.0 |

## Feeding systems in northern Australia

While the adage "all farms are different" remains true, there have been some major common developments on farms. Emphasis has been on the fresh milk market, which demands continuity of supply, and to achieve a low seasonality index of 1.1 (ratio of milk intake in month of highest and lowest production). Farmers have adopted increasingly complex, interventionist feeding systems (Figure 1), enabling a high degree of control over production (Moss & Lowe, 1993). There has been a cumulative adoption of technology. Winter forage cropping was added to the perennial pasture base, with the subsequent adoption of concentrate feeding, irrigation, annual winter pastures, cropping for silage production, silage feeding, and incorporation of various by-products. Kerr & Chaseling (1992) showed that 70% of the variation between Queensland farms in annual milk production is explained through differences in feeding inputs (Table 2). In this analysis the constant, interpreted as milk output without any of these inputs, was 400 L/ha, a figure close to that measured on degraded, unfertilised perennial grass pastures (Cowan *et al.*, 1995a).

A description of the chronology of technology adoption is shown in Figure 2, together with projections as to changes over the next 5 years (Cowan *et al*., 1998). The values are calculated from production and input values for a farm with 0.4 ha/cow of irrigated creek flats. Perennial dryland pastures, such as *Chloris* spp., accounted for 40% of milk production in 1975 compared with 20% now. The role of these pastures has also changed from being a primary source of forage to a support role, enabling cows to be pastured in wet weather or while annual pastures are being established, and providing a source of fibre while cows are grazing very high quality winter pastures. These grasses are high in neutral detergent fibre (NDF, 55% to 80% DM) and calculations suggest a maximum level of inclusion in the diet at 50% for a milk production level of 18 L/cow daily, decreasing to zero at 30 L/cow. In practice herds producing over 25 L/cow use very little or none of these grasses in the feeding program.

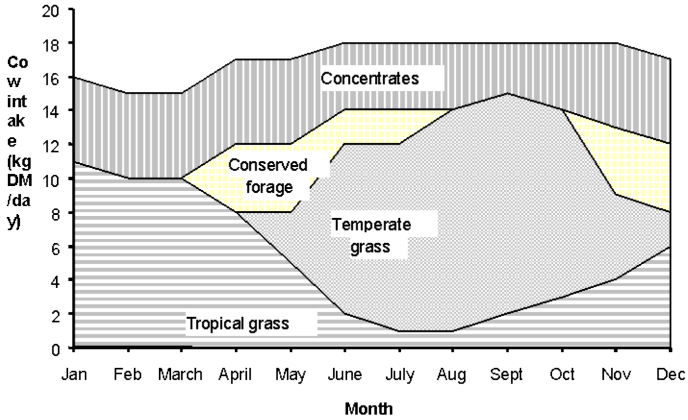


**Figure 1** Seasonal change in feed intake for a dairy cow producing 6000 L milk annually in a typical feeding system in northern Australia (from Cowan & Lowe, 1998).

**Table 2** Factors associated with the annual productivity of Queensland dairy farms and marginal response rates in multiple regression analyses

| Factor | |
|---|---|
| Number of farms | 1822 |
| Constant (production without improvements; L/farm/year) | 71433 |
| | |
| Feeding | Additional milk per unit |
| Energy as concentrates (L/MJ ME) | 0.128 |
| Nitrogen fertiliser (L/kg N)[A] | 4.36 |
| Winter irrigation area (L/ha) | 3078 |
| Summer irrigation area (L/ha) | 1103 |
| Hay and/or silage fed (L/kg DM) | 0.60 |
| Total farm area (L/ha) | 95 |

[A] Nitrogen and irrigation are used in combination on irrigated area, and the effects are additive.

Though the amount of concentrate (grain, molasses, protein meal) given to cows has increased to a present level of 2.0 t/cow annually, the proportion of milk attributed to this feed has tended to decrease from 50% to 30% of production (Figure 2). In the cited example, and farms with feed costs less than 14 cents/L, purchases of concentrates average 20% of gross milk income (Busby & Lake, 1996). On farms with feed costs over 18 cents/L concentrate purchases account for 40% of gross milk income. The by-product whole cotton seed (WCS) is commonly used in feeding programs, and on selected farms by-products such as brewers' grains, pineapple skins, palm kernel extract and copra meal have been effectively used to reduce the cost of supplementary feeds.

**Figure 2** Past estimates and projections of the milk output from feeds on a typical dairy farm in northern Australia.

Annual pastures, based on temperate pasture species and intensive irrigation and fertilisation, were adopted around 1975 and have had a major impact on productivity. The proportion of milk output attributed to these pastures has increased from zero to 25% of total production. These pastures occupy 6% of total farm area on farms deemed to be irrigated (>0.13 ha/cow; Kerr *et al*., 1996). The productivity of these pastures is 3 to 5 times that of improved dryland pastures (Fulkerson *et al*., 1993) and in the order of 10 times that of native pastures. Though costs per hectare are high it has been demonstrated that the operating cost per unit of utilised dry matter may often be lower than for dryland pastures (Chopping & Walker, 1993). On a whole farm basis these pastures can substantially reduce the total cost of production, as labour and capital costs are spread over a greater volume of production (Cowan, 1997).

Within the northern dairy industry there has been considerable resistance to the incorporation of silage in feeding systems, much of which was based on the negative experiences with tropical grass silage. However, this decade has seen the rapid acceptance of silage made from specialist crops, particularly maize. In 1995, 36% of farms were using crop based silage, up from 2% in 1986 (Kerr *et al*., 1996). Two thirds of this silage was home grown, producing silage at a cost of approximately 9 cents/kg DM in the pit, but often competing with annual pastures for irrigation water. The balance of water use is important as the economic incorporation of maize silage into feeding programs has been shown to depend firstly on making a sufficient quantity, and secondly on having high protein pastures (irrigated annual pastures) available to integrate into the feeding program (Cowan, 1999). Farms using large amounts of silage consistently have larger herd sizes (by 40 to 60 cows), and higher production per cow than farms not using silage (Cowan *et al*., 1991; Kaiser & Evans, 1997).

*Dryland farms*

Dryland farms, those with <0.04 ha irrigation/cow, have had particular problems in meeting a market which demands a continuous supply of milk. Production is more directly influenced by variations in rainfall, and there is a greater relative input of concentrates compared with irrigated farms (Chopping & Walker, 1993). The lower farm productivity also means capital and labour costs per litre are relatively high (Bake *et al*., 2000).

To be competitive dryland farms will need to modify the production system to a greater extent than irrigated farms. One way of achieving a competitive base may be through conserved fodder, though this is difficult to implement. The farmer is faced with the choice of growing a dryland crop, normally forage sorghum, or purchasing maize silage from neighbours who have irrigation. Present varieties of forage sorghum are similar in quality to tropical grass silage, and the low digestibility means that the milk response on feeding out is limited (Cowan & Kerr, 1983). The cost of purchased maize silage in the pit is high, often around 15 cents/kg DM. On feeding out both types of silage it is usually not possible to integrate the silage with high protein pastures, and substantial quantities of purchased protein meal need to be incorporated in the ration (Moss *et al*., 1994). The result is a high feed cost of production.

## Potential of feed systems

Cowan (1997) estimated the potential to increase milk production on northern dairy farms. Potential increases in productivity were based on greater inputs of irrigation, silage and cereal concentrates (Table 3).

More recent modelling of feed systems has shown there is also substantial potential to increase productivity of paddocks on dairy farms in northern Australia (Kerr *et al*., 1998). In an analysis of Queensland farms it was demonstrated that irrigated and dryland pastures were each producing 60% of levels achieved by the top 10 percentile of farms, and approximately one third of levels consistently achieved in research. A small number of individual farms are achieving levels of production similar to those measured in research (C. Findsen, personal communication).

**Table 3** Estimates of the major input changes associated with future productivity gains from subtropical dairy farms (from Ashwood *et al*., 1993; updated by Cowan, 1997)

| Category of farm | | Input level | |
|---|---|---|---|
| | | Present | Potential (year 2002) |
| Restricted irrigation and pastures (0 to 0.13 ha/cow of irrigation) | Irrigation (ha) | 5 | 25 |
| | Concentrates (t/cow.year) | 1.2 | 2.5 |
| | Number of milking cows | 77 | 140 |
| | Conserved forage - purchased (t DM) | 40 (estimate) | 140 |
| Unrestricted irrigation and pastures (>0.14 ha/cow of irrigation) | Irrigation (ha) | 24 | 80 |
| | Concentrates (t/cow.year) | 0.8 | 1.3 |
| | Number of milking cows | 70 | 150 |
| | Conserved forage - homegrown (t DM) | 50 (estimate) | 150 |
| Dryland and cropping (Darling Downs) | Concentrates (t/cow.year) | 1.2 | 3.0 |
| | Number of milking cows | 90 | 120 |
| | Conserved forage - homegrown (t DM) | 50 | 250 |
| | Hay - purchased (t DM) | 25 | 150 |

These increases in farm productivity are likely to be associated with substantial increases in stocking rate and fertiliser inputs. In a tropical upland area with 1250 mm annual rainfall, Davison *et al.* (1985) considered a stocking rate of 3.0 cows $ha^{-1}$ to be sustainable at an applied nitrogen rate of 400 kg N $ha^{-1}$ $year^{-1}$, with an average output over 3 years of 8 550 kg milk $ha^{-1}$ $year^{-1}$. At higher stocking rates, there was rapid weight loss by pregnant cows during the dry season and weed invasion of the pasture. In a lower rainfall (800 mm), subtropical environment, Cowan *et al.* (1995b) considered a stocking rate of 2 cows/ha optimum for a Rhodes grass pasture receiving 300 kg N $ha^{-1}$ $year^{-1}$.

Reason & Chaseling (1993) studied the effects of three levels of applied nitrogen (300, 400 or 500 kg N $ha^{-1}$ annually) on a portion of each of 12 commercial farms, and measured an incremental response of 11 L milk/kg applied nitrogen. A summary of long-term experiments with nitrogen fertiliser applied to dryland tropical pastures demonstrated responses from 4 to 14 L milk/kg applied nitrogen, with an average of 8 L milk/kg Nitrogen. (Cowan *et al*., 1993). These stocking rates and levels of fertiliser input are considerably higher than current practice on farms, where values are 0.6 cows/ha on the improved pasture area of the farm, and 40 kg nitrogen/ha respectively (G Hetherington, personal communication 2000).

Where grass was irrigated, Chopping *et al.* (1976) reported milk yields up to 19 000 kg $ha^{-1}$ $year^{-1}$ at a stocking rate of 7.9 Holstein Friesian cows $ha^{-1}$ on pangola grass pasture receiving 672 kg N $ha^{-1}$ $year^{-1}$. Lowe *et al*. (1991) demonstrated milk yields of 14 000 kg $ha^{-1}$ over summer and autumn in a subtropical environment on Rhodes grass and paspalum *(Paspalum dilatatum)* pastures receiving 400 kg N $ha^{-1}$ $year^{-1}$ and stocked at 7.5 Holstein Friesian cows $ha^{-1}$.

With annual temperate pastures under irrigation, one hectare of irrigated ryegrass costs around $ 850 annually, producing 12 000 L milk/ha (7 cents /L) on the highest 10 percentile of farms. However under average management, milk production is 6 000 L milk/ha (14.1 cents /L). With research results in long-term trials showing 18 000 L milk/ha is feasible there is also considerable scope for increased productivity from irrigated pastures (Lowe *et al*., 1999).

In assessing the potential of feeding systems, a starting point is the capacity of the farm to grow forage. This is appropriate, as both grazed pasture and conserved fodder are potentially lower in cost than purchased feeds (Chopping, 2000). It is also a feedstuff needed in large amounts, as the dairy cow cannot be given a diet of 90% grain. We can value add to the forage base by bringing in off-farm feed resources which are competitively priced, such as grains and by-products. In this way the capacity of the farm system is calculated as in Table 4.

The capacity of the farm to use concentrates is based on the forage amount, as we believe from dairy farm accounting figures (Bake *et al*., 2000) that around 35% grain in the diet of the milking cow is an economic optimum. This is about 25% grain in the total food for milking cows and followers. The cows' intake is influenced by the quality of the pasture. On dryland farms there is more tropical grass, and on irrigated farms more ryegrass and clover. Dry matter intake and milk yield per cow would normally be higher on farms with irrigation. The number of cows the farm can support can be calculated from the total capacity of the farm to provide food, and the estimated dry matter intake per cow from the forage base. Farm accounting figures show farmers have 10% to 15% of milk income to pay wages and meet living expenses, and Table 4 shows of farm type and forage productivity on the indicative income for these purposes.

## Measures of efficiency

**Table 4** Estimates of the forage productivity of the average northern Australian dairy farm, together with predicted optimum inputs of concentrate to complement forage, and the anticipated carrying capacity of the farm (Cowan, 1998)

| Measurement | Productivity of pastures and crops | | |
|---|---|---|---|
| | Below average farm | Average farm | Top 10 percent of farms |
| | | Dryland (*irrigated)* | |
| Capacity for pasture consumption (t DM/year) | 300 (380) | 500 (650) | 800 (1020) |
| Capacity for using concentrates[A] (t DM/year) | 100 (130) | 170 (220) | 270 (340) |
| Total feed capacity (t DM/year) | 400 (510) | 670 (870) | 1070 (1360) |
| Cow intake, with followers) (t DM/year) | 8 (10) | 8 (10) | 8 (10) |
| Number of cows (capacity/intake) | 50 (51) | 84 (87) | 135 (136) |
| Wages and living ($/year) | 8300 (10,100) | 28300 (34800) | 56500 (67,300) |

In the feeding system described above milk production per cow is a useful measure of efficiency, as scarce resources need to be directed as far as possible to milk production. The high input of off-farm feeds enables the farm to support a relatively high stocking rate, ensuring a high utilisation of home grown forage. It is fundamental to efficient feeding systems that this resource be used efficiently (Lowe *et al*., 1999). However the return on feed costs and the dilution of capital and labour costs, are also enhanced by having a reasonably high level of production per cow. This level is well above that able to be supported by pasture alone. In analyses of farm data the economic optimum appears to be about 7000 L milk per cow (Busby & Lake, 1996). This argument is further supported by evidence of a positive association of efficiency of concentrate and paddock use with level of milk production in Queensland herds (Table 5).

Values are for a 100 ha cow milking area, on undulating land and 20% creek flats. Milk price is $ 0.30/L. Irrigation is taken as sufficient to water the creek flats on irrigated farms. [A] The term concentrate is used to represent cereal grains, molasses, and other crop and vegetable by-products.

**Table 5** Estimates of milk produced from grazed pastures and response to concentrate feeding in 11 herds producing more than 750 000 L milk/year, compared with average herds (Kerr & Chalesing, 1992)

| | State average | High producing herds |
|---|---|---|
| Milk (L/cow/year) | 4051 | 4863 |
| Concentrates (t/cow/year) | 1.1 | 2.0 |
| Milk per hectare, less any off farm inputs (L/year) | 21 42 | 38 26 |
| Response to concentrates (L/kg) | 0.7 | 1.2 |

Some further measures of efficiency on farms are shown in Table 6. Around 20% of farms meet the benchmarks for financial parameters of living expenses, labour and return to capital, compared with 70% of farms with feed costs at or below the benchmark level of 13 cents/L (Bake *et al*., 2000). As discussed earlier there is a large capacity to increase productivity of farm paddocks, and consequently the total farm.

## Sustainability

The Standing Committee on Agriculture (1991) defines sustainable agriculture as ‘the use of farming practices and systems which maintain or enhance the economic viability of agricultural production, the natural resource base, and other ecosystems which are influenced by agricultural activities’. Grass pastures can be very effective in maintaining the economic viability of animal production and the natural resource base, though two concerns expressed about their sustainability are the potential for applied nutrient fertilizers to move and affect other ecosystems, and the longevity of the pasture. Experience in tropical and subtropical regions suggests that grass pastures will not persist for long periods unless they are grown in association with effectively nodulated legumes or supplied with regular applications of nitrogen fertiliser. The level of nitrogen required is estimated to be in the order of 100 kg Nha-1 year-1 (Robbins & Bushell, 1986; Cowan *et al*., 1995c).

Grass-based pastures are effective in rebuilding soil carbon content and improving water infiltration rates in soils degraded through the processes of continuous cropping and erosion (Dalal *et al.*, 1991). Grasses are more effective in this than are legumes (Clarke *et al.*, 1967). Barnes (1981) measured increases in soil organic carbon, total nitrogen, exchangeable bases, and crop yields following a ley pasture of *Cynadon nlemfuensis* vs. *robustus*. There are a number of economic and social factors to consider in the choice of pastures as permanent or ley swards, but it is likely there use will increase as part of a sustainable use of tropical and subtropical soils (Humphreys, 1994).

**Table 6** Some key efficiency parameters relevant to subtropical dairy farms (Cowan *et al*., 1998; Bake *et al*., 2000)

| Category | Components | Benchmark efficiency ratio or comment |
|---|---|---|
| Financial | Living expenses<br>Labour<br>Service capital | 32% of gross income |
| | Feed costs | 13 cents/L milk |
| Production | Water supply | 3 ML per cow |
| | Water efficiency | 2500 L milk/ML |
| | Cow production | 7500 L milk/cow.year |
| | Farm component area | 5000 L milk/ha from dryland pasture<br>12000 L milk/ha from irrigated pasture<br>60 t/ha from irrigated maize silage |
| Marketing | Irrigated farms | take advantage of winter incentive with a bias to autumn calving (40% of cows) |

The use of zero till methods to introduce cool season growing species such as ryegrass, oats and annual clovers (*Trifolium* spp.) into tropical grass swards in the autumn has gained widespread acceptance (Lowe & Hamilton, 1985). Advantages of this combination are an improved continuity of forage supply compared with conventional tillage, less exposure of soil to erosion during the high rainfall months of the year, and more flexibility in grazing animals on the firm base associated with minimum tillage compared with the soft base associated with cultivation.

Higher temperatures in the subtropics and tropics change the rate of nutrient cycling (Lavelle & Swift, 1993) and promote a more active process of nitrogen fixation associated with grasses (Weier, 1980). The interaction of soil type with nutrient has not been extensively studied, but present results suggest that, at modest levels of nitrogen application (i.e. up to 300 kg N $ha^{-1}$) the rate of nitrogen leaching through the profile is very slow, even in extremely porous soils (B. Prove, 1996, Queensland, personal communication). At present the proportions of pasture areas in the tropics and subtropics which are receiving high levels of applied fertilizer are in general much lower than in intensively farmed temperate areas.

Losses of surface applied urea to the air can be substantial, in the order of 30 to 70% of that applied (Catchpoole *et al.*, 1983). The loss is closely related to reliability of rainfall following application (Murtagh, 1975) and amount of ground cover of grass or trash (Fenn & Hossner, 1985). Present indications are that gaseous losses are likely to be a more important loss than leaching through soil profiles. Methane production is higher with grass-fed animals than with those fed grains (Blaxter & Wainman, 1964), though with the increased levels of production associated with well fertilised pastures, the amount of gas produced per unit of livestock product is decreased (Sibbald & Hutchings, 1994). On Australian farms approximately 60% of greenhouse gas emissions are in methane from ruminant digestion (T. Davison, personal communication). The flux of methane in tropical agricultural systems is not well understood. For example, Mosier *et al.* (1991) demonstrated a capacity of tropical soils to take up and oxidize methane.

Though not directly related to sustainability, there are a number of influences on farmers to care for the environment. These are better described as quality assurance measures, and are often linked to marketing of the product. Quality assurance at the milk harvesting site is now universal, and is linked to safe food regulations and milk marketing (Collingwood, 2000). Other issues now being addressed through this mechanism are cow welfare, management of vegetation and water courses, and efficiency of use of natural resources (Gramshaw & Carter, 2000).

## Management of heat load

In addition to effects on the feed-based, high summer temperatures, often associated with high relative humidity, have a direct effect on production and reproduction in the cow. Since the predominant method of harvesting herbage is grazing, the need to walk up to 3 km to pasture of crop and then graze this area adds to the heat load of the cow. The combined effects of high temperatures and the need to walk result in unique practical difficulties in herd management and cow nutrition.

The grazing effort of Holstein-Friesian cows begins to decrease at ambient temperatures above 26 ºC (Cowan, 1975), and above 32 ºC cows do almost no effective grazing between morning and afternoon milking (Grainger *et al*., 1996).

It would be expected that the quality of night grazing would be important during summer and a 16% increase in annual milk fat production per cow has been measured as the proportion of the farm used for night grazing increased from 20% to 80% (Rees *et al*., 1972). There is a tendency to put cows on paddocks close to the dairy at night, and this would exacerbate the effects of heat stress on production by limiting the food intake at night.

In a thermoneutral environment, approximately 5 - 20 ºC in Holstein-Friesian cows, the energy demands of walking for the average cow of 550 kg are about 1.2 MJ/km on a horizontal plane, with an additional 0.02 MJ for each metre of vertical movement up slopes. Higher values of up to 6 MJ/km have been quoted. There is a rapid increase in the energy demands when animals are walking under heat stress, particularly if they are high-producing. A practical range of values to use for farms with a mix of flat and sloping land may be 2 MJ/km for low producing cows (<15 L/day) and 5 MJ/km for high producing cows (>25 L/day).

As a greater tonnage of purchased feed is integrated into feeding systems feeding pads are being developed close to the milking unit, and cows are confined to these areas during hot days. Shade is provided close to these pads on most farms, and water sprinklers on a small proportion (Davison & Andrews, 1997).

## Future

### *Family income*

I believe the single most important issue is the need to ensure a high net income for young farming families. It is imperative to attract young people to farms, to support a lifestyle commensurate with that enjoyed by the rest of society, and to encourage investment in farm development. No longer is it acceptable that the farm income just cover cash costs, there must be a substantial personal income as well.

Associated with this change is the fact that the amount of money required to support a family is also increasing rapidly. We currently use a figure of $ 30 000 net income from the farm, and this has increased by 50% over the past 5 years. No doubt many farmers with large investments would wish to make considerably more than this.

The combination of changing expectations and the rising cost of living demands a rapid increase in the profitability of dairy farming. Our figures suggest that in the range of 10% to 20% of gross income can be used to provide family income, and from this some decisions on the scale of business necessary can begin to be made. For example, a single family farm returning 15% of gross income as personal income would require a gross income in the order of $ 200 000 annually. This may equate with around 750 000 L of milk sales. On the assumption that the farm is run efficiently, we now have a target for production, which will support a level of profit acceptable to many people.

### *Whole farm planning*

A sound feeding system is the basis for a competitive dairy industry, but it is no longer possible to plan these systems in isolation from other aspects of dairy farming. The feeding system will impact on the marketing of milk, or increasingly the market for milk impacts on the feeding system. This is being encouraged by a move to individual contracts to supply milk. The environmental consequences of feeding systems, both intended and unintended, have a major influence on their continuation. The feeding system must ensure the maintenance of natural resources. The feeding system must be compatible with the efficient use of capital and labour, and result in a reasonable cash income to the farm families. We need to plan feeding systems with all these issues in mind (Nicholson, 1995).

The ability to model whole farms in this way, and so assess the interactions involved, is not developed. Models of natural resource use and feeding systems are being developed in isolation. Models of market trends and supply lines are also being developed separately. It is a major challenge for the future to build integrated models which enable a holistic assessment of substantial changes on feeding systems. These need not be solely quantitative models, but incorporate expert systems, knowledge bases, response functions and risk management. There is a range of machine learning methodologies now available to assist in these developments.

A partial advance in this direction is being made through strategic farm planning models. In northern Australia, the development of DAIRYPRO (Kerr *et al*., 1999) has integrated knowledge bases, the experience of "experts", and response functions developed from farm data. The model facilitates an assessment of farm productivity, compares this with the average farm for that region and with the expert's opinion on the potential of the farm, and enables "what if" scenarios to be compared. The model isolates relatively large components of the farm, such as winter irrigation area, and makes broad suggestions as to how efficiency may be improved. Though far from complete, there is a range of more specific models capable of looking into more details in each of these components. Some examples are ration formulation, irrigation management, nutrient balance assessment, and feed planning. The co-ordination of all this effort, and its integration into a whole farm context, is a major challenge for the future.

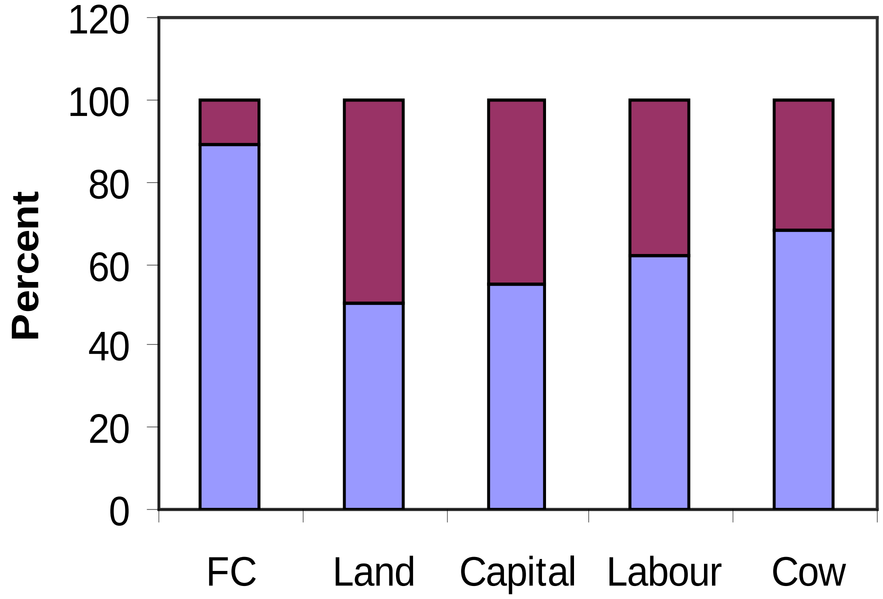


**Figure 3** Relative efficiency of components of feeding systems on Queensland dairy farms. Units are; average feed cost (FC); average land productivity (Land); average return on assets (Capital); L milk harvested per labour unit (Labour); and milk production per cow (Cow). Each value is expressed as a percentage of benchmarks representing best practice. Note that average feed costs are below the current benchmark figure (11.6 vs. 13.0 cents/L milk).

Within the farm business schedule more attention needs to be given to the efficiency of resource use. We have concentrated on feed cost per L milk for many years, and this remains an important benchmark. However, capital costs, including the cost of cows, overhead and labour costs have become a greater proportion of total costs (currently 66% of total cost; Busby, 2000). Figure 3 shows the relative efficiency of using land, capital, labour and cows on the average northern Australian farm. Overall efficiency must take into account all of these ratios. For example, an increased input of purchased feed may increase fed cost per L, but reduce total cost by reducing depreciation and overhead costs by a greater amount. A recent analysis of opinion about the industry in the future suggested people saw this occurring through much larger herds (Cowan *et al*., 2000).

*Technology*

If subtropical dairy production is to be competitive with that in temperate zones, there is a need to embrace appropriate technology. Systems of production in the subtropics of Australia have drawn heavily on temperate experience. Only limited attempts have been made to develop a highly productive and tropically adapted system of production. This is despite evidence of high potential for production per hectare (Chopping *et al*., 1976), and evidence that tropically adapted cows can be competitive with temperate breeds (Bodero & Reason, 1988). Much of the recent research has been aimed at incremental improvements in the adaptation of temperate plants and animals to the tropical zone.

It could be argued that the subtropics starts with a competitive advantage in that the amount of solar radiation is high (Cooper, 1970). However, our ability to convert that radiation into milk is limited. In the longer term it is difficult to see how the use of temperate plants and animals would give the subtropics a competitive advantage, and alternate systems which make optimum use of adapted plants and animals may be needed.

Associated with this thought is the question "will genetic engineering and biotechnology give the subtropics a chance to catch up in efficiency?" Modern breeding methods have been applied to temperate plants and animals for much longer than for tropical species, and it may be difficult to make relative gains through quantitative genetics. Instead it may be efficient to use new genetic technology to make quantum changes in characteristics of plants and animals. The feasibility of doing this, and the acceptability to the public, are yet to be determined.

Another aspect of technology likely to have a big impact on feeding systems is robotic milking. The convenience of the machinery will need to be balanced against modifications needed to the feeding system to enable cows to have continuous access. This trend will favour intensive or feedlot operations, and could be aligned with current trends in the industry.

## Conclusions

Subtropical feeding systems have developed rapidly over the past 30 years, to be efficient in servicing domestic markets. There is now a need to make further developments suited to serving an international market. There is substantial capacity for further productivity gains on farm, though the bases for calculating efficiency need to be broadened. Emphasis on the farm will be on models suited for whole farm decision making, new technology to enhance efficiency of developing systems, and competitive business principles.

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