Northern dairy feedbase 2001.
5. Integrated dairy farming systems for northern Australia

A. ASHWOOD[1], D. KERR[2], R. CHATAWAY[3] AND T. COWAN[4]
[1]*North Coast Agricultural Institute, Wollongbar, New South Wales*
[2]*Queensland Department of Primary Industries, Brisbane*
[3]*Oakey and*
[4]*Mutdapilly Research Station, Ipswich, Queensland, Australia*

Abstract

The predominant dairy farming systems used in northern Australia were identified as: (i) pasture-based, unrestricted irrigation; (ii) pasture-based, restricted irrigation; (iii) cropping systems; and (iv) feedlot systems. An analysis of the present inputs used in these systems and the associated cost structures was made using real farm data, and estimates of probable changes over the next 8 years made from recent trends in the industry and the estimates of farmers, extension officers and research workers.

These models show the complex nature of dairying in northern Australia, with a wide range in the level of use of major inputs such as concentrates, fertilisers, conserved fodder and irrigation. A high level of management skill is needed to carry out sucessfully the multiple tasks performed on these farms. The major constraints in the pasture-based and cropping systems related to the suitability of available forages and their management. In the cropping and restricted-irrigation systems there is scope for using higher levels of concentrates. The constraints to feedlotting included the regular supply of feeds, difficulties in balancing rations, land suitability and environmental concerns. All large herds shared some constraints in terms of farm layout, heifer rearing and reproductive management.

Correspondence: Mr A. Ashwood, North Coast Agricultural Institute, Wollongbar, NSW 2477, Australia

It was concluded that the recent growth in productivity on pasture and cropping farms will be maintained, through the use of higher quality pastures and forages, increased concentrate feeding and the conservation of greater amounts of fodder. Growth in feedlot dairying will be restricted to the large, by-product feeders and a small number of individual units established in favourable cropping areas.

Introduction

The dairy industry in the tropics and subtropics supplies a whole-milk market requiring a continuity of supply throughout the year. Unlike Queensland, northern NSW has the option of varying supply due to the flexible market milk scheme but seasonal calving is not practised by farmers at this point of time.

Production levels of dairy farms in Queensland and northern NSW are quite low despite the widespread use of concentrates. Average milk production is 3400 l/cow in northern NSW (Fulkerson 1992) and 3197 l/cow in south-east Queensland (Kerr 1993). This is not a true reflection of the potential of dairying in the tropics. Farmers using much of the present pasture and feeding technology have herd averages of 7000 l/lactation, with 10% of farms in Queensland producing above 5000 l/lactation (Davison 1990).

Anon. (1988) defined the major dairying areas in Queensland into 4 regions, SE Queensland, Darling Downs, Central Queensland and the Atherton Tablelands, supplying 44, 29, 12 and 15% of the state's milk, respectively. Northern NSW has approximately 50% of NSW suppliers and provides 40% of the state's milk. Milk production in the tropics has improved at a greater relative rate than in the temperate dairying areas. Queensland herd-recorded production has increased from 65% of that in Victoria in 1960 to 95% in 1989 (Chopping and

Cuda 1991). This paper describes the main farming systems presently used in the tropics and subtropics and discusses the opportunities and constraints of potential systems.

Present dairy production systems

Dairying in the tropics can be categorised into 4 main systems:

- pasture-based systems, unrestricted irrigation;
- pasture-based systems, restricted irrigation;
- cropping systems; and
- feedlot systems.

In all systems cows are calved all-year-round, requiring a constant supply of feed to achieve optimum production. Present feeding systems in northern Australia are characterised by their inability to maintain forage quality and quantity throughout the year. This limitation is addressed through the intensification of forage management and supplementary feeding. It has led to the development of increasingly complex interventionist farming systems (Table 1).

The systems based on summer grasses, legumes and winter forage crops (e.g. oats and vetches), whilst superior to the unimproved pasture systems previously used, were unreliable and supported relatively low stocking rates. Heavily nitrogen-fertilised pastures remain a major component of present pasture-based systems.

Much of the information on Australian tropical dairying systems relates to literature prior to 1970, though extensive work on various components of high input systems has been conducted at Mutdapilly and Kairi Research Stations (Lowe 1991). Subsequent information on the biological and economic sustainability of the various dairying systems in the tropics and subtropics has been obtained from observations on commercial farms (Kerr and Chaseling 1992).

Change — an ongoing process

Like other dairying areas, farmers in northern Australia have to cope with the cost-price squeeze. In 1970 the price received for a litre of milk was 2.6 times the cost of production but this has fallen to 1.6 in 1990. Farmers have recognised that this can be overcome only by increased production or reduced costs of production, and have accepted the challenge. For instance, about 75% of the variation between Queensland farms in annual production is explained through the variation in use of such practices as improved feeding and breeding management (Table 2).

Increased productivity will require a range of feeding and management technologies to be implemented. Table 2 shows a number of technical and management areas that can lead to increased production, with greatest gains being made through a combination of factors.

From a technical viewpoint, farmers can improve productivity by:

- maximising the capacity of the present system; and/or
- selecting technology-management options as part of a long-term plan to change the system and increase farm production and profits.

It is usually less expensive to develop the unused capacity of the farm. Improved feed and pasture management leads to increased productivity and margins. Implementing new technology often involves capital investment plus increased operating costs and interest repayments. Meeting these costs requires quite substantial lifts in production using improved management skills. Nevertheless, the long-term trend indicates that periodically it may be necessary to consider new capital investments.

Economic importance of increased production

The question is often asked by farmers whether maximum production and maximum financial

Table 1. Chronological development of dairy pasture systems in the tropics.

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 grasses + nitrogen fertiliser	ryegrass (irrigated)	0.8
1990	crops (maize silage; lucerne)	clover-ryegrass (irrigated)	1.5

Table 2. Factors associated with the annual productivity of Queensland dairy farms (Kerr *et al.* 1993).

Factor	Linear regression coefficients	Significance level
Number of farms	1822	
Constant (production without improvements, l/farm/yr)	71433	P<0.001
Feeding		
Energy (concentrates; l/MJ ME)	0.128	P<0.001
Nitrogen fertiliser (l/kg N)	4.36	P<0.001
Winter irrigation area (l/ha)	3078	P<0.001
Summer irrigation area (l/ha)	1103	P<0.001
Hay and/or silage fed (l/kg)	0.181	P<0.001
Farm area (l/ha)	95	P<0.001
Management		
Artificial insemination (l/% of cows bred to AI)	127	P<0.01
Herd recording (l/yr of herd recording)	1118	P<0.01
Shed type (herringbone v walkthrough; l/yr)	18283	P<0.001

return coincide under most conditions. Extensive surveys of farm production and costs, undertaken over the last five years, show that increased feeding of forages and concentrates increases the efficiency of feed utilisation for milk production (Kerr and Chaseling 1992). This is consistent with overseas experience (Bath 1985).

Statistical and financial information on Queensland dairy farms indicate that high producing cows are more feed-efficient, have lower variable costs and higher margins/cow than low producing cows (G. Busby and G. Chopping, personal communication; Table 3).

The data show that gross margin/cow increased with production/cow. With high producing herds, both feed costs/cow and profit/cow were higher. Herds averaging approximately 5500 l/cow had a gross margin/cow more than twice that of herds averaging 2500 l/cow. Farm profitability depends not only on the profitability per cow but also on the number of cows milked. These studies have also shown that the larger herds produced more milk per cow.

Overseas studies (Schmidt and Pritchard 1987) demonstrated that increased feeding doubled production per cow (6364 to 11 818 l/cow). When milk production was profitable for a given set of costs and returns, it was economical to increase the feeding level of cows provided they responded with increased production (i.e. they were not at their genetic potential).

Pasture-based systems

The information used here to predict levels of production and profit of pasture systems with unrestricted irrigation is based on group consensus (W. Fulkerson, personal communication), and information on the restricted irrigation system was obtained from Queensland figures prepared for the DRDC Farm Research and Development Strategy Review 1991 (N. Delaney, personal communication) (Table 4).

Tropical pastures

A substantial number of farmers in northern NSW and Queensland have the potential for unrestricted irrigation (i.e. >0.5 ha/cow). The limited area of irrigation with the typical unrestricted farm in Table 4 reflects the fact that the irrigation potential of these farms has not been developed to capacity.

Most tropical pastures for dairying are now pure grass swards fertilised with nitrogen (Reason *et al.* 1989). The main advantage of the nitrogen-fertilised tropical grass system is that it is a simple system able to support high stocking rates. Annual milk production from grass-N pastures ranges from 6000–9000 l/ha under rainfed conditions (Teitzel *et al.* 1991) at stocking rates of 2 cows/ha in dry areas (800 mm) to 2.6 cows/ha in high rainfall areas (1200 mm).

Table 3. Relationship between costs, returns and milk yield/cow for south-east Queensland for 1989–90 (135 farms; G. Busby and G. Chopping, personal communication).

Milk yield costs	Low (<3000 l/cow)	Medium (3000–5000 l/cow)	High (>5000 l/cow)
Total feed costs (c/l)	11.9	11.2	11.0
($/cow)	296	438	603
Total variable costs (c/l)	20.6	19.7	19.5
($/cow)	513	770	1070
Income over variable costs ($/cow)	374	570	760

The low voluntary intake of tropical grasses is associated with high fibre content, low digestibility percentage and a large quantity of indigestible fibre (Minson 1980). This is reflected in milk production levels of 9-12 l/cow/d. This level appears to be the maximum milk production possible from tropical grasses without supplementation (Stobbs 1971; Cowan *et al.* 1974). Without the use of supplements and winter pastures, nitrogen-fertilised tropical pastures have a production potential of 3500 l/cow/lactation.

Temperate pastures

Temperate pastures do not persist under raingrown conditions in the subtropics and tropics, which places constraints on production and reduces profit due to the cost associated with the need to re-establish such pastures. Generally the solution to poor persistence of perennial temperate pastures has been to revert to annual temperate pastures. These species have improved the quantity, quality and seasonal availability of pasture (Chopping *et al.* 1982a, 1982b; Murray *et al.* 1982; Lowe *et al.* 1985; Moss *et al.* 1985, 1986, 1987).

Table 4. Typical features of present pasture-based dairying systems in Queensland[1] and northern NSW[2].

Parameter	Restricted irrigation	Unrestricted irrigation
Farm area (ha)	140	100
Summer forage-pasture (ha)	96	60
Winter forage-pasture (ha)	15	14
Irrigation (ha)	5	8
Grain (t/cow)	1.2	0.8
Total stock	97	88
Milkers	77	70
Labour units (family)	1½	1½
Labour units (casual)	1	1
Capital costs ($)	—	642 000
Cash costs ($)	—	77 040
Gross milk income ($)	95 360[3]	86 400
Total milk production (l/farm)	298 000	270 000
Cow milk production (l/year)	3 225	3 214

[1] Data prepared for the DRDC Farm Research and Development Strategy Review 1991 (N. Delaney, personal communication).
[2] W. Fulkerson (personal communication).
[3] Less marketing and cartage, the average milk price is 32c/l.

"High-N ryegrass" is the most widely used temperate pasture with potential to produce 10 000–15 000 l/ha (Chopping and Cuda 1991). It is a simple system tolerating high stocking rates and frequent grazing, based on either annual or perennial ryegrass. Annual pastures involve the cost of resowing and have serious establishment problems in wet autumns. Under present management systems, perennials may persist into the third year, but invariably require oversowing in that year, and re-establishment in the fourth.

Despite various practices such as strategic nitrogen application (Cameron 1969) and improved irrigation (Cameron 1967), persistence of perennial ryegrass remains a problem (Fulkerson *et al.* 1993). Although temperate pastures have played an important role in improving production, their sustainability under present management systems is questionable due to the requirement for high levels of nitrogen fertiliser. Clovers support higher milk production than ryegrass (Murray *et al.* 1982) and also have some environmental advantages (Chopping and Cuda 1991). Difficulties which have limited their contribution to a more cost-effective pasture-based system include the need to control bloat and weeds.

Potential of pasture-based systems

Despite the low milk production levels from present pasture-based systems, there appears to be scope for productivity gains by using pastures (temperate and tropical) more efficiently and by increased use of supplements and conserved forages (pastures and crops). Features of the potential pasture-based systems are shown in Table 5.

Table 5. Potential dairy farm pasture models for Queensland and northern NSW.

Parameter	Restricted irrigation	Unrestricted irrigation
Farm area (ha)	180	100
Pasture area (ha)	150	90
Summer pasture (ha)		
grass	90	50
crop	10	10
Winter pasture (ha)		
perennial rye	15	40
annual rye	5	20
Irrigation potential (ha)[1]	25	80
Milkers (cows)	140	150
Grain (t/cow/yr)	2.5	1.3
Conserved forage (tDM)	140 (purchased)	150 (bunker)
Labour units (family)	1½	1½
Labour units (contract)	2	1
Cow production (l)	7 000	6 000
Total milk production (l/farm)	980 000	900 000
Capital costs ($)	1 020 000	900 000
Cash costs ($)[2]	156 800	122 000
Gross milk income ($)[3]	313 600	288 000

[1] Area that can be irrigated — serviced by underground mains.
[2] Estimated as 0.5 × gross milk income.
[3] Returns less levies and cartage i.e. 32 c/l.

The main features of the potential pasture-based systems include:

- Well managed tropical pastures appropriately fertilised and irrigated will produce 10 500 kg/ha DM (plot yields of kikuyu — 30 000 kg/ha DM).
- The summer crop (soybean, cow peas, maize) is used as silage and also serves as a cleaning crop for the resowing of perennial ryegrass-clover pasture.
- The perennial ryegrass-clover is optimally irrigated and fertilised to yield 12 500 kg/ha DM (plot yields are greater than 20 000 kg/ha DM). Surplus perennial ryegrass-clover pasture is ensiled.
- Annual ryegrass is directly drilled into summer pastures in April and watered to provide 9 500 kg/ha DM (plot yield greater than 20 000 kg/ha DM).
- Concentrates are fed at an average of 4.3 kg/cow/d but levels vary according to seasonal conditions and pasture management requirements. Higher levels of feeding are used in the restricted irrigation system to compensate for the reduced availability of temperate pasture.
- A feed-out area (feed pad and loafing area) should be used during wet weather and seasonal feed shortfalls.
- Adequate quantities of silage are stored (pasture, maize or other crop).
- With the restricted irrigation pasture system, even further emphasis is placed on feed management through the use of supplements and proper ration formulation.

Constraints to achieving the potential of pasture-based systems

Basic limitations to achieving the potential of the pasture-based systems include the following:

- The lack of a high quality and reliable legume in summer pastures.
- Temperate pastures are usually a limiting resource and are frequently managed to meet herd feed requirements rather than to maximise pasture productivity and persistence.
- Pasture and feed management require a full understanding of all components of the system and require long-term planning of the various components of the system.
- Farmers may perceive the systems as complex and will not completely accommodate all the components, making the system unworkable and less sustainable.
- The productivity of white clover is limited by rainfall distribution and irrigation management, with yields fluctuating from year to year (Jones 1982; Ivory 1982).
- Waterlogging is a common problem in autumn — early winter causing reduced pasture establishment and low production. Drainage and wet weather feed management are essential components of the system.
- Present tropical pasture management depends on low stocking rates, leading to low quality pastures and competition for land to establish temperate pastures during autumn.
- Concern over the long-term effects of high rates of N on soil acidity and the effect of soil nutrient imbalances on herd health. Reason *et al.* (1989) showed that blood calcium and phosphorus levels were reduced after 4 years of high nitrogen application.

- High quality maize silage can be produced in the tropics and subtropics (A.G. Kaiser, personal communication) but in practice there is considerable variability in quality and quantity.
- A substantial number of the crops grown in the subtropics have low nutritive value.
- The planned management and removal of surplus pasture is not a common practice in pasture-based systems. Cutting, harvesting and storage to optimise quality are essential where high milk production levels are expected.

Cropping systems

The Darling Downs and South Burnett are the major cropping areas of the subtropics. Features of this region include low rainfall (600–750 mm), limited irrigation (68% of farms are dryland; Anon. 1988), soils of moderate to high fertility, and close proximity to sources of grain and cotton seed, and the physical and production features of a typical cropping farm with limited irrigation (0.1 ha/milker) are illustrated in Table 6.

The table shows that at present approximately 50% of the cultivated area is used for oats (some barley and triticale), 15% for forage sorghums, 5% for forage millets, and 15% for lablab, with only a few farms growing maize (Thompson 1991). The area is considered to be semi-irrigated (Anon. 1988) and forage production is directly related to rainfall. The basis for the feeding estimates of the present system is shown in Table 7.

Present cropping systems

Tropical pastures and forages. The bulk of summer feed is supplied by early maturing sorghum x sudan grass forage. This is complemented by later plantings of lablab and sweet sorghum forage to provide feed until May. Lucerne provides 25 tonnes of hay with a similar amount of grazing. Unimproved pasture contributes limited amounts to the feed supply (Table 7). Surplus summer feed is baled for use during winter in combination with purchased crop stubble.

Temperate pastures and forages. Plantings of winter feed (March–July) comprise 5 ha of irrigated annual pasture and 50 ha of cereal

Table 6. Physical and production characteristics of present and potential cropping systems.

Parameter	Present	Potential
Farm size (ha)	200	200
Cultivation (ha)	110	110
Unimproved pasture (ha)	90	80
Improved pasture (ha)	0	10
Winter forage		
Irrigated annual (ha)	5 (rye)	5 (rye-clover)
Dryland (ha) — oats	50	45
— medic	0	10
Summer forage		
Irrigated lucerne (ha)	5	5
Dryland lucerne (ha)	0	10
Crop — restricted irrigation (ha)	5 (sorghum)	5 (soybean)
Dryland grass forage (ha)	30	20
Dryland legume forage (ha)	15	25
Forage/lucerne hay (ha)	50	50
Soybean for silage (ha)	0	25
Forage crop silage (ha)	0	25
Purchased may		
— stubble (t)	25	0
— cereal (t)	0	50
— lucerne (t)	0	100
Purchased grain (t/cow)	1.2	3.0
Stock (cows)	110	150
Milkers (cows)	90	120
Labour units (family)	1.5	1.5
Labour units (contract)	0.1	1.0
Total milk production (l)	440 000	1 117 000
Production/cow (l)	4 000	7 800
Stock sales ($)	13 000	20 000
Capital costs ($)	594 000	950 000
Cash costs ($)	83 527	245 023
Gross milk income ($)	140 800[1]	357 440

[1] Return less levies and cartage, i.e. 32 c/l.

crops. Production from both winter and summer forage crops is limited by low fertiliser inputs (60 kg/ha N), inappropriate grazing management (open paddock) and varietal selection.

Supplementary feeding. Concentrate is fed in the bails at 4 kg/cow/d. No grain is fed to heifers after weaning. Supplementary roughage is all home-grown apart from 25 tonnes of crop stubble purchased annually.

Labour. In addition to family labour, casual labour is employed for one month of the year.

Potential cropping systems

Through intensification of the cropping program, the increased use of supplementary feeding (both grain and roughage), the employment of a full-time labour unit and significant capital investment, improvements can be made in gross

Table 7. Basis for feeding estimates — present typical farm.

Forage type	Area	DM yield	Utilisation rate	Total DM available
	(ha)	(kg/ha)	(%)	(t)
Forage sorghum (early)	25	9 000	40	90
Sweet sorghum (late)	10	6 000	40	24
Lablab	15	4 000	40	24
Lucerne	5	15 000	60	45
Native pasture	90	2 000	40	72
Oats	50	4 000	40	80
Ryegrass	5	9 000	60	27
Total (home-grown)				**362**
Cereal stubble		22 500	70	16
Grain				120
Total (all feed)				**498**
Animal requirements	**Daily (kg DM)**	**Number of days**	**Number in group**	**Total (t DM)**
Milking cows	13	300	90	351
Dry cows	8	65	90	47
Replacements				
0–1	3	365	20	22
1–2	5	365	20	36
2–calving	7	270	20	38
Total				**494**

margins, operating profit and return to owner's capital (Table 6).

The changes made to the farming system are as follows:

Tropical pastures and forages

- The introduction of late maturing grass forages to improve regrowth potential and increase feed quality.
- Increased planting of legumes.
- Improved grazing and agronomic management. This is relevant for both summer and winter forage crops and includes: increased fertiliser inputs on grass forage crops (180 kg/ha N); intensified grazing management (strip-grazing coupled with back-fencing); and improved timeliness in planting. The benefits of these changes on dry matter yield and utilisation rates are illustrated in Table 8. Higher utilisation rates are given for crops used for hay or silage. Other crops could be conserved as necessary to aid forage management.
- The replacement of the conventional combine with a minimum tillage planter will allow for an increase in the effective cropping area through opportunistic double cropping. It will reduce fuel and labour inputs, maintain soil structure, reduce erosion and improve water conservation (Freebairn 1992).
- Low cost development of unimproved pasture using fertiliser and medics.

Temperate pastures and forages

- Selection of late maturing, rust-resistant ryegrass and oat varieties.
- Introduction of legumes into the cropping program.

Supplementary feeding. The level of concentrate fed to milkers will be increased to 10 kg/cow/d. Heifers will be supplemented at approximately 2 kg/hd/d. The use of stored roughage will increase to the equivalent of 250 t hay/yr (100 home-grown, 150 purchased).

Increased use of supplementary feed should increase the efficiency of the farming operation in terms of gross margins and return to capital. Given the present commodity prices for grain and cotton by-products the potential for value-adding to these products cannot be overlooked. The practice will also buffer the farm against regular (seasonal) and irregular (drought, flood) feed shortages, provide a more uniform diet to cows and allow grazing in summer to be minimised

Table 8. Basis for feeding estimates — potential farm.

Forage type	Area	DM yield	Utilisation rate	Total DM available
	(ha)	(kg/ha)	(%)	(t)
Forage sorghum + *Pennisetum*				
(early) — grazing	12	12 000	55	79
(early) — silage	8	12 000	80	77
Lablab	25	5 000	50	63
Lucerne (irrigated) (graze and hay)	5	18 000	70	63
Lucerne (dryland)	10	7 000	60	42
Native pasture	80	2 000	40	64
Improved pasture	10	4 000	50	20
Soybeans-silage	5	6 000	80	24
Cowpea	10	3 000	50	15
Ryegrass-clover	5	12 000	60	36
Oats	45	7 000	60	189
Medic	10	4 000	60	24
Total (home-grown)				**696**
Lucerne hay		90 000	80	72
Cereal hay		45 000	80	36
Concentrates		437 000		437
Total (all feed)				**1241**
Animal requirements	**Daily (kg DM)**	**Number of days**	**Number in group**	**Total (t DM)**
Milking cows	21	300	150	945
Dry cows	9	65	150	88
Replacements				
0–1	5	365	35	64
1–2	9	365	35	115
Total				**1212**

to avoid heat stress and heavy dependence on low quality forages.

Labour. Employing a full-time labour unit is integral to the achievement of high production and quality of life. Without this labour unit, grazing management will not be optimal and timeliness of planting, irrigating, fertilising and hay/silage production will be less than ideal. In addition, inadequate time will be available to mill the required amount of grain for the concentrate ration and this will have to be bought-in.

Constraints to cropping systems

To allow high levels of production, attention must be given to several areas of forage and feeding management.

Forage variety selection. Forage sorghums range in their time of flowering, leaf:stem ratio, protein concentration and digestibility level (Stuart 1990). Consideration should be given to the milk production potential of cereal and sorghum crops for silage, and the role of these agronomic factors. There has been no new release of tropical legumes since Highworth lablab (Wildin 1974) and there is a need for better summer legume crops for grazing and silage.

Grazing management. The rapid growth rates of forage crops create difficulties for management as digestibility declines rapidly with advancing maturity. The problem can be reduced by integrating fodder conservation with grazing management. The labour cost is a limitation to the introduction of more intensive grazing management practices.

The extensive nature of most dryland cropping farms results in excessive energy use at the expense of milk production, particularly in periods of heat stress. Increased emphasis on management of heat stress (shade and semi-feedlot nutrition) would improve production and profits.

Land sustainability. Continuous cultivation and crop removal reduces soil fertility and may lead to significant degradation through erosion of sloping lands. This can be reduced by soil conservation management e.g. stubble mulching, minimum tillage, opportunity cropping (Knowles and Jackson, personal communication). The adoption of soil management technology has been disappointing and is presently being assessed (Blacket and Hamilton 1992). The benefits of ley farming are well recognised and have a key role in sustainable farming systems (Dalal *et al.* 1991) but there is presently a low usage in cropping systems in the tropics and subtropics.

Supplementary feeding. Greater use of supplements is needed to increase farm efficiency. To increase the relatively low quantity of concentrate fed per cow, extension personnel must address the following concerns of farmers:

- Buying-in grain is just buying-in milk. Many farmers are not convinced that they can 'value-add' to grain despite present commodity prices.
- Paddock feed is the cheapest feed, so other feeds should be used as sparingly as possible. Many fail to recognise the true cost of paddock feed and to recognise that concentrates can complement paddock feed.
- Limited on-farm storage capacity to take advantage of low priced grain at harvest.
- Inadequate cash flows to make large capital investments.
- An inadequate knowledge of stock nutrient requirements and ration formulation.

Feedlot systems

The trend to fewer farms producing more milk will continue. Studies overseas and in Australia indicate that larger dairy enterprises are more efficient with greater economies of size. Better managed farms can produce any given level of output at a lower average cost and have larger optimal levels of output (Turkington and Townson 1978; Dawson and Hubbard 1987; D. Kerr, unpublished data).

One method of increasing output to take advantage of greater economies of scale is to adopt a feedlot system similar to those seen in other countries, notably north America. While the profit per litre of milk is less in this system, total farm profit can reach acceptable levels by having large herd sizes.

Further development of feedlots may include the use of grain and/or by-products. It will probably include a maize silage component in a combination of feed sources. Feedlotting may expand on the Darling Downs region of Queensland where the incorporation of grain could value-add to the grain produced in this region.

Potential feedlot systems

Feedlot systems similar to those described by Grieve *et al.* (1980) have been suggested in other countries such as Sweden (Frank 1982), Germany (Brandt and Rohr 1981) and France (Calais 1990). A summary of the benefits of a maize silage-based feedlot system for dairy cows was given by Grieve *et al.* (1980) who stated that corn silage has a high energy content, can be handled easily and produces high yields per hectare. It is anticipated that feedlot systems similar to those mentioned above will be adopted in Australia with grain or by-products being fed in addition to silage (maize, sorghum and legumes).

The feedlot system described by Davison (1992) is based on forage sorghum silage. The optimum system should use maize silage as this feed has a higher energy content at 10.5 MJ/kg DM compared with 9.5 for forage sorghum (A.G. Kaiser, personal communication). An outline of the components of a feedlot are shown in Tables 9, 10, 11 and 12. This case study feedlot has been adapted from the United States of America and is presently operating in the Beaudesert area of south-east Queensland (Davison 1992).

Table 9. Physical, production and income components of the potential feedlot system (Davison 1992).

Parameter	Value
	($)
Farm size (405 ha)	2 025 000
Irrigation area (142 ha)	
Dairy herd (500 cows)	400 000
Replacements (250 stock)	136 000
Dairy shed and yards	300 000
Plant and equipment	217 000
Buildings (e.g. storage, barn, effluent)	690 000
Feed plant and equipment	217 000
Total capital costs	3 985 000
Gross milk income (4 million l at 32 c/l)	1 280 000
Stock sales	65 000
Total costs (including depreciation)	1 080 000
Net income	265 000

Table 10. Summary of home-grown crop yields (Davison 1992).

Crop	Area	DM yield	Total DM yield
	(ha)	(t/ha)	(t)
Sorghum silage	100	22	2200
Pea/wheat silage (same area as above as a winter crop)	100	6	600
Sorghum grain	100	5	500
Wheat grain or Faba bean (same area as above)	100	3.7	370
Miscellaneous (soybean/peas)	23	6	138

The crop rotation consists of: May — plant peas/wheat; October — harvest peas/wheat and plant sorghum; December — harvest sorghum; April — harvest ratoon sorghum.

Table 11. Summary feed requirements (t DM/yr) (Davison 1992).

Feed	Milkers	Dry cows	Heifers	Total	Total + 15%	Home-grown
Sorghum silage	1050	160	460	1670	1920	2200
Legume silage (including legume bean)	450	80	180	710	820	740
Grain	1275	35	180	1490	—	870
Whole cotton seed	300	0	0	300	—	—
Protein concentrate	150	0	30	180	—	—

Table 12. Ration mixes and range of costs for milkers in the optimum feedlot (Davison 1992).

Feed type	Intake	Cost	Cost
	(kg DM/cow/d)	($/t DM)	($/cow/d)
Grain	8.5	80–150	0.68–1.28
Protein meal	1.0	250–400	0.25–0.40
Mineral pre-mix	0.5	600	0.30–0.30
Sorghum silage	7.0	75–105	0.53–0.74
Legume silage	3.0	75–105	0.23–0.32
Whole cotton seed	2.0	140–170	0.28–0.34
Total	22.0		2.27–3.38

Sensitivity of feed costs

The factor with the most impact on the profitability of the operation is feed costs (Davison 1992) with each $0.50 increase in daily feed costs increasing annual costs by $75 000 (Table 13). R. Dawes (personal communication) contends that the major constraint to the full feedlot system is the massive capital cost and that the money is borrowed and has to work like all investments.

Constraints to feedlot systems

Forage management

Limits to the growth of each crop. In general there are few physical limitations to the growth of maize or forage or grain sorghum in the areas that would be suitable for positioning a feedlot. A critical factor would be the availability of water which could be a problem in the Darling Downs area.

Table 13. Effects of lactating cow feed costs on nett income (Davison 1992).

Feed costs ($/cow/d)	2.50	3.00	3.50	4.00
Total feed costs ($/yr)	375 000	450 000	525 000	600 000
Nett income ($)	340 000	265 000	190 000	115 000

The major limitations to the use of maize as a crop for ensiling are the limited geographic areas to which the crop is suited, a lack of irrigation water, the low ME value of many crops grown in the subtropics, and the need for expensive machinery such as precision seed drills and cultivators. Dairy farmers are often limited in their ability to establish suitable crop rotations necessary for disease control (A.G. Kaiser, personal communication).

The major limitations to the use of forage sorghum as a crop for ensiling are the low ME content of the silage, the need for multiple harvests and possibly lower water-use efficiency compared with maize (Abeytunge 1983; Kerr *et al.* 1987). One advantage of forage sorghums is that, under dryland conditions, there is a better chance of a successful crop due to the hardier nature of sorghum.

Feed management

Balancing rations. Feeding maize silage as the only source of forage has no adverse effect on the level of production or growth of cows (Grieve *et al.* 1980). Maize silage has a lower concentration of some minerals (calcium, potassium, iron, manganese and zinc) but this is usually corrected by the addition of these elements in mineral supplements or the combination of other forages, notably hay (Grieve *et al.* 1980). Maize silage is deficient in protein and additional protein should be included in the ration. This can take the form of protein meals such as soybean or cotton seed. The source of protein is critical to the economics, and as far as possible should be provided from home-grown legumes. In general, a feedlot system based on maize silage is a biologically viable alternative for dairy production provided the ration is balanced with the correct minerals and protein.

Feed intake. Grieve *et al.* (1980) demonstrated an increase in dry matter intake by cows when hay was included with maize silage in the diet, and this should be investigated further. Calamari *et al.* (1991) demonstrated that dry matter intake of cows on a maize silage diet over a 5-year period was affected primarily by animal-dependent factors such as production, time since calving, body weight and age. Diet-dependent factors were concentrate quality and fibre content. Concentrate quality can have an impact on total intake which may have implications for by-product feedlots.

Land resources

Land suitability. Many factors have to be considered before establishing a feedlot. Some of these factors are discussed by Watts (1992) and include site selection, infrastructure, land requirements, topography, soil types, climate and surface waters.

Site selection: In general the most economically viable location for a feedlot is close to feed supplies. In Queensland the most likely location would be close to the grain supply areas of the Darling Downs for grain-based feedlots and close to food manufacturing industries for by-product feedlots.

Infrastructure: The site must be selected so that it has suitable access for transport of feed. It must have a continuous supply of good quality water, electricity and labour.

Land requirements: There must be sufficient land available to allow for feed handling and storage, water storage, ponds, effluent disposal and a buffer zone.

Topography: It is preferable that holding ponds be filled by natural drainage, so a gentle slope from the dairy to the ponds is necessary. The topography of the effluent-disposal areas should be such that cropping is possible and the movement of manure-spreading vehicles is not limited. It is common for odour problems to develop where the air from a feedlot drifts down a valley at night to a residential area.

Soil type: Soil type needs to be considered when constructing effluent ponds.

Climate: Most problems are highlighted in wet conditions and rainfall intensity and frequency must be considered.

Surface waters: The feedlot should be sited, designed and managed so that the quality of both surface and ground water is not degraded by runoff or seepage from the ponds or waste-utilisation areas. This can be achieved by the provision of a suitable buffer area between the feedlot and any watercourses.

The check-list shown above is not exhaustive but does demonstrate the multitude of economic, environmental and animal welfare issues that have to be considered before a feedlot can be established. As environmental factors such as odours and pollution of surface and ground water can affect the whole community, it is important that farmers get the right advice before the feedlot is established. A code of practice on the lotfeeding of beef cattle has been submitted to the Senate Standing Committee on Rural and Regional Affairs (Anon. 1992a) and it could be assumed that many of the practices discussed in this document could be applicable to the dairy industry in the future.

Land availability and cost. Projected population growth in south-east Queensland indicates an additional 235 000 people by the year 2001 for the Brisbane statistical region and 200 939 for Moreton, with an estimated 154 800 new dwellings required to house this increased population (Anon. 1991). This population increase must put pressure on available land, and dairy farmers close to population centres will be tempted to sell as land values increase. Other factors such as effluent disposal and air pollution may force the closure of some enterprises that are close to major population centres.

Environmental issues. A workshop on the research and development priorities for waste management recently identified the major requirements as the quantification of the wastes produced at feedlots and the development of sustainable methods for waste disposal (Anon. 1992b).

Additional large herd management constraints

Farm layout and area

Effective farm layout may help avoid most of the problems associated with handling large numbers of cows and this depends on the area of the farm. Provision to handle large numbers of milkers in wet weather is of paramount importance as it is under adverse conditions that most of the problems occur (Moxley 1991). The location of the feed pad, storm water drainage and effluent-disposal systems will dictate the location of a feedlot and all these factors need to be investigated. A check-list of actions to be considered when selecting the site for a feedlot is discussed in the land resources section.

Milking routine

If herd sizes increase, it will be a reflection of the need to have economies of scale. The management of larger herds will involve detailed planning and the establishment of a strict routine. French experience suggests that, in large herds, adjustment of milking time by one hour has a significant effect on all aspects of milk production (Veris and Schwarzbacher 1990). Moxley (1991) states that "the bigger the number of cows, the bigger the mess if a strict routine program is not adhered to". A great deal of planning is required to manage large herds. Some research resources may be needed to help determine the most effective milking routine.

Calf rearing

There are few technical limitations to large scale calf rearing if health and hygiene recommendations established from research over the years are maintained (R. Moss, personal communication). Problems that may occur could be due to a lack of adequate extension advice or problems with labour. Calf rearing usually requires a specialist with good observation skills and it is preferable that the same person rears all calves throughout the year. R. Moss (personal communication) estimates that calf rearing will require a total labour commitment of approximately one-third of a person/year, depending on herd size.

Herd health

Herd health management schemes, conducted by local veterinarians in many regions, would be expected to expand in the future as a more professional approach to herd health management is required. These schemes may involve a whole-farm service. Tranter (1985) categorised the types of farmers and the services required.

The first category is the farmer who requires drugs and farm supplies only; the second requires treatment of clinical cases only; the third requires regular monthly visits. This third category of farmer is most likely to remain in business by the year 2000 and able to take advantage of the benefits of a whole-herd health program. At present these programs offer advantages in that they address the problems of major diseases such as mastitis, lameness and poor reproductive performance, which result in the greatest economic losses but have not been addressed by traditional veterinary practices. The future trend must be for a more integrated approach between veterinary practitioners and nutritional consultants as described by Kelly *et al.* (1988). This integrated approach will be useful in diagnosing health problems as many reproductive problems are nutritionally linked.

Reproduction

The use of artificial insemination and herd recording allows the farm manager to select genetically superior stock and continue the genetic gains that are a feature of all well managed dairy farms. These genetic gains should go hand-in-hand with other gains achieved by better nutrition and management. The percentage participation rate for herd recording in Queensland has increased over the years from 8% in 1970 to 53% in 1990 (M. Lake, personal communication). Increasing awareness by farmers of the advantages of artificial insemination and herd recording suggests that usage of these management tools will increase in the future.

Artificial insemination requires expertise in both the insemination technique and the detection of oestrus. In larger herds, oestrus detection is a major contributor to poor reproductive performance (Kerr and Buchanan 1983).

Labour management

The availability and management of suitable staff are critical to the production and profitability of expanding enterprises (Drynan 1991). They can be major barriers to new initiatives and activities. As dairying becomes more intensive and complex the requirement for well trained rather than unskilled labour will become increasingly important. The University of Queensland's Gatton College, Lawes and Alexander College, Tocal (NSW) provide dairy management courses. Unlike in NSW, a farm apprenticeship scheme is not available in Queensland.

Financial management

The lack of basic bookkeeping and budgeting is seen as a serious limitation to examining performance and production (Blacket and Hamilton 1992). The intensification of farming systems requires even more sophisticated financial management as costs increase and input-output relationships become more involved. The question of identifying the optimal combination of the factors of production involving price, milk supply and the various management and technology components is complex, requiring analysis to improve business management decisions.

Extension constraints and opportunities

The view that research and development is a linear process and that farmers are the passive recipients is increasingly being challenged and reassessed. There is clear evidence that this is not the case since the function of extension is to transfer and nurture the pool of agricultural knowledge embracing all those that contribute in the communication process, including farmers. Farmers are subsequently legitimate extension workers (Salmon 1980) and need to be consulted in the research and development process.

Theory and practice

Increasingly it is being accepted that farmers, like other adult learners, can articulate their own interests, issues and needs. It is also recognised that farmers are a heterogeneous group with a wide range of socio-economic aspirations, reservations and beliefs which affect production and management decisions. Invariably this means that the decision making process is more complex than previously thought. It is extremely important therefore that more consideration is given to situational and personal factors when considering the presentation and uptake of various sets of management innovations.

Extension is further complicated by the fact that the farmer's interpretation of the issue is often not in terms that make a solution possible (Tully 1967). Numerous additional factors such as marketing and promotion, interstate and intrastate marketing practices contribute to the complexity of farm management decisions (Kelleher *et al.* 1991) and can even lead to a sense of lost control of farm operations (Anderson 1981).

Piccone and Schoorl (1987) argue that extension needs to move away from the heavy science — technology transfer orientation to the management of human endeavour. However, B. Frank (personal communication) makes a useful distinction between extension and technology transfer. Extension is extending information that supports the maintenance and development of people, organisations and communities whereas technology transfer is the provision of specific information which is an important part of the extension process.

The availability of suitable technology is not the only prerequisite for information transfer, and measuring the rate of adoption underestimates the importance of situational and personal factors. These factors influence farmer perceptions and preparedness to change (B. Frank, personal communication).

The traditional extension model of innovation diffusion will remain important with homogeneous audiences that are actively seeking new areas to increase productivity. Other more appropriate extension models are becoming increasingly more important to accommodate the situational and personal factors which determine the level of farmer interest or disinterest in new technology. Acknowledgement that farmers have different perceptions and goals has led to the examination and introduction of extension processes and methodologies that more adequately incorporate complex farmer behaviour.

Farmer involvement

Technology is not universally applicable or relevant to all farms and there are groups or target audiences that require specific information. Where farmers have formed subject groups to exchange technical information and discuss management practices, the effect on the adoption of new technology has been significant (Russell *et al.* 1989). It is now clearly recognised that scientists must identify and work with discrete groups of people who share common interests and problems (Oakley 1988). Where farmers have formed themselves into self-help organisations, the extension process is even more effective (Mathur 1983).

There is an increasing awareness of the necessity to see farmers as co-consultants in any research and extension process (Campbell 1988). When farmers have been invited to participate in a process of identifying the most pressing areas for ongoing and future research and development, they have responded very positively (Ampt and Ison 1989).

Farmers are also concerned whether recommendations are in a usable form and are workable and economically justifiable in "real life". Russell *et al.* (1989) indicated that farmers have a strong desire to participate in setting the research and extension agenda. The strength of any joint management venture is that the activities become more of an integrated activity with increased involvement and ownership.

There is a need for more efficient ways of handling technical information. Expert systems (Kerr 1992) may help extension officers give technically accurate advice as they can incorporate the reasoning strategies of specialised experts. This technology may help with the delivery of technical information. An expert system has been described by Smith (1989) as "a structured approach to knowledge representation that gives users ready access to the latest technical information. Such systems also encapsulate the expert's reasoning strategies". Such systems would run on computers of standard configuration.

Traditionally, extension advice has been based on research station results. It has been suggested that these results may be biased due to inappropriate experimental design or the experiment not running long enough (Cowan 1985) and that validation of research results may be needed (T. Cowan, unpublished data). This can be done by surveying farmers to determine the rate of adoption of certain technologies and to estimate the milk response rate to each technology. This could highlight problems that may occur with interactions between technologies that are not observed under a research station environment.

Equations could be developed for these data with the potential to allow for these interactions. These equations can be programmed in an expert system and the results specific to the region in question displayed on the computer screen. The expert knowledge incorporated in the system could allow for factors specific to a particular region or any social factors such as individual farmer goals and aspirations. Expert systems technology may allow much of this information to be obtained from the computer by programming into the expert system "rules of thumb" obtained from experts in the field.

Additional factors

The notion of barriers to adoption logically exists only under the traditional concept of extension since it rests on the conceptualisation that the new technologies are beneficial to farmers. Under the new extension concepts, where farmers are setting the agenda, barriers to adoption should not be a concern.

Sometimes the knowledge base is rejected by farmers on a very rational basis, at least from their viewpoint. Vanclay (1992) suggested that farmers do not necessarily articulate their reasons for non-adoption but their reasons include the following and closely relate to situational and personal factors:

Complexity. The more complex the innovations, the greater the resistance to adoption. Complexity makes the innovation more difficult to understand and generally requires greater management skills which increases the risk associated with the innovation.

Divisibility. This allows for partial adoption since it allows farmers to accept components they can identify with other farming activities. Partial adoption can be a form of trial adoption and can lead to complete adoption over time.

Incompatibility. Farmers are likely to adopt innovations that are compatible with other farm and personal objectives, e.g. the expenditure on capital machinery may not be compatible with situational and personal factors.

Economics. The more economically beneficial the innovation, the greater the rate of adoption, although farmers do not always act in an economically rational way.

Conflicting information. No information is free from debate about its applicability and effectiveness.

Capital cost. In addition to the prospect of profits, farmers also consider the capital required to adopt a new technology. Often capital investment may mean foregoing income until the new system is established.

Intellectual outlay. In addition to capital costs there are costs of learning how to do things differently. New technology may require greater knowledge or retraining.

Loss of flexibility. Sustainable management practices may require that the farmers lock into management systems and certain technical constraints.

Increasingly, farmers will become influential in determining what research and extension is done. Not only are farmers becoming involved in the research and development processes but also they are strongly recommending to funding bodies what priority is given to projects that are jointly managed by extension officers, farmers and research workers.

Clearly research and development priorities will be based on the perceived needs of farmers and their involvement in the conception, implementation and evaluation of programs through participative management strategies (Chamala and Mortiss 1990).

Research needs

In addition to the needs for research raised in previous papers, the following issues require attention by the research and extension communities:

- research and extension need to be conducted within the context of whole-farm systems;
- the economics of the various systems of dairying in northern Australia need to be investigated; and
- participative, farmer-driven extension programs need to be developed.

Specific issues requiring attention are:

- quantify wastes from feedlots and develop sustainable methods of waste disposal; and
- identify the most effective milking routine for large herds.

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