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ECONOMIC RESEARCH REPORT NO. 44 (AUGUST 2009)

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Abstract
The complementary forage rotation (CFR) aims to achieve high levels of home-grown forage to complement high performance dairy pastures. Variable cost budgets indicate that total variable costs for CFR are similar to those of a well managed, high input pasture, approximately $110/t dry matter (DM) utilised (range being from $97 to $118 and from $98 to $128/t DM for CFR and Pasture treatments, respectively). The similar costs of forage production indicate that the potential of pasture production and utilisation should be fully exploited before CFR is considered, and CFR has potential to replace more expensive feeds such as concentrates. When concentrate was partially replaced by growing CFR, and including associated infrastructure costs, CFR had to occupy an area of more than 10 per cent of the dairy area of a modelled farm, when CFR occupied 20 per cent of the dairy area there was a 10 per cent reduction in feed costs. Stochastic budgeting was applied to examine fertiliser price risk and yield risk. Under fertiliser price variability the average cost of pasture was $121/t utilised DM and a maximum cost of $149/t DM, and the cost of CFR fodder was $112 and $123/t DM, respectively, due to the 2.3 times higher efficiency of use of nitrogen for the former than for the latter. Including forage yield variability, using minimum (~60 per cent less yield than target), most likely (~25 per cent less yield than target) and maximum (target yield) yield distributions, the CFR had a higher average cost of forage than the high input pasture system, being $139/t DM and $133/t DM respectively. The likelihood of reducing pasture utilisation for a 'good' pasture manager would be much lower than the risk of having a yield reduction in one or more of the CFR crops, was and reflected in the pasture system having a minimum yield only 33 per cent less than the target yield of 18 t DM/ha in the simulations undertaken. The risk analysis including both price and yield risk simultaneously, indicate that the average variable cost of CFR forage is similar to well managed, high input pasture.

Keywords: dairy; complementary forage rotation; pasture; maize silage; legume; Brassica; economic; evaluation; Australia
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Acronyms and Abbreviations Used in the Report

ABARE	Australian Bureau of Agricultural and Resource Economics
CDF	Cumulative distribution function
CFR	Complementary Forage Rotation
CFS	Complementary Forage System
DM	Dry matter
DPI Vic	Department of Primary Industries, Victoria
EMAI	Elizabeth Macarthur Agricultural Institute, NSW DPI, Camden
MilkBiz	A dairy farm business management software package by NSW Department of Primary Industries
MJME	Megajoules of metabolisable energy
RoA	Return on Assets

Executive Summary

Australian dairy farmers manage their businesses in the context of a deregulated market that is exposed to a highly competitive and protectionist international dairy trade. This has historically resulted in declining terms of trade. Increased competition for land in many of Australia's traditional dairying regions from both alternate agricultural and non-agricultural activities has further increased the effective cost of operating dairy businesses. Dairy farmers respond by increasing farm productivity, with increased stocking rates and production per cow. This has been achieved by increasing the quantity of purchased feed, particularly concentrates, and increased production of home-grown feed from pastures and forage crops. At the same time, the increasing cost of dairy land, projections of increased grain costs, and limited availability and increasing cost of irrigation, highlight the potential benefits of technologies aimed at increasing the production of home-grown feed. The complementary forage rotation (CFR) component of the Future Dairy project aims to achieve high levels of home-grown forage to complement high performance dairy pastures.

A previous economic analysis of the potential impact of CFR in the East Gippsland area of Victoria with major inputs by Dan Armstrong (Victorian department of Primary Industries) examined two case studies. An '*average'* pasture-based dairy farm, in which the farmer may ask the question, what role, if any, could a CFR play in his/her farming system? The second case study involved a 'fodder reliant' dairy farm, in which the farmer may ask, how does growing more forage through a CFR compare to buying more land/water, or buying supplements or just doing what I currently do, better?

The analysis concluded that a CFR had the potential to increase profit in both cases, but, as expected with strong dependence on forage yields and what proportion of the farm area is devoted to CFR. Also as expected, implementation of CFR was more risky on the relatively small farm (55 ha), than on the fodder reliant farm (>270 ha).

The implicit message highlighted in these analyses is that CFR can be a realistic option only after the potential of pasture utilisation has been fully exploited. Therefore, a step-wise analysis of the cost of feed production, risk, impact of infrastructure costs, and whole farm implementation is warranted.

The analysis undertaken is reported in two parts. In this study, the economic evaluation of the CFR technology is structured to progressively evaluate the technology by using variable cost budgets and cost budgets incorporating additional capital costs and risk based upon the data from paddock-scale comparison at Elizabeth Macarthur Agricultural Institute (EMAI). A companion study (Alford, Garcia, Farina and Fulkerson, 2009*b*) extends this cost analysis by applying steady state whole farm budgets to compare alternate or progressive scenarios that might be considered by farmers looking at the potential to increase farm productivity through their feeding system.

Key questions and results

The economic evaluation addressed a set of key questions:

1. *What is the cost of forage production with CFR in comparison to well managed, high input pasture and bought in feed? This is the basic question, as if CFR costs were similar to the cost of concentrate then there would be little gained in going any further in the analysis.*

This question was addressed by using variable cost budgeting methodology. Results clearly indicate that total variable costs for CFR are very similar to those of a well managed, high input pasture, approximately $110/t dry matter (DM) utilised (range being from $97 to $118 and from $98 to $128/t DM for CFR and Pasture treatments, respectively). The similar costs of forage production for both well managed, high input pasture and a CFR option indicate that: a) the potential of pasture production and utilisation can (and should) be fully exploited before CFR is considered, and b) CFR has potential as an option to replace more expensive feeds such as concentrates. Therefore further analysis of the technology was warranted.

2. *How do additional capital costs needed to implement CFR impact upon the cost of the CFR? Does the CFR have a role as a replacement for more expensive feeds like concentrates?*

Although both well managed, high input pasture and CFR have similar variable production costs, we also need to consider any additional capital costs that the technology may incur. The above question was addressed using a cost budgeting methodology, adopting a conservative approach in which a hypothetical farmer implements CFR in different proportions of his/her farm (100 ha of milking area) with the goal of just replacing more expensive concentrates (i.e. without exploiting the potential of increasing the number of cows milked due to increased production of home grown feed).

Total annual amortised infrastructure costs were $281/ha, which offset any potential advantage of replacing concentrates when growing CFR on only 10 per cent of the farm area. When CFR occupies 20 per cent of the land there was a 10 per cent reduction in feed costs. Thus, the additional infrastructure costs required to implement CFR do have an impact on the average cost of feed production. However since the infrastructure cost is an overhead cost, the impact is 'diluted' as an increasing area of the farm is used for CFR. Results also suggest that even if a farmer did not increase cow numbers or total milk production, the benefits of partially replacing expensive concentrates with forage produced by a CFR would be significant (10 per cent reduction in total feed costs or greater as concentrate prices increase).

3. *How robust are these variable costs in relation to changes in the price of key inputs such as fertiliser and reductions in forage yield?*

This question addresses key issues in relation of not achieving target forage yields and the price of key inputs such as fertiliser. The question was addressed using a stochastic budgeting methodology. For a well managed, high input pasture, the variability in fertiliser price based on historical data indicated a mean cost of production of $121/t utilised DM and a maximum cost of $149/t DM, while for the CFR these figures were lower, being $112 and $123/t DM, respectively. This 'lower' risk for the CFR than pasture in relation to changes in fertiliser price is due to the 2.3 times higher efficiency of use of nitrogen for the former than for the latter.

In terms of forage yield variability, using minimum (~60 per cent less yield than target), most likely (~25 per cent less yield than target) and maximum (target yield) yield distributions, the CFR had a higher average cost of forage than the high input pasture system, being $139/t DM and $133/t DM respectively. The likelihood of reducing pasture utilisation for a ‘good’ pasture manager would be much lower than the risk of having a yield reduction in one or more of the CFR crops, and this was partly reflected in the pasture system having a minimum yield only 33 per cent less than the target yield of 18 t DM/ha in the simulations undertaken.

The risk analysis using stochastic modelling including both price and yield risk simultaneously, indicate that the average variable cost of CFR forage is similar to well managed, high input pasture in relation to changes in the price of fertiliser and reductions in forage yield. However, no additional risk of crop failure has been considered as this would be highly variable and specific to particular regions.

1. Introduction

Australian dairy farmers like other agricultural producers, have generally faced declining terms of trade. Over the last 20 years, the industry has operated in a business environment where the average annual decline in terms of trade has been in the order of 1.8 per cent (ABARE, 2006). Further, producers in New South Wales, Queensland and Western Australia, that previously operated in regulated domestic milk markets, had to adjust to a deregulated market from 2000. As a consequence of this increasingly competitive market, producers remaining in the industry have responded by increasing the size of their dairy businesses, through acquiring more land, increasing the productivity of the current land resource, or both (ABARE, 2003).

Since 1989/90, Australian dairy farm numbers have decreased 48 per cent from 15,396 to 8,055 in 2006/07, while at the same time the number of dairy cows on Australian farms has increased by over 9 per cent, to 1,810,000 (Dairy Australia, 2007). While average farm size has varied over this period, the net result has been a steady increase in stocking rates on Australian farms (ABARE, 2006). Milk yield per cow has increased over this same period from 3,781 L/cow/year in 1989/90 to 5,163 L/cow/year by 2006/07, a 37 per cent increase. This increase in both stocking rates and production per cow has been attributed to improved pasture management practices, herd genetics and increased supplementary feeding (Dairy Australia, 2007). For example, between 1991/92 and 2004/05 the quantity of concentrates fed including grain and byproducts, increased from 0.58 t per miking cow to 0.9 t per head (Lubulwa and Shafron, 2007). Likewise, there has been a trend of increased home grown forage conserved as silage or hay on Australian dairy farms, with a 53 per cent increase in tonnes of hay or silage cut on a per hectare basis over the period 1991/92 to 2004/05 (Lubulwa and Shafron, 2007).

This continuing focus by Australian dairy farmers on increasing intensity of their production systems to improve productivity has occurred as land resources and key inputs such as grain and water have increased in cost and are predicted to continue to do so in the medium and longer terms. Land values in dairy regions have also increased considerably as competition for dairy land, both for dairy farming and for competing purposes, has increased. For example, in Victoria, dairy land values have increased on average by 5.4, 5.3 and 5.3 per cent per annum for Western Victoria, Gippsland and Northern Victorian regions, respectively, over the last 10 years. This increase in the cost of dairy land has intensified further during the last five years with the Western Victoria, Gippsland and Northern Victorian regions recording average annual increases in values of 9, 14.1 and 16.8 per cent (Dairy Australia, 2006*b*). ABARE (2006) discusses the impact of rising land prices in Victorian dairying regions highlighting that land values have increased some 5.3 per cent per annum in nominal terms, with the average price in 2005 being approximately $7,750/ha. This includes both irrigated and non-irrigated farms. On a Victorian regional basis, dairy land prices in 2005 ranged from $7,000/ha in Western districts to $11,500/ha in Gippsland. Dairy land values in other states have also increased significantly with traditional coastal districts in NSW and Queensland experiencing high demand from non-agricultural industries, including lifestyle land development.

Given the higher land values, farmers have increased their stocking rates while also lifting yield per cow, and they have done this in part by increasing the level of purchased inputs, such as feed grain, as previously discussed. However, global demand has increased for grain and is expected to continue in the medium to long term, leading to higher grain prices (Dairy Australia, 2007). An additional concern expressed by Australian livestock industries, and mirrored globally, is increasing competition from the biofuels industry for feed grains, which is expected to add further upward pressure on feed grain prices (Dairy Australia, 2007).

Irrigation water costs and availability are also an ongoing concern for Australian dairy farmers. Changing public policy in regard to environmental water flows and market prices for irrigation water has increased the emphasis upon water use, requiring farmers to look at the efficiency of water use in producing feed for dairy cattle (Dairy Australia, 2007).

Therefore technologies that are aimed at increasing home-grown feed, including pastures and forage crops, are increasingly relevant for the Australian dairy industry and farmers have demonstrated a propensity to increase forage production at least incrementally as indicated by industry surveys (Lubulwa and Shafron, 2007). It is in this context that the Complementary Forage System (CFS) research project as part of Future Dairy has been conducted (García and Fulkerson, 2005).

This report provides a preliminary economic assessment of implementing a complimentary forage rotation (CFR) including maize, a legume and a brassica, as part of the CFS at the farm level which also includes intensive pasture production and associated feeding of supplements. It is based upon experimental results both from the field trial level and at the experimental farm level, along with modelling of anticipated results as the experiments continue.

Given the likely pressures on dairy farmers, in terms of needing to produce more feed per hectare and per ML of water, the FutureDairy project's major focus has been the potential to significantly increase home-grown forage to lift farm productivity. The method under investigation has been through the application of an intensive CFR in addition to an intensively managed pasture system (García and Fulkerson, 2005).

Ultimately, this preliminary economic analysis aims to determine if in fact the proposed CFR system has the potential to increase farm profitability compared to current industry production systems and alternative production scenarios. The method applied in this economic analysis is explained including the sources of costs and the physical and economic assumptions used. Results and discussion are presented including some risk analyses to examine the potential robustness of the CFR system compared to more traditional systems. Finally, broad conclusions are summarised with qualifications and limitations of this economic analysis detailed.

2. The Complementary Forage Rotation Experiment

2.1. Overview of CFR project and results

The experiment was conducted at Elizabeth Macarthur Agricultural Institute, Industry and Investment NSW. The experimental design was a Complete Block Randomised Design with four replicates and two treatments randomly assigned within each block to paddocks that varied in size from 0.46 to 0.78 ha. The experiment was conducted over three years.

The treatments consisted of:

A **Pasture Control** representing a typical ’high input, intensively managed‘ sub-tropical pasture (kikuyu, *Pennisetum clandestinum*) as the base pasture with predominant growth over summer, oversown with a short rotation ryegrass (*Lolium multiflorum*) in early autumn. Best practice fertiliser, irrigation and pasture management were applied.

The **Complementary Forage Rotation (CFR) System** representing a “high input, intensively managed” forage rotation system consisting of three phases within a single production year: maize for silage production, a Forage Rape as a break crop, and a legume to fix atmospheric nitrogen.

Paddocks were grazed or harvested as required and detailed measurements of forage yield and quality were made. Also details of inputs were recorded.

Results for the three years of the study have been published in García *et al*. (2008). Briefly, the CFR treatment achieved greater than 42 t DM/ha compared to 17 to 18 t DM/ha for the pasture control treatment (Table 2.1). These yields are reported as utilised for the grazed forages including pasture, Forage Rape and Persian Clover and harvested for maize silage. Therefore, 20 per cent silage wastage was assumed for the economic analysis. Details on nutrient inputs and irrigation are provided in Appendix 1.

Table 2.1 Mean Forage Yield (tonnes DM/ha)

Year	Pasture Control	CFR-Maize	CFR-Forage Rape	CFR- Persian Clover	CFR-Total Utilised*
1	17.3	26.6	12.0	3.5	36.8
2	18.0	26.2	10.7	5.1	36.8
3	17.0	29.2	11.6	3.9	38.9
Mean	17.4	27.3	11.4	4.2	37.5

*Total DM produced by the three crops used in the CFR system, after deducting 20 per cent wastage incurred in storing and feeding out maize silage.

3. Economic Evaluation of CFR

3.1. Case studies including CFR -Maffra, Victoria

A preliminary economic study of the potential impact of CFR in a commercial dairy farm system has been carried out within the Pilot Integration study at Maffra in Victoria, with major inputs by Dan Armstrong (Department of Primary Industries Victoria). The study looked at two cases, an '*average*' pasture based dairy farm in which the farmer may ask the question, what role, if any, could a CFR play in his/her farming system? The second case was that of a '*fodder reliant*' dairy farm, in which the farmer may ask, how does growing more forage through a CFR compare to buying more land or supplements or just doing what I currently do, better?

Each of these scenarios were explored using real case studies, built out of the Future Farming Systems modelling project and have been reported in management guidelines for the CFR (Kenny, 2007).

The first case study was a 55-ha family farm in northern Victoria, calving 180 cows in spring and using mainly owner/operator labour. An implementation of CFR on 6 per cent, 36 per cent or 45 per cent of the total farm area was compared to increasing pasture utilisation from 10 to 12.5 t DM/ha/year.

The study showed that CFR has the potential to increase total return on assets but only if forage yields in the CFR area were above 28 t DM/ha. It also showed that increasing pasture utilisation was a less risky option to increase profitability than implementing CFR. The implicit message is that farmers should exploit the potential of pasture production before moving into more complex (but potentially more productive) systems such as CFR.

The second case study was a farm comprising a milking area of 98.5 ha and two outblocks (one of 116 ha used primarily for growing fodder for silage and hay, and for raising young stock; and another one of 71 ha of dryland pasture, used mainly for dry cows during winter). Nearly 500 cows were milked at peak number, with a 80:20 spring:autumn calving pattern. Only 22 ha (<10 per cent of total area) were used to grow CFR, as this was the area previously used for growing maize for silage.

This case study also showed potential for the CFR option to increase profit, although the advantage was only marginal and was yield-dependant. Clearly the ability to spread the fixed infrastructure cost over greater production (higher yields) is critical when such a small proportion of the total area is used to grow CFR.

Overall, both case studies have highlighted that:

- The logical role of CFR as a forage option is after the potential of pasture utilisation has been fully exploited.
- CFR has the potential to increase farm profit although this will depend on the yields achieved and the area used, considering full utilisation of extra infrastructure needed.
- More detailed insight and analysis into the cost of feed production, risk, impact of infrastructure costs and the implementation of CFR into a complementary forage system (CFR + pasture) is warranted.

3.2. Economic evaluation methodology

Economic evaluations of new technologies such as CFR at the farm level are important in informing farm managers. Further, such analyses are a major component toward the task of undertaking benefit-cost analyses of agricultural research projects. These evaluations frequently contribute to the ranking of research proposals and therefore, depending upon the purpose of the analysis, farm-level evaluations may be done *ex-ante* or *ex-post*. Additionally, farm-level evaluations also contribute to future research and extension activities associated with a new technology (Pannell, 1999).

While a new technology may produce a measurable improvement in productivity in research trials, the farm-level benefits of the technology may vary widely. Thus a naive extrapolation of experimental results is potentially misleading (Alston, Norton and Pardey, 1995). This variability is a result of a multiplicity of factors including different climatic and resource endowments between farms and farming regions, different farming systems, as well as farm managers with different levels of experience, skills, risk attitudes, perceptions and wealth (Pannell, 1999). In the case of the CFR component of the Future Dairy project, sequential plot and experimental farm results combined with results of technology adoption on commercial partner farms are designed to provide industry relevant measures of CFR system outcomes.

The information required to undertake farm-level evaluation of a technology is not always immediately obvious. In discussing the evaluation of agricultural research, Pannell (1999) identifies a number of components of information that are applicable to the evaluation of technologies at the farm level and these provide the basis for the following discussion. Any method utilised to undertake farm-level evaluations of new technologies should address as many of these information categories as possible. These components include:

- *Quantifying the biological, technical and/or management changes from the new technology*:
  Agricultural technologies vary in the complexity of their application to current production systems. Some technologies may involve relatively little alteration to current technical or management practices. For example, a 'simple' new technology such as a new active ingredient in a chemical treatment affording it a greater efficacy may result in an easily quantifiable increase in yield. In contrast, many new technologies may involve complex technical and management changes on the farm including the different timings of current practices and the introduction of new practices, such as in the case of the CFR system.

- *Costs to the farm in implementing the new technology on a per hectare or per farm basis*:
  Costs to the farm include the direct investment required by the farm to access the new technology including capital investment and ongoing variable costs. Importantly, it may be necessary to account for the timing of when these costs are incurred within the evaluation period. Account must also be made for the income forgone from activities replaced as a consequence of the adoption of the new technology.

- *Economic benefits accruing on a per hectare or per farm basis*:
  Similar to the treatment of costs, the benefits from the uptake of a new technology on a farm must be determined as well as the timing of these benefits relative to the

evaluation period selected. Also, the costs saved from other activities replaced as a consequence of adoption of the new technology on a farm should be determined.

- *Potential level of adoption on a farm*:
  An economic evaluation requires an estimate of the potential area of a farm that a new technology could be applied to. For example, a new technology such as a new plant variety might only be suited to growing on a certain soil type on a farm, while technologies such as the CFR will be dependent upon soil type and irrigation availability.

- *Extent of adoption of the technology on the individual farm*:
  The extent of adoption refers to quantifying the proportion of the potential area to which the new technology is applied, as well as the timing of this uptake of the technology over time on a farm. Feder, Just and Zilberman (1982) differentiate between farm-level adoption of a technology and aggregate adoption. This concept is consistent with the notion of the intensity of adoption on a farm (Foltz and Chang, 2002), which is especially applicable to technology inputs such as chemical treatments or plant varieties which are divisible. In the case of the CFR system the extent of adoption on a farm could vary in terms of the total farm area devoted to the CFR system, or adoption of only components of the CFR system.

- *Quantifying the impact of side effects from implementation of the new technology either internal or external to the farm:*
  The side effects of a new technology may be either positive or negative, and their impact, internal or external to the farm (Pannell, 1999). Technologies applicable to one enterprise on a farm may directly affect the relative competitiveness of a concurrent farm enterprise, or preclude the continuation of another activity. For example, due to the requirement of certain insecticides in cotton, grazing of adjoining areas by livestock may be restricted due to the risk of chemical residues in animal products. Alternately, the introduction of a legume crop within a cereal cropping rotation confers yield and quality benefits to follow-on cereal crops, for example, by improving the nitrogen content of the soil and acting as a disease break for soil borne pathogens (eg., Reeves, Ellington and Brooke, 1984; Holford and Crocker, 1997). Such relationships reinforce the need for the significant biological and technical interrelationships that a new technology alters in a farm system to be adequately described in an evaluation.

  Side effects from uptake of a new technology may also be external to the individual farm, for example environmental externalities (Pannell, 1999). Zilberman, Khanna and Lipper (1997) discuss the need to evaluate the benefits of new technologies in mitigating negative environmental externalities of current agricultural production systems. Farm-level evaluation of technologies can be enhanced by placing constraints upon the production system to minimise particular negative environmental externalities, such as capturing externalities through the addition of abatement constraints (or costs) to the evaluation (eg., Petersen, Schilizzi and Bennett, 2003). This information requires sufficient detail of the technical and biological relationships of the farming system to be captured by the evaluation technique.

3.3. Method applied in this analysis

A variety of analyses can be used to examine the potential economic benefits and costs of the CFR system for Australian dairy farmers. Given the broad dairy production systems and geographic regions that the CFR system may be applicable to, it was deemed appropriate that a series of analytical approaches from partial analyses such as variable cost analyses to whole farm case studies be employed. This allows for a progressive assessment of the technology being examined as the analyses become more detailed.

Initial analysis of cost budgets of the CFR system compared with pastures are transparent and detail various input requirements and yields and are readily adjusted to meet specific farm situations. Further such simple analyses can be adapted to look at the sensitivity of the technology to changes in key input costs or yield assumptions and provide a feel for how price changes for required inputs such as fertiliser or yield variations influence the cost of the CFR technology compared to a high input pasture technology. Ultimately however, economic analysis of farm technologies such as those involving feeding systems must take a whole farm perspective rather than only focus upon an input cost analysis, since forage or pasture production is an intermediate output. Thus, the economic impact of the CFR technology to the dairy farm can only be measured by accounting for all inputs and resulting outputs and income which are included in whole-farm profitability. These are reported in the companion volume (Alford *et al*. 2009*b*).

4. Economic Data and Variable Costs Budgets

4.1. Variable cost assumptions

It was assumed that all cultivation activities for both CFR and pasture systems and silage operations were undertaken using contractors. This approach more fully captures the direct costs associated with fodder and pasture production.

A summary of major input costs included in the CFR and pasture budgets and their sources are provided in Table 4.1. Example budgets for an annual CFR and pasture budget are included in Tables 4.2 and 4.3, while the annual variable cost budgets averaged across replicates for each year are provided in Appendix 2. Rates for machinery contractors were taken from the Agricultural Contractors Association recommended rates for 2006 and exclude GST (AACA 2007*a*,*b*). Fertiliser costs and seed costs were obtained from the University of Sydney accounts, which were the commercial prices paid for delivery of fertilisers and seed to the Future Dairy project in 2006, exclusive of GST (denoted by “Retail price” in Table 4.1).

For this initial analysis, the budgets were constructed for each of the three years of the plot experiments using average inputs for the replicates for each treatment. Results from the variable cost analysis are averaged across the four replicates for each of the three years for both the CFR and Pasture treatments, using 2005/06 prices, exclusive of GST. The initial analysis was only based on variable input costs, while infrastructure costs associated with the use of maize silage are considered in later analyses.

Table 4.1 Summary of variable costs used in the CFR and Pasture budgets (2006 dollar values)

Input	Price/unit	Source
Seed costs		
- Forage rape	$ 5.00/kg	Various agricultural suppliers[1]
- Persian clover	$ 4.45/kg	”
- Maple Pea (cv. Seacada)	$ 0.80/kg	”
- Maize	$ 8.00/kg	”
Fertilizer costs (delivered)		
- Lime	$ 50 /t	Various agricultural suppliers[1]
- MAP	$ 684 /t	”
- DAP	$ 667 /t	”
- Nitram	$ 500 /t	”
- Urea	$ 631 /t	”
- Muriate of Potash	$ 608 /t	”
- Blend (24-4-13)	$ 700 /t	”
- Single superphosphate +Mo	$ 400 /t	”
- Triple superphosphate	$ 646 /t	”
Herbicide costs		
- Glyphosate	$ 5.00 /L	NSW DPI crop budgets
- pre-emergent (Dual Gold)	$ 12.00/L	Various agricultural suppliers[1]
Cultivation rates		
- direct drilling	$ 85.15/ha	Western Victorian AACA
- fertiliser spreading	$ 92.27/ha	South Gippsland AACA
- boom spraying	$ 21.00/ha	Western Victorian AACA
- rolling (seed bed)	$ 30.00/ha	Western Victorian AACA
Maize Silage rates		
- rolling silage	$ 3.00/t wet	Local contractor
- precision chop & cartage	$ 390.00 /ha	Local contractor
- plastic	$ 1.10/m^2	Top Fodder website
- feedout costs	$30/hr	NSW DPI machinery costs

[1] Prices obtained from various agricultural suppliers from purchases made by University of Sydney and NSW DPI

Table 4.2 Example of CFR variable costs budget (mean of year two replicates)

Forage Rape and Persian Clover CFR Components

	Yield
Forage Rape	10.7 (t DM utilised forage)
Persian Clover	5.1 (t DM utilised forage)
Total (Forage Rape +Clover)	15.8 (t DM utilised forage)

	units/ha	**$/unit**	**$**
Seed - Forage rape (kg)	5	$ 5.00	$ 25.00
Fertilizer (kg)			
- Superphosphate + Mo	250	$ 0.40	$ 100.00
- Triple superphosphate	100	$ 0.65	$ 64.60
- Muriate of Potash	250	$ 0.61	$ 152.00
- Blend (24-4-13)	300	$ 0.70	$ 210.00
- topdress - Urea	450	$ 0.63	$ 283.95
Contractor rates (hrs)			
- roll	1	$ 31.50	$ 31.50
- initial fertilizer	0.2	$101.50	$ 20.30
- topdressing (Nitrograze)	0.1	$101.50	$ 10.15
- topdressing (Urea)	0.1	$101.50	$ 10.15
Seed - Persian clover (kg)	15	$ 4.45	$ 66.75
Herbicide (Glyphosate) (L)	3	$ 5.00	$ 15.00
Contractor rates (hrs)			
- spray	1	$ 22.00	$ 22.00
- sowing	1	$ 53.55	$ 53.55
Total Variable Costs ($/ha)			$1,064.95
Total (Forage Rape + Persian Clover) Variable Costs $ / t DM utilised forage			$ 67.40

Note: Irrigation costs for the Forage Rape and Persian Clover components of the CFR are included in the Maize variable cost component of the variable cost budget.

Table 4.2 (cont'd). Example of CFR variable costs budget (mean of year two replicates)

Maize CFR Component			
		Yield	
Maize Silage Yield		26.2 (t DM utilised forage)	
Feedout wastage	20 %		
	units /ha	**$/unit**	**$**
Seed - Maize (kg)	31.25	$ 8.00	$ 250.00
Fertilizer (kg)			
- DAP	400	$ 0.67	$ 266.80
- MAP	100	$ 0.68	$ 68.40
- Triple Superphosphate	18	$ 0.65	$ 11.63
- Blend (24-4-13)	88	$ 0.70	$ 61.60
- Urea	530	$ 0.63	$ 334.43
- Muriate of Potash	400	$ 0.61	$ 243.20
Herbicide (L)			
- pre-emergent herbicide (Dual Gold)	3	$ 12.00	$ 36.00
- glyphosate	3	$ 5.00	$ 15.00
Contractor rates (hrs)			
- direct drill	1	$ 89.25	$ 89.25
- topdressing (Urea)	0.2	$101.50	$ 20.30
- presowing fertiliser spreading	0.1	$101.50	$ 10.15
Irrigation (ML)	6.6	$ 30.00	$ 198.00
Silage costs			
- precision chop/ cartage (hrs)	1.5	$260.00	$ 390.00
- rolling (wet t)	79	$ 3.00	$ 238.18
- plastic seal (m^2)	63	$ 1.10	$ 69.30
- feedout costs (hrs)	13.1	$ 30.00	$ 393.00
Total Variable Costs ($/ha)			$2,695.24
Total Variable Costs ($ /t DM forage after wastage)			$ 128.60

Note: No allowance for labour has been included for irrigation labour, except where contractor charges are used.

Table 4.3 Example of Pasture variable costs budget (mean of year two replicates)

Pasture			
		Yield	
Pasture		18 (t DM utilised forage)	
	units /ha	**$/unit**	**$**
Seed - annual ryegrass (kg)	30	$ 4.00	$ 120.00
Fertilizer (kg)			
- triple superphosphate	200	$ 0.65	$ 129.20
- muriate of potash	200	$ 0.61	$ 121.60
- Blend	425	$ 0.70	$ 297.50
- topdress - Urea	1,325	$ 0.63	$ 836.08
Contractor rates (hrs)			
- sowing	1	$ 53.55	$ 53.55
- fertiliser spreading x2	0.1	$101.50	$ 20.30
- topdressing Urea x10	0.1	$101.50	$ 101.50
- slashing	0.2	$ 72.45	$ 14.49
Irrigation (ML)	7.4	$ 30.00	$ 222.00
Total Variable Costs ($/ha)			$1,916.22
Total Variable Costs ($/t DM utilised forage)			$ 106.46

Note: No allowance for labour has been included for irrigation labour, except where contractor charges are used.

5. Results

5.1. Average variable costs

The results including averages for each of the treatments for each year, are provided in Table 5.1. They are expressed in terms of average cost per tonne of DM, per MJ of metabolisable energy (MJ ME) and on a cost per hectare basis.

Table 5.1 Summary of average costs ($) derived from the variable cost budgets for CFR and Pasture treatments

	$/tDM		**$/MJ ME**		**$/ha**	
	CFR	Pasture	CFR	Pasture	CFR	Pasture
Year 1	118	128	0.0121	0.0135	4,330.28	2,206.17
Year 2	102	106	0.0105	0.0112	3,760.19	1,916.22
Year 3	97	98	0.0100	0.0103	3,788.46	1,665.87
Average	**106**	**111**	**0.0109**	**0.0117**	**3,959.65**	**1,929.42**

The variable cost analysis indicates that the average cost of the CFR treatment on an area basis, $3,960/ha, is 105 per cent greater than the cost for the high input pasture system, $1,929/ha. However, the average level of fodder utilised, after allowing for 20 per cent wastage of maize silage in the CFR system, is 37.5 t DM/ha, or 115 per cent more than that achieved under the pasture system, from which an annual average of 17.4 t DM of pasture was utilised (Table 2.1). Similarly the average quality, in terms of metabolisable energy, is higher for the CFR fodder (9.71 MJ ME/ kg DM) than from the pasture treatment (9.47 MJ ME/kg DM). Consequently, the cost per unit of energy is lower for the CFR, 1.1 c/MJ ME than the pasture system, 1.2 c/MJ ME.

The simple variable cost analysis shows that on a per unit of feed utilised basis the CFR has a slightly lower average variable cost than the high input pasture, $106/t DM for the CFR compared with $111/t DM for the high input pasture. In practice, this comparison suggests that the two systems produce feed at a comparable price on a per unit of feed output and the ranges in annual variable costs for the two systems (based upon the results from the experimental results over the three years) were similar at $97 to $118 per t DM for the CFR and $98 to $128 per t DM for the pasture control system. However, this variable cost analysis does not take into account a number of factors that will influence the potential economic benefits or otherwise, of the CFR system compared to a high input pasture system. These factors include:

- fixed costs required to effectively feed out maize silage such as a feed pad and associated laneways and equipment. However, additional benefits from the use of a feedpad, for example, might accrue to the farm, such as improved wet weather management, and better tactical feeding of cows;
- new management skills required by the farm manager (as with the adoption of any new technology);
- additional labour, particularly management labour in operating the CFR system;
- cost of implementation;
- impact on the sustainability of the agricultural system using CFR compared with a pasture system; and
- different production and price risk exposure.

Infrastructure and labour costs are considered in subsequent whole farm analyses while production and price risk exposure is addressed in the next section.

5.2. Risk analysis

Farm businesses are exposed to an array of risks, including market and financial risk as well as production risks associated with the climate and biological systems. Therefore, risk should be considered at the whole-farm level, requiring large amounts of data and for a specific geographic region. However, a stochastic budget including only variable costs of forage production can be used as a preliminary risk assessment of the CFR system compared with the pasture system, as it provides an initial means to compare the sensitivity of the CFR system to the high input pasture system to changes in key inputs (fertiliser prices) and yield. Risk analyses based on fertiliser price and yield probability distributions were undertaken using the @Risk software (Palisade Corporation, 2004). Simulations were undertaken separately, that is fertiliser price risk only, yield risk only and then price risk plus yield risk combined. Results were compared using stochastic dominance criteria to determine which forage system on average, is likely to have lower variable costs given the specified price and yield risks modelled. The risk analyses were based upon the previously described budgets (Section 1.4) except for the stochastic variables which are detailed below. The budgets use 2005/06 dollar values.

Price risk – Fertiliser price

The major input into the intensive CFR system is fertiliser. To achieve the targeted 40 t DM/ha per year, high levels of fertiliser are necessary. These fertiliser inputs are detailed in Appendix 1, Table A1. Therefore, farmers are exposed to price risk as a result of fluctuations in the price of various fertilisers. Fertiliser applications are also present in the pasture system used as the control in this experiment.

Annual fertiliser price data over the period 1985 to 2005 for Australia were examined to determine probability distribution functions for single superphosphate, diammonium phosphate, potassium chloride and urea (ABARE, 2006). All prices were adjusted to 2005/06 dollars. The probability distributions were determined from analysis of the price data series using BestFit software (Palisade Corporation, 2004) and the distribution for each price series was selected, based upon fit statistics and visual assessment of the probability distribution with the price observations (Appendix 3). The price distributions represent the frequency with which a price is likely to occur across a defined price range. A summary of the price probability distributions are provided in Table 5.2.

Simulations were undertaken for both the CFR and pasture treatments. Historical price series were not available for all the fertiliser types used in the experiment, however the key fertiliser inputs to the CFR including urea, DAP, potash and superphosphate were, and these fertilisers represent some 70 and 66 per cent of the total expenditure on fertiliser in the CFR and pasture treatments respectively, based on the base analysis using 2005/06 prices.

Table 5.2 Examples of selected price distributions used in the risk model

Output	Units	Probability distribution	Distribution parameters
Single superphosphate	$/kg	Inverse Gaussian	μ=0.12838, λ=7.81902, Lower bound = 0.25
Urea	$/kg	Weibull	α=2.9032, β=0.34245, min value =0.45
Potash	$/kg	Beta General	α_1 = 4.29964 , α_2 =2.58943, min = 0.5, max =0.9248
Diammoinium Phosphate	$/kg	Log Logistic	α=5.64144, β=0.21503, λ = 1327.507

Figure 5.1 shows the cumulative distribution functions for the CFR and high input pasture systems mean annual variable cost in terms of t DM when fertiliser price risk is included. A feed production cost curve towards the left hand side of the graph indicates that the cost (per t DM) of the feed is likely to be lower than the alternate feed production cost curve (or distribution), towards the right hand side of the graph.

Including the variation in fertiliser prices, over the period 1985 to 2005 indicates that the CFR system variable costs is less sensitive to the variation in prices over the price distributions tested, given the average DM yields across the three years for the CFR and pasture experiments. That is, the CFR curve is more vertical than the pasture curve and has a smaller range of possible variable cost values. It was found in the stochastic simulation that the CFR system had a lower average variable cost per t DM of $112 and lower maximum variable cost in the simulation of $123/t DM, compared with the pasture system's average and maximum variable cost of $121/t DM and $149/t DM, respectively. Since the pasture system had a lower minimum variable cost in the simulation than the CFR system, $99/tDM compared with $102/tDM, it can be interpreted from Figure 5.1 that the CFR system dominates the pasture system according to second degree stochastic dominance criteria, for the given stochastic fertiliser prices included in the simulation. This is expected given the higher average output of dry matter per unit of fertiliser nutrient input in the two systems (see Tables 2.1 and A1).

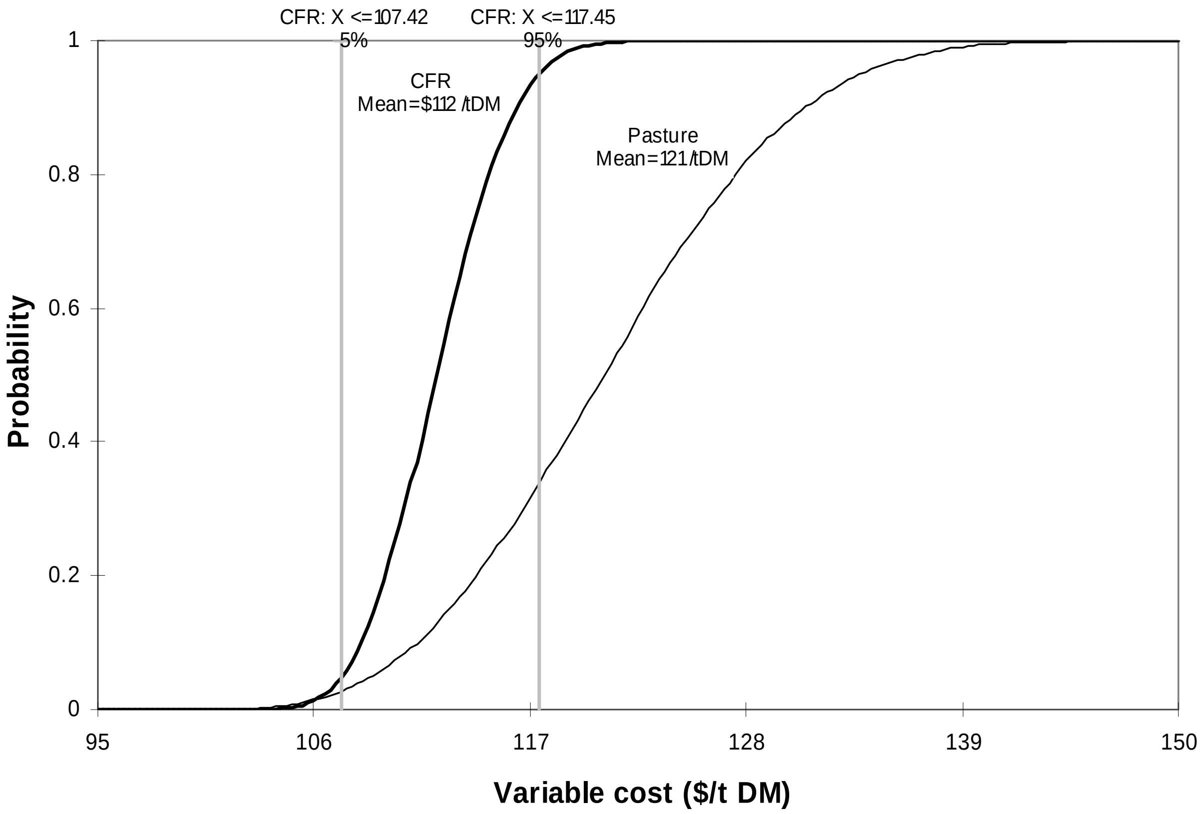


Figure 5.1 Comparison of the cumulative distribution functions incorporating price risk, for the CFR and pasture mean annual variable cost

Production Risk - Yield Variation

The analysis of production risk using stochastic variable costs budgets is based upon simple triangular risk distributions from researchers' perceptions of the likely variation in yields obtained from the CFR crops and intensively managed pasture. This required that researchers define the yield distributions in terms of a minimum, maximum and a most likely yield for each of the different crops. This was necessary since there were insufficient observations of yield in the experiment with only three years of data and four replicates. Elicitation of expected range yields from researchers or producers is recognised as a valid means of obtaining risk data (Hardaker, Huirne and Anderson, 1997). Such an analysis could be improved by asking farmers in a region what their expectations for various crop yields might be, although many may not have had experience themselves of some of the particular crops. Otherwise alternative sources of data about production risk might be obtained by searching for previous records in experimental or commercial crops in specific dairy regions, or further modelling of crop growth and production for various regions using historical climatic data.

The estimated distributions from research participants were included in the stochastic model using triangular distributions (refer to Table 5.3), and a relatively conservative approach was taken whereby the upper yield was taken as the average yield obtained for each crop over the three year experiment.

Table 5.3 Estimated yield applied in the stochastic budget model for triangular risk distributions

Crop	Units	Minimum	Most Likely	Maximum
Forage rape	t DM/ha, utilised	5	9	11
Persian clover	t DM/ha, utilised	2	3	5
Maize	t DM/ha, before wastage	12	20	27
Pasture	t DM/ha, utilised	12	14	18

The result of the stochastic yield simulation was that the well managed, high input pasture system dominated the CFR system in terms of the average variable cost per unit of dry matter utilised. The pasture system, given the assumed yield distributions described in Table 5.3, had a mean cost of $133/t DM for feed utilised compared with $139/t DM for utilised forage for the CFR (see Figure 5.2). The average variable cost distribution curve for the CFR lies wholly to the right (that is, having a higher average cost) of the pasture cost distribution curve (first degree stochastic dominance). This result indicates that the CFR may increase the yield risk, in terms of the average cost of home-grown forage, above that incurred by the well managed high input pasture, and emphasises the importance of yield in the implementation of the CFR on farm.

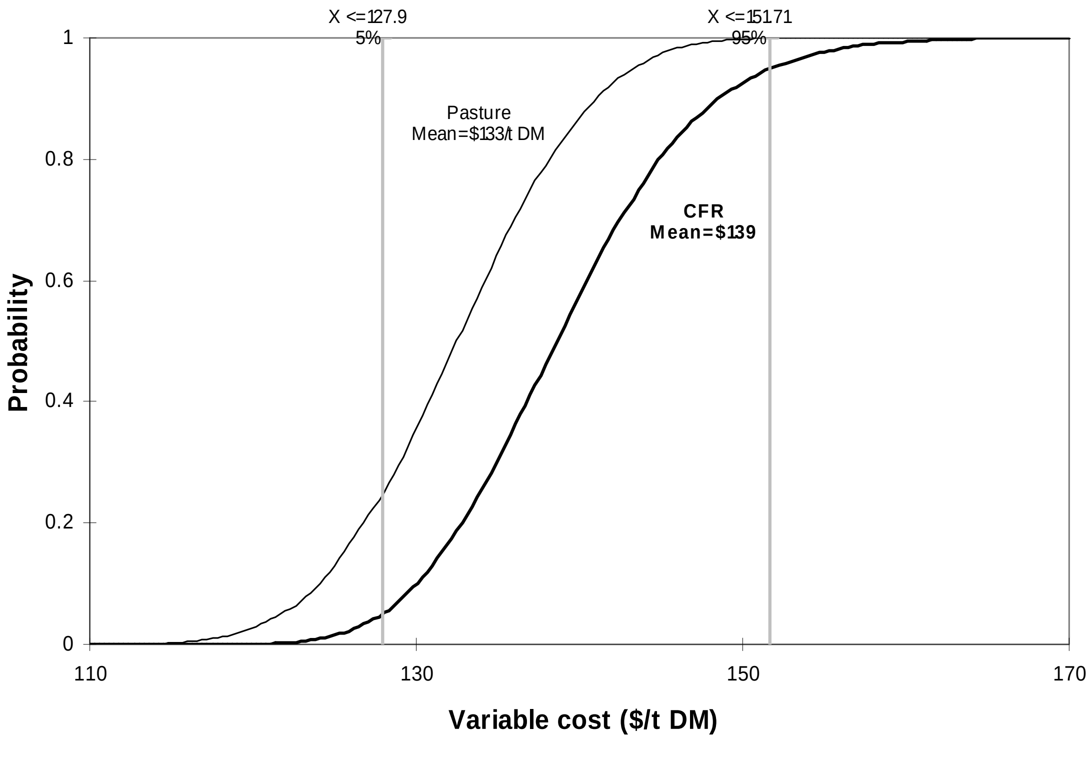


Figure 5.2 Comparison of the cumulative distribution functions incorporating yield risk, for the CFR and pasture mean annual variable cost

Price and production risk combined

An examination of the simulation results and the resulting cumulative distribution functions (CDFs) (Figure 5.3) indicate that the two forage systems have the same average variable cost per t DM, $145/t DM when fertiliser price risk and yield risk are considered simultaneously. Neither system clearly dominates, with the pasture system having a lower minimum average cost, $108/t DM compared to the CFR minimum cost of $117/t DM, but having a higher maximum variable cost of $196/t DM compared to the CFR maximum cost per t DM utilised of $187.

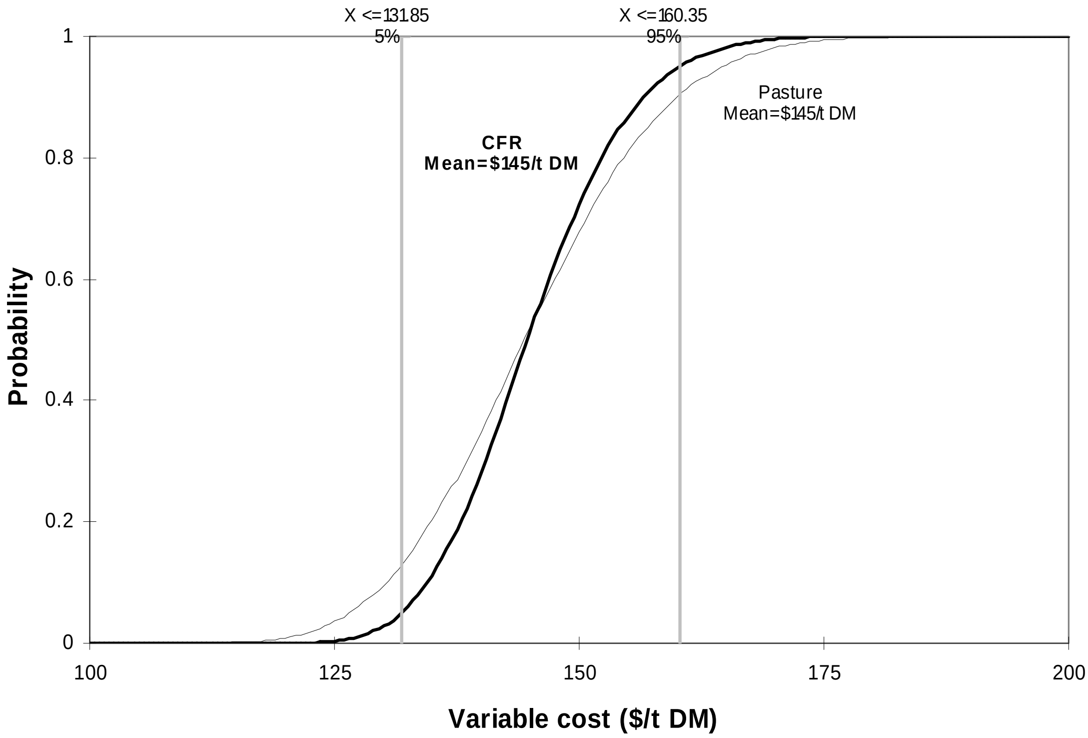


Figure 5.3 Comparison of the cumulative distribution functions incorporating price and yield risk, for the CFR and Pasture mean annual variable cost

5.3. Discussion of fertiliser price and forage yield risk analysis

Given the assumptions and data included in the stochastic budgets for the risk analyses, it appears that the CFR is comparable to the pasture system when examining the average variable costs of the fodder systems with respect to fertiliser price risk and potential forage yield risk. While the CFR appears to increase the risk, in terms of the average cost of forage, when yield variability was examined, the CFR had a lower risk with respect to fertiliser price variability. The CFR's higher average output of dry matter per unit of fertiliser nutrient input compared to the well managed, high input pasture systems, reduces the risk of the CFR, in terms of average variable cost per t DM utilised, to fertiliser price variability. When both fertiliser price and yield risk were considered concurrently, both systems produce forage at the same average cost, $145/t DM utilised. Thus, for a risk averse farmer it would appear that based upon the input (fertiliser) price variability and forage yield variability considered together in this analysis, the CFR system does not increase the level of risk in terms of the average variable costs of forage production to the producer.

However, it should be noted that this study only examines variable costs and does not consider fixed costs such as additional silage feed-out facilities or machinery. Further, additional risks might also include:

- reliance on the timely availability of contractors for the harvesting of maize silage;
- crop failures, for example, the likelihood of certain climatic events occurring at critical times during the CFR production cycle, such as wet weather at maize planting or harvesting; and
- financial and business risk that might be incurred through capital expenditure to implement the CFR system.

A further limitation of the analyses presented thus far is that there are insufficient data from the experiment for an analysis using historical yield data to better validate likely crop yield variation. Further, this is also true of particular crops such as maize being grown for silage in certain areas or different crops performance under various irrigation systems such as flood irrigation, as frequently occurs in parts of Victoria and southern inland NSW. Alternative means of obtaining data to capture yield variations for the CFR system may be warranted.

5.4. Evaluation of CFR: Feed related variable costs and infrastructure cost analysis

The CFR system could require a significant investment in farm infrastructure relating to the handling of forages especially maize silage and the capacity to appropriately feed out the forage. Further, it is necessary to consider where the silage could be fed out to the dairy herd. This analysis investigates this cost in additional infrastructure as a potential barrier for farmers to adopt an intensive forage feeding system. A partial budgeting approach is used here.

Many farms already have some of the necessary facilities. A survey of Bonlac suppliers in 2000 indicated that 45 per cent of these farms from across Victoria have some form of feed pad, but the standard and capacity of such feedpads would be likely to vary considerably (Bonlac, 2000). The appropriate feed pad design and construction will depend upon the number of cows, the expected utilization of the pad, associated fencing and laneways, machinery to be used, as well as site characteristics, amongst other factors. For example, the Goulburn Broken Catchment Management Authority Guidelines (2002) identify various designs that vary from under $10,000 to in excess of $100,000, equivalent to $11,500 to $115,000 in 2006/07 dollar terms based upon the CPI index (ABARE, 2007).

However, it was deemed appropriate for this analysis to take a conservative approach to the question of infrastructure costs and assume a farm system that required both equipment to feed out maize silage and a feed pad on which the silage would be fed to the herd.

The following partial budget analysis required a number of assumptions to be made (refer to Table 5.4). Firstly, that introducing a CFR system replaces some use of concentrate feed, while cow numbers are maintained along with annual production per cow. In practice, farmers would likely intensify their production per hectare if they were to adopt the CFR technology, in addition to substituting fodder for purchased grain, making the scenario presented here particularly conservative.

Sensitivity analyses included investment scenarios requiring a high capital investment of $250,000 and two concentrate prices reflecting prices delivered on-farm, high ($350/tDM, $389/t as fed) and low ($280/tDM, $310/t as fed). These prices were based upon historical prices with the average commercial prices (nominal and exclusive of freight) paid for concentrates on an ’as fed‘ basis by the NSWDPI dairy at Camden of $280/t in 2004, to $380/t in both 2005 and 2006.

Table 5.4 Key assumptions included for the modelled farm

Milking area	100 ha
Stocking rate	3.2 cows/ha
Dry Matter intake	5,464 kg DM/cow/lactation
Milk yield	6,557 L/cow/lactation (assumes 1.2x DMI)
Pasture utilised	12,000 kg DM/ha/year
Pasture intake	3,750 kg DM/cow
Pasture in total diet	69 %
Concentrate	1,714 kg DM/cow

The investment scenario for necessary infrastructure was included in the feed cost and infrastructure analyses with the feedpad, effluent system, laneways and fencing infrastructure and associated machinery to feedout the maize silage, including a silage wagon, amortised and included as annual costs. This captures both principle and interest charges and conservatively assumes a zero salvage value at the end of the economic life for the feedpad and machinery. An interest rate of 9 per cent was used in the analyses. The infrastructure scenario is summarised in Table 5.5. The annual amortised cost was included on a per hectare basis to estimate total feed costs per cow and per hectare. This is conservative and includes costs for items such as the feedpad, which are at the upper end of the ranges cited from the literature reviewed.

The base scenario described above was compared to three scenarios where the pasture area put to CFR was progressively increased; that is 10 or 20 per cent of the pasture area was replaced by the CFR system. The goal of this analysis was to evaluate the potential of CFR to reduce the amount of concentrate without changing the number of cows or total milk production.

In the base case, the effect of dairy area put under CFR on total feed costs including the high cost infrastructure are provided in Table 5.6. In the control scenario where there is no CFR, additional feed to meet production is provided by concentrate at the mid price of $310/t DM. Feed costs are $3,036/ha or $949/cow. As the CFR is introduced, 10 per cent CFR, the cost increases to $3,083/ha or $963/cow as additional infrastructure and labour for feeding out silage are incorporated all at once. As the CFR occupies more land, the effect of diluting the fixed infrastructure charge combined with the lower cost per kilogram of dry matter of CFR feed relative to the high input pasture, results in approximately 10 per cent decrease in feed and infrastructure cost at 20 per cent dairy area to CFR, compared with the control scenario.

Table 5.5 Silage infrastructure investment scenario for feed related cost analysis

<u>Scenario</u>		
Amortised cost of Infrastructure		
Feed pad + laneway/fencing	$200,000	
Interest rate	9%	
Lifespan	25 years	
		$20,361.25
Amortised cost of Wagon/implements		
Wagon/attachments	$50,000	
Interest rate	9%	
Lifespan	10 years	
		$7,791.00
	Total Annual Cost	**$28,152.25**
		($281.52/ha)

This illustrates that due to the fixed cost nature of the infrastructure required to utilise the maize silage, a minimum area must be put to CFR. Under current assumptions this area is in excess of 10 per cent of the dairy area.

This result, however, was based upon a relatively high infrastructure charge, thus if a lower level of infrastructure was required this would result in a potentially smaller minimum area being put to CFR. This analysis does not identify an optimum area to put to CFR. This would vary for each individual farm depending upon their specific farm resources and constraints.

The sensitivity of combined feed and CFR infrastructure costs to changes in CFR yield and concentrate prices were also investigated. Results are presented in Table 5.7 and illustrated graphically in Figure 5.4. When CFR yield is reduced by 25 per cent and concentrate prices are relatively high at $350/t DM, the 20 per cent of area to CFR scenario still has a lower feed related cost than the pasture only system, after including infrastructure costs. In the case of lower concentrate costs only at the 20 per cent level of CFR, the CFR system has equivalent feed related costs as the pasture only scenario. At 50 per cent reduction in CFR yield, the CFR system has higher feed related costs than the control.

Feed related costs are more sensitive to yield variation in the maize component of the CFR system than the winter forages component (Forage Rape and Persian Clover). Thus, at a 20 per cent area put to CFR and high concentrate price, a 50 per cent decrease in maize yield results in an overall decrease in feed related costs of 4 per cent compared with the control, while a 50 per cent reduction in the winter forage component of the CFR results in an overall 7 per cent decrease in feed related costs compared with the control. This is illustrated in Figure 5.4, where at both high and low concentrate prices the 50 per cent reduction in maize results in no or minimal improvement in feed costs relative to the control scenario, denoted by a relatively horizontal line in graphs *b)* and *d)* (Figure 5.4). The value of the CFR in reducing feed related costs to meet the target milk production described for the scenario, is reduced at lower concentrate feed costs.

Table 5.6 Effect of varying proportion of dairy area put under CFR on the cost of feed and associated CFR infrastructure charges

	% of total dairy area into CFR		
Physical data	**0 (control)**	**10**	**20**
CFR yield (kg/ha)	0	28269	28269
Total cow number	320	320	320
Total utilised pasture (kg)	1200000	1080000	960000
Total pasture/cow (kg DM/cow)	3750	3375	3000
Total pasture+forage/cow (kg DM/cow)	4150	4458	4867
% forage	76	82	89
Kg hay/cow	400	200	100
Kg hay/farm	128000	64000	32000
Kg grain/cow	1314	1006	597
Total grain/farm	420480	321790	191100
Total CFR/farm	0	282690	565380
Economic data			
Annual infrastructure ($/ha)		282	282
Extra labour (2hr/day x 250 days/yr x $20/h)		$00	100
Total cost of Pasture ($/ha)	1328	1195	1062
Concentrate ($/ha)	1325	1014	604
CFR ($/ha)	0	301	600
Hay ($/ha)	384	192	96
Total feed cost ($/ha) (including infrastructure)	3036	3083	2744
Total feed cost ($/cow)	949	963	857
% cost relative to control	**100%**	**100%**	**90%**

Table 5.7 Sensitivity of feed cost per hectare to area of dairy area put to CFR at high and low concentrate costs

Scenario 1: Total infrastructure cost of $250,000 and concentrate @ $350/t DM

Forage yield (tDM/ha)						% farm area under CFR			CFR cost
Forage Rape	Legume	Maize	Total CFR	% Reduction in:		0	10	20	($/kg DM)
11.4	3.9	21.9	37.2	Total CFR	0	1.00	1.00	0.88	0.106
8.6	2.9	16.4	27.9		-25	1.00	1.04	0.95	0.142
5.7	2.0	10.9	18.6		-50	1.00	1.10	1.07	0.213
11.4	3.9	16.4	31.7	Maize	-25	1.00	1.02	0.92	0.125
11.4	3.9	10.9	26.2		-50	1.00	1.04	0.96	0.151
8.6	2.9	21.9	33.4	Winter forage	-25	1.00	1.01	0.90	0.119
5.7	2.0	21.9	29.5		-50	1.00	1.03	0.93	0.134

Scenario 2: Total infrastructure cost of $250,000 and concentrate @ $280/t DM

Forage yield (t DM/ha)						% farm area under CFR			CFR cost
Forage Rape	Legume	Maize	Total CFR	% Reduction in:		0	10	20	($/kg DM)
11.4	3.9	21.9	37.2	Total CFR	0	1.00	1.03	0.93	0.106
8.6	2.9	16.4	27.9		-25	1.00	1.06	1.00	0.142
5.7	2.0	10.9	18.6		-50	1.00	1.13	1.13	0.213
11.4	3.9	16.4	31.7	Maize	-25	1.00	1.05	0.96	0.125
11.4	3.9	10.9	26.2		-50	1.00	1.07	1.01	0.151
8.6	2.9	21.9	33.4	Winter forage	-25	1.00	1.04	0.95	0.119
5.7	2.0	21.9	29.5		-50	1.00	1.06	0.98	0.134

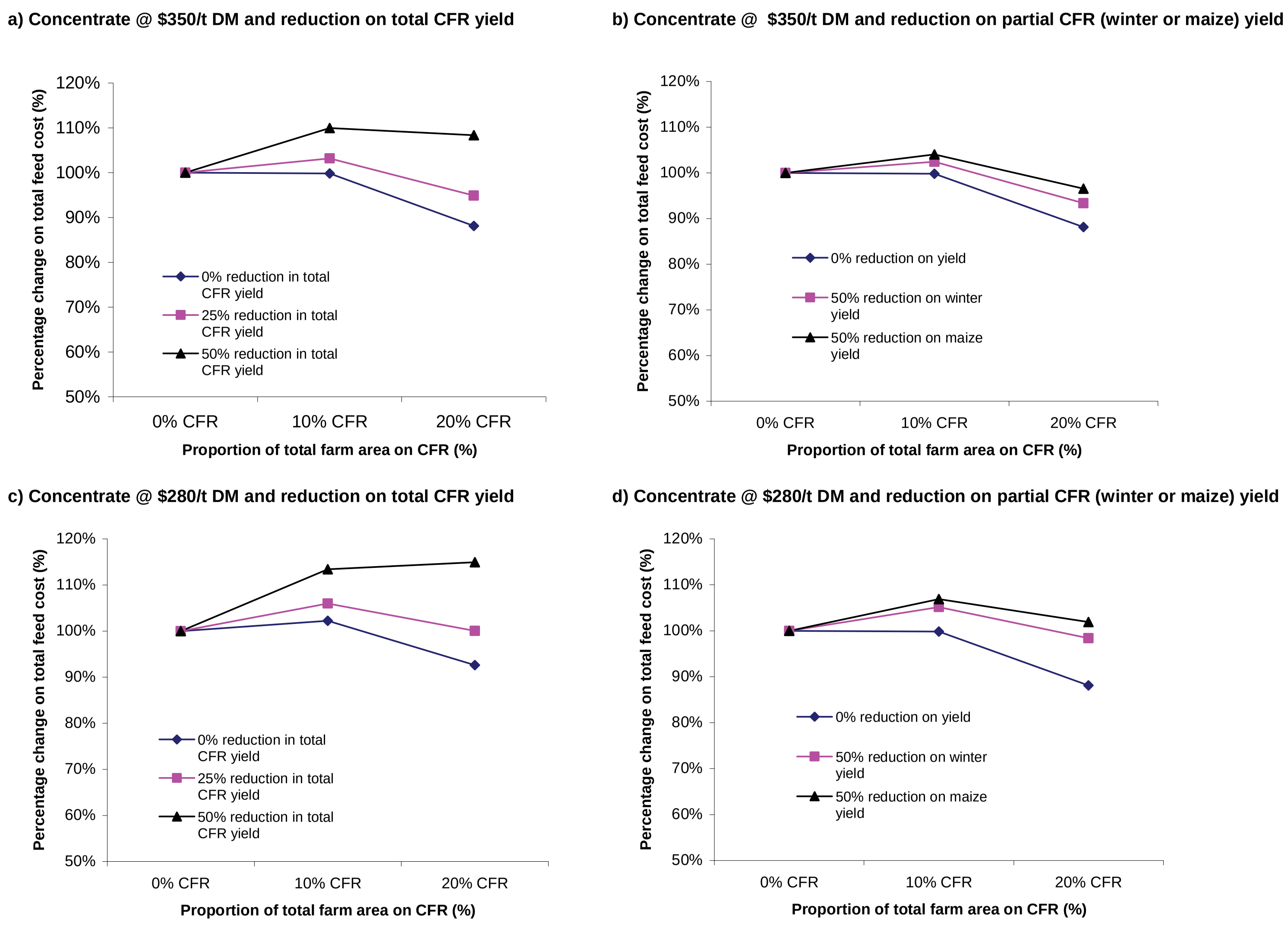


Figure 5.4 The impact of CFR area and the reduction of partial and total forage yield on the total feed cost change relative to non-CFR farm.

6. Conclusions

Initial variable cost analysis indicates that, on average, the CFR system compares favourably with the average per unit cost of feed from the high input pasture on a per tonne dry matter basis ($106 /t DM versus $111 /t DM) and on a per ME basis (1.1 ¢/MJ ME versus 1.2 ¢/MJ ME for CFR and pasture, respectively). The two systems indicate similar costs on a per t DM utilised basis with similar ranges in average variable costs across the experimental years, $97 to $118 for the CFR per t DM and $98 to $128 per t DM for the high performance pasture. As this comparison between CFR and pasture costs was using a high-input pasture (and assuming that low-input pasture would be also lower in cost), the clear message emerging from this is that little or no advantage is to be expected for implementing CFR unless the potential of pasture production has been fully exploited.

Further, an initial analysis of the yield and price risks associated with the CFR system compared with a high input pasture system using stochastic dominance criteria, also showed that with respect to the effect of likely variations (based upon researchers consensus opinion), in yield of both the CFR and the pasture system and changes in fertiliser prices (based on historical variation) simultaneously, the CFR system appeared robust with the same average variable cost per unit of dry matter. When the yield variation was considered in isolation, the CFR had a higher average cost per t DM utilised. With regard to fertiliser prices, the CFR had a greater probability of having a lower average cost per unit of forage utilised, reflecting the higher average dry matter output per unit of fertiliser input obtained by the CFR system. This risk analysis, however, does not include the possibility of not harvesting the maize silage crop due to unfavourable weather conditions (e.g., a very wet harvest period), as such risks would vary considerably between regions.

Following on from the initial variable cost analysis, the CFR technology was investigated in terms of total dairy feed costs for a hypothetical farm, importantly including necessary infrastructure cost required to feed out maize silage. This analysis highlighted that due to the fixed cost nature of the infrastructure costs a minimum area of a farm's dairy area would be necessary to at least match the cost of feed from a pasture plus purchased concentrate only farm. In the scenario tested, 10 per cent minimum area under CFR was required for average feed costs (including infrastructure related costs) of the CFR farm to match those of the pasture and concentrate-only farm. While at 20 per cent of area put to CFR, there was a 10 per cent reduction in feed cost compared to the nil CFR farm. The optimal area put to CFR was not determined and would be dependent upon the specific physical, financial, and management resources and constraint of individual farms as well as the farm manager's attitude towards risk.

Further, sensitivity of feed related costs of the CFR incorporating the infrastructure costs to feed out silage were compared with the pasture and concentrate only farm, with respect to forage yield from the CFR and separately the maize or winter forage components. When CFR yield is reduced by 25 per cent and concentrate prices are relatively high at $350/t DM, the CFR scenarios still have lower feed related cost than the pasture only system after including infrastructure costs. Potential cost advantages of the CFR are reduced as concentrate prices decrease, so that when CFR yield is reduced by 50 per cent, the CFR system has higher feed related costs than the control at a concentrate price of $280/t DM.

CFR feed related costs were found to be more sensitive to yield variation in the maize component of the CFR system than the winter forages component (Forage Rape and Persian

Clover). So that at a 20 per cent area put to CFR and high concentrate price, a 50 per cent decrease in maize yield results in an overall decrease in feed related costs of 4 per cent compared with the control, while a 50 per cent reduction in the winter forage component of the CFR results in an overall 7 per cent decrease in feed related costs compared with the control for the scenario and associated assumption described.

The result of this initial variable cost and risk analysis indicates that the cost of feed provided by the CFR compares favourably with high input pastures on an average variable cost basis. Further, for the yield variations tested and across historical price variation of the major fertiliser prices, the variable cost of CFR system is comparable with the high input pasture system. These results indicate that further analysis of the CFR technology is warranted.

It should be noted that CFR costs would still be considerably higher if compared to a low input pasture system. While partial analysis of costs is a useful first step in an economic analysis of a new technology, providing a broad indication of the costs of the technology compared to alternate technologies, in the case of alternate home-grown feed systems, it does not ultimately provide a measure of the technology's impact on farm profitability. A companion report examines the CFR technology in a whole farm setting and reports on the potential profitability of the technology (Alford *et al*. 2009*b*). However ultimately, identifying the profit maximising production systems for a particular farm depends upon individual farmers' goals and objectives, as well as a particular farm's suite of resources and constraints.

Limitations of this initial analysis have been highlighted. Considerable information to undertake a thorough economic evaluation of a new technology on farm as identified by Pannell (1999), including whole farm budgets to look at the impact on dairy farm profit rather than examining an intermediary output such as feed, is essential. Additionally, implementation of the CFR system will require changes to the current production system in the short term, for example, taking out a proportion of pasture area to sow to CFR which will impact on short term feed supply, while long term adjustments such as infrastructure costs will also be incurred. These short term and long term factors will impact upon the farm business cash flow and require investigation using development budgets to examine the financial implications of implementing the change. Further, while some risks based upon yield variation and fertiliser prices have been examined so far, there is a need to more closely investigate a variety of risks including production risk for dairy farmers adopting the CFR system, such as climatic risks associated with maize production.

Several key messages for industry arise from this economic analysis:

Firstly, similar costs of production of CFR and high-input pasture imply that, for individual farms, there would be no need or advantage in implementing CFR unless the potential production of pasture has been fully exploited.

Secondly, for farmers who have already fully exploited the potential production of pasture and need to grow their enterprise without the possibility of accessing more land CFS is a clear alternative to increasing the use of bought in feed, particularly at current and predicted future prices of concentrates. A CFS may also be potentially economic if water irrigation is limited; or the cost of water is so high that water becomes the economic driver in decisions about forage options.

Thirdly, the potential role of CFR to replace more expensive feeds such as concentrates will be worthwhile only when particular minimum of the dairy farm area is used to grow CFR. In the case studies presented here, at least 10 per cent of the total farm area was necessary for growing CFR. This is due to the combined effect of spreading the fixed infrastructure cost over more forage produced and the actual cost of the necessary additional infrastructure, although the significance of the latter will vary among individual farms.

References

AACA (2007*a*). South Gippsland Suggested Contracting Rates Cultivation Services and Fodder Services, Australian Agricultural Contractors Association. Available http://www.a-a-c-a.org./nav.htm

AACA (2007*b*). Western Victorian Suggested Contracting Rates Cultivation Services and Fodder Services, Australian Agricultural Contractors Association. Available http://www.a-a-c-a.org./nav.htm

ABARE (2003). *Productivity and Profit*, Australian Dairy Industry Series 03.1, December, Canberra. Conducted on behalf of Dairy Australia, Melbourne.

ABARE (2006). *Production Systems, Productivity, Profit and Technology*, Australian Dairy Industry Series 06.1, October, Canberra. Conducted on behalf of Dairy Australia, Melbourne.

ABARE (2007). *Australian Commodity Statistics 2007*, Australian Bureau of Agricultural and Resource Economics, Canberra.

ABARE (2008). *Australian Commodities March Quarter 08.01*. Australian Bureau of Agricultural and Resource Economics, Canberra.

Alford, A.R., Griffith, G.R. and Davies, B.L. (2003). *Livestock Farming Systems in the Northern Tablelands of NSW: An Economic Analysis*, Economic Research Report No.12, NSW Agriculture Orange, October.

Alston, J.M., Norton, G.W. and Pardey, P.G. (1995). *Science Under Scarcity. Principles and Practice for Agricultural Research and Evaluation and Priority Setting*. Cornell University Press; Ithaca.

Bonlac (2000). A survey on environmental management of Bonlac dairy farms. Bonlac Foods Limited, Milk Supply Group.

Dairy Australia (2006*a*). *Australian Dairy Industry in Focus 2006*. Dairy Australia, Melbourne.

Dairy Australia (2006*b*). *Dairy 2006: Situation & Outlook. Report to the Australian Dairy Industry*. Dairy Australia, Melbourne.

Dairy Australia (2007). *Dairy 2007: Situation & Outlook. Report to the Australian Dairy Industry*. Dairy Australia, Melbourne.

Dillon, J.L. and Anderson, J.R. (1990). *The Analysis of Response in Crop and Livestock Production*, Third edition, Pergamon Press, Oxford.

Dillon, J.L. and Hardaker, J.B. (1984). *Farm Management Research for Small Farmer Development*. FAO Agricultural Services Bulletin 41, Rome.

Farquharson, R.J. (1991). A Farm Level Evaluation of a New Twinning Technology in Beef Cattle. *Review of Marketing and Agricultural Economics*, **59** (1), pp. 66-86.

Feder, G., Just, R.E. and Zilberman, D. (1982). Adoption of agricultural innovation in developing countries: a survey. *World Bank Staff Working Paper*, No. 542. The World Bank, Washington, D.C.

Foltz, J.D. and Chang, H.H. (2002). The Adoption and Profitability of rBST on Connecticut Dairy Farms. *American Journal of Agricultural Economics*, **84** (4), pp. 1021-1032.

García, S.C. and Fulkerson, W.J. (2005). Opportunities for future Australian dairy systems: a review. *Australian Journal of Experimental Agriculture*, **45**, pp. 1041-1055.

García, S.C., Fulkerson, W.J. and Brookes, S.U. (2008). Dry matter production, nutritive value and efficiency of nutrient utilization of a complementary forage rotation compared to a grass pasture system. *Grass and Forage Science*, ***63*** (3) pp. 284-300.

Ghodake, R.D. and Hardaker, J.B. (1981). *Whole-Farm Modelling for Assessment of Dryland Technology*. Economic Program Progress Report No. 29, International Crops. Research Institute for the Semi-Arid Tropics (ICRISAT), Andhra Pradesh.

Goulburn Broken Catchment Management Authority (2002). *Dairy Cattle Feedpad Guidelines. For the Goulburn Broken River Catchment*. Prepared by The Dairy Cattle Feedpad Working Group, Sheparton Irrigation Region Implementation Committee, GBCMA and Murray Dairy.

Hardaker, J.B., Huirne, R.B.M. and Anderson, J.R. (1997). *Coping with Risk in Agriculture*. CAB International, Wallingford UK.

Holford, I.C.R. and Crocker, G.J. (1997). A comparison of chickpeas and pasture legumes for sustaining yields and nitrogen status of subsequent wheat. *Australian Journal of Agricultural Rsearch*, **48** (3), pp. 305-315.

Kenny, S. (2006). Snapshots of our Dairy Australia levy at work: Future Dairy – Innovations to meet tomorrow's challenges.Victorian Dairy Conference, Dairy Extension Centre.

Lubulwa, M. and Shafron, W. (2007). *Australian Dairy Industry: Technology and Farm Management Practices, 2004-05*. ABARE Research Report 07.9 Prepared for Dairy Australia, Canberra, April.

Makeham, J.P. and Malcolm, L.R. (1993). *The Farming Game Now*. Cambridge University Press, Melbourne.

Malcolm, L.R. (2004*a*). Farm Management analysis: a core discipline, simple sums, sophisticated thinking. *AFBM Journal* **1** (1), pp. 45-56.

Malcolm, B. (2004*b*). Where's the economics? The core discipline of farm management has gone missing! *The Australian Journal of Agricultural and Resource Economics*, **48** (3), pp. 395-417.

Palisade Corporation (2004). *Palisade Decision Tools*. Palisade Corporation; Newfield, New York.

Pannell, D.J. (1999). On the estimation of on-farm benefits of agricultural research. *Agricultural Systems*, **61** (2), pp. 123-134.

Petersen, E., Schilizzi, S. and Bennett, D. (2003). Greenhouse gas and groundwater recharge abatement benefits of tree crops in south-western Australian farming systems. *The Australian Journal of Agricultural and Resource Economics*, **47** (2), pp. 211-231.

Reeves, T.G.; Ellington, A. and Brooke, H.D. (1984). Effect of lupin wheat rotations on soil fertility, crop disease and crop yield. *Australian Journal of Experimental Agriculture and Animal Husbandry*, **24**, 595-600.

Tronsco, J.L. (1985). *An ex ante evaluation of three new beef technologies developed for the conditions of the Lake region of Chile*. Unpublished PhD. thesis, University of New England, Armidale, N.S.W.

Zilberman, D.; Khanna, M. and Lipper, L. (1997). Economics of new technologies for sustainable agriculture. *The Australian Journal of Agricultural Economics*, **41** (1), pp. 63-80.

Appendix 1: Nutrient and Water Inputs to CFR and Pasture Treatments

Table A1. Major nutrient inputs from fertilisers (kg/ha)

	Nitrogen	Phosphorus	Potassium	Sulphur
Year 1				
CFR - Forage Rape	236	42	104	0
CFR - Legume	105	42	21	0
CFR – Maize	329	104	204	10
CFR Total Yr 1	**670**	**188**	**329**	**10**
Pasture Yr 1	**632**	**79**	**220**	**0**
Year 2				
CFR - Forage Rape	279	55	164	0
CFR - Legume	-	-	-	-
CFR – Maize	347	109	211	10
CFR Total Yr 2	**626**	**164**	**375**	**10**
Pasture Yr 2	**712**	**57**	**155**	**0**
Year 3				
CFR - Forage Rape	210	55	139	0
CFR - Legume	-	-	-	-
CFR – Maize	350	120	234	11
CFR Total Yr 3	**560**	**175**	**373**	**11**
Pasture Yr 3	**545**	**56**	**152**	**0**

Table A2. Irrigation requirements (mm/crop/year)

	Pasture	CFR Maize	CFR Forage Rape	CFR Legume
Year				
1	826	439	306	85
2	741	316	243	104
3	697	415	228	102
Mean	755	390	259	97

Appendix 2: Annual Average Variable Cost Budgets

CFR Annual Variable Cost Budget
Average across replicates
CFR Year 1

FORAGE RAPE Year 1 — 2005/06 dollar values

Forage Rape Yield	12.0 (t DM/ha utilised)		
	units /ha	**$/unit**	**$**
Seed (kg)	5	$ 5.00	$ 25.00
Fertilizer (kg)			
- Superphosphate + Mo	306	$ 0.40	$ 122.40
- Single superphosphate		$ 0.36	$ -
- Nitram	197	$ 0.50	$ 98.50
- Muriate of Potash	103	$ 0.61	$ 62.62
- Blend (24-4-13)	400	$ 0.70	$ 280.00
- topdress - Urea	158	$ 0.63	$ 99.70
Contractor rates (hrs)			
- roll	1	$ 31.50	$ 31.50
- initial fertilizer	0.2	$101.50	$ 20.30
- topdressing (Nitrograze)	0.1	$101.50	$ 10.15
- topdressing (Urea)	0.1	$101.50	$ 10.15
Total Variable Costs ($/ha)			$ 760.32

PERSIAN CLOVER Year 1

Persian Clover Yield	3.5 (t DM/ha utilised)		
	units /ha	**$/unit**	**$**
Seed (kg)			
- Persian Clover	15	$ 4.45	$ 66.75
- Maple Pea (cv. Secada)	210	$ 0.80	$ 168.00
Fertilizer (kg)			
- Blend (24-4-13)	164	$ 0.70	$ 114.80
- Triple Superphosphate	177	$ 0.65	$ 114.34
- topdress – Urea	143	$ 0.63	$ 90.23
Herbicide -Glyphosate (L)	3	$ 5.00	$ 15.00
Contractor rates (hrs)			
- spray	1	$ 22.00	$ 22.00
- sowing	1	$ 53.55	$ 53.55
- pregrazing fertiliser spreading	0.1	$101.50	$ 10.15
Total Variable Costs ($/ha)			$ 654.83

Note: Irrigation costs associated with Forage Rape and Persian Clover crops are included in the Maize component of the CFR budget.

CFR Year 1 (continued)

MAIZE Year 1 — 2005/06 dollar values

Maize Yield	26.6 (t DM utilised forage)		
Feedout silage wastage	20%		
	units /ha	**$/unit**	**$**
Seed (kg)	31.25	$ 8.00	$ 250.00
Fertilizer (kg)			
- Lime	4000	$ 0.05	$ 200.00
- MAP	102	$ 0.68	$ 69.77
- DAP	407	$ 0.67	$ 271.47
- Urea	533	$ 0.63	$ 336.32
- Muriate of Potash	407	$ 0.61	$ 247.46
Herbicide (L)			
- pre-emergent herbicide (Dual Gold)	3	$ 12.00	$ 36.00
- glyphosate	3	$ 5.00	$ 15.00
Contractor rates (hrs)			
- lime spreading	0.2	$101.50	$ 20.30
- direct drill	1	$ 89.25	$ 89.25
- topdressing (Urea)	0.2	$101.50	$ 20.30
- presowing fertiliser spreading	0.1	$101.50	$ 10.15
Irrigation (ML)	8.3	$ 30.00	$ 249.00
Silage costs			
- precission chop/ cartage (hrs)	1.5	$260.00	$ 390.00
- rolling (wet t)	81	$ 3.00	$ 241.82
- plastic seal (m^2)	63	$ 1.10	$ 69.30
- feedout costs (hrs)	13.3	$ 30.00	$ 399.00
Total Variable Costs ($/ha)			$ 2,915.13
Total Variable Costs, after wastage (/t DM)			$ 136.99

Total CFR

Total forage yield (t DM/ha)	42.1	36.78	after wastage
Total variable cost ($/ha)	$ 4,330.28		
$ /t DM (after wastage)	**$ 117.73**		

Note: No allowance for labour has been included, including irrigation labour.

CFR Year 2

FORAGE RAPE + PERSIAN CLOVER COMPONENTS Year 2

2005/06 dollar values

Forage Rape Yield	10.7 (t DM/ha utilised)	
Legume Yield	5.1 (t DM/ha utilised)	
Combined yield (Forage Rape+ Legume)	15.8 (t DM/ha utilised)	

	units /ha	$/unit	$
Seed – Forage Rape (kg)	5	$ 5.00	$ 25.00
Fertilizer (kg)			
- Superphosphate + Mo	250	$ 0.40	$ 100.00
- Triple superphosphate	100	$ 0.65	$ 64.60
- Muriate of Potash	250	$ 0.61	$ 152.00
- Blend (24-4-13)	300	$ 0.70	$ 210.00
- topdress - Urea	450	$ 0.63	$ 283.95
Contractor rates (hrs)			
- roll	1	$ 31.50	$ 31.50
- initial fertilizer	0.2	$101.50	$ 20.30
- topdressing (Nitrograze)	0.1	$101.50	$ 10.15
- topdressing (Urea)	0.1	$101.50	$ 10.15
Seed- Persian Clover (kg)	15	$ 4.45	$ 66.75
Herbicide (L)			
- Glyphosate	3	$ 5.00	$ 15.00
Contractor rates (hrs)			
- spray	1	$ 22.00	$ 22.00
- sowing	1	$ 53.55	$ 53.55
Total Variable Costs ($/ha)			$ 938.49

Note: Irrigation costs associated with Forage Rape and Persian Clover crops are included in the Maize component of the CFR budget.

CFR Year 2 (continued)

MAIZE Year 2 2005/06 dollar values

Maize Yield 26.2 (t DM utilised forage)

	units /ha	$/unit	$
Seed – Maize (kg)	31.25	$ 8.00	$ 250.00
Fertilizer (kg)			
- DAP	400	$ 0.67	$ 266.80
- MAP	100	$ 0.68	$ 68.40
- Triple SuperP	18	$ 0.65	$ 11.63
- Blend (24-4-13)	88	$ 0.70	$ 61.60
- Urea	530	$ 0.63	$ 334.43
- Muriate of Potash	400	$ 0.61	$ 243.20
Herbicide (L)			
- pre-emergent herbicide (Dual Gold)	3	$ 12.00	$ 36.00
- glyphosate	3	$ 5.00	$ 15.00
Contractor rates (hrs)			
- direct drill	1	$ 89.25	$ 89.25
- topdressing (Urea)	0.2	$101.50	$ 20.30
- presowing fertiliser spreading	0.1	$101.50	$ 10.15
Irrigation (ML)	6.6	$ 30.00	$ 198.00
Silage costs			
- precission chop/ cartage (hrs)	1.5	$260.00	$ 390.00
- rolling (wet t)	79	$ 3.00	$ 238.18
- plastic seal (m^2)	63	$ 1.10	$ 69.30
- feedout costs (hrs)	13.1	$ 30.00	$ 393.00
Total Variable Costs			$ 2,695.24
Total Variable Costs (after wastage) per t DM			$ 128.59

Total CFR

Total forage yield (t DM/ha)	42.0	36.8	after wastage
Total variable cost ($/ha)	$ 3,760.19		
Total variable costs ($ /t DM utilised)	**$ 102.29**		

Note: No allowance for labour has been included including irrigation labour.

CFR Year 3

FORAGE RAPE + PERSIAN CLOVER COMPONENTS Year 3 2005/06 dollar values

Forage Rape Yield 11.6 (t DM/ha utilised)
Legume Yield 3.9 (t DM/ha utilised)
Combined yield 15.5 (t DM/ha utilised)

	units /ha	$/unit	$
Seed – Forage Rape (kg)	5	$ 5.00	$ 25.00
Fertilizer (kg)			
- Superphosphate + Mo	250	$ 0.40	$ 100.00
- Triple superphosphate	100	$ 0.65	$ 64.60
- Muriate of Potash	200	$ 0.61	$ 121.60
- Blend (24-4-13)	300	$ 0.70	$ 210.00
- topdress – Urea	300	$ 0.63	$ 189.30
Contractor rates (hrs)			
- roll	1	$ 31.50	$ 31.50
- initial fertilizer	0.2	$101.50	$ 20.30
- topdressing (Nitrograze)	0.1	$101.50	$ 10.15
- topdressing (Urea)	0.1	$101.50	$ 10.15
Seed - Persian Clover (kg)	15	$ 4.45	$ 66.75
Herbicide –Glyphosate (L)	3	$ 5.00	$ 15.00
Contractor rates (hrs)			
- spray	1	$ 22.00	$ 22.00
- sowing	1	$ 53.55	$ 53.55
Total Variable Costs ($/ha)			$ 939.90

Note: Irrigation costs associated with Forage Rape and Persian Clover crops are included in the Maize component of the CFR budget.

CFR Year 3 (continued)

MAIZE Year 3 2005/06 dollar values

Maize Yield	29.2 (t DM utilised forage)		
Feedout silage wastage	20%		
	units /ha	**$/unit**	**$**
Seed – Maize (kg)	31.25	$ 8.00	$ 250.00
Fertilizer (kg)			
- DAP	400	$ 0.67	$ 266.80
- MAP	170	$ 0.68	$ 116.28
- Blend (24-4-13)	70	$ 0.70	$ 49.00
- Urea	530	$ 0.63	$ 334.43
- Muriate of Potash	450	$ 0.61	$ 273.60
Herbicide (L)			
- pre-emergent herbicide (Dual Gold)	3	$ 12.00	$ 36.00
- glyphosate	3	$ 5.00	$ 15.00
Contractor rates (hrs)			
- direct drill	1	$ 89.25	$ 89.25
- topdressing (Urea)	0.2	$101.50	$ 20.30
- presowing fertiliser spreading	0.1	$101.50	$ 10.15
Irrigation (ML)	7.5	$ 30.00	$ 225.00
Silage costs			
- precission chop/ cartage (hrs)	1.5	$260.00	$ 390.00
- rolling (wet t)	88	$ 3.00	$ 265.45
- plastic seal (m^2)	63	$ 1.10	$ 69.30
- feedout costs (hrs)	14.6	$ 30.00	$ 438.00
Total Variable Costs ($/ha utilised)			$ 2,848.56
Total Variable Costs (after wastage) per tDM			$ 121.94

Total CFR

Total forage yield (tDM/ha)	44.7	38.9	after wastage
Total variable cost ($/ha)	$ 3,788.46		
Total variable costs ($ /t DM utilised)	**$ 97.49**		

Note: No allowance for labour has been included including irrigation labour.

Pasture Annual Variable Cost Budget
Average across replicates

PASTURE Year 1 — 2005/06 dollar values

Pasture Yield 17.3 (t DM/ha utilised)

	units /ha		$/unit	$
Seed - Annual Ryegrass (kg)	30	kg/ha	$ 4.00	$ 120.00
Fertilizer (kg)				
- Lime	4000	kg/ha	$ 0.05	$ 200.00
- triple super	301	kg/ha	$ 0.65	$ 194.45
- potash	321	kg/ha	$ 0.61	$ 195.17
- Blend	458	kg/ha	$ 0.70	$ 320.60
- topdress - Urea	1136	kg/ha	$ 0.63	$ 716.82
Contractor rates (hrs)				
- sowing	1	hrs/ha	$ 53.55	$ 53.55
- lime spreading	0.2	hrs/ha	$101.50	$ 20.30
- fertiliser spreading (x 2)	0.1	hrs/ha	$101.50	$ 20.30
- topdressing Urea (x 10)	0.1	hrs/ha	$101.50	$ 101.50
Slashing (hrs)	0.2	hrs/ha	$ 72.45	$ 14.49
Irrigation (ML)	8.3	ML/ha	$ 30.00	$ 249.00
Total variable costs ($/ha)				$ 2,206.17
Total variable costs ($ /t DM utilised)				$ 127.52

Note: No allowance for labour has been included including irrigation labour.

Pasture Annual Variable Cost Budget (continued)

PASTURE Year 2			2005/06 dollar values
Pasture Yield	18.0 (t DM/ha utilised)		
	units /ha	**$/unit**	**$**
Seed - Annual Ryegrass (kg)	30	$ 4.00	$ 120.00
Fertilizer (kg)			
- triple super	200	$ 0.65	$ 129.20
- potash	200	$ 0.61	$ 121.60
- Blend	425	$ 0.70	$ 297.50
- topdress - Urea	1325	$ 0.63	$ 836.08
Contractor rates (hrs)			
- sowing	1	$ 53.55	$ 53.55
- fertiliser spreading (x 2)	0.1	$101.50	$ 20.30
- topdressing Urea (x 10)	0.1	$101.50	$ 101.50
Slashing (hrs)	0.2	$ 72.45	$ 14.49
Irrigation (ML)	7.4	$ 30.00	$ 222.00
Total variable costs ($/ha)			$ 1,916.22
Total variable costs ($ /t DM utilised)			$ 106.46

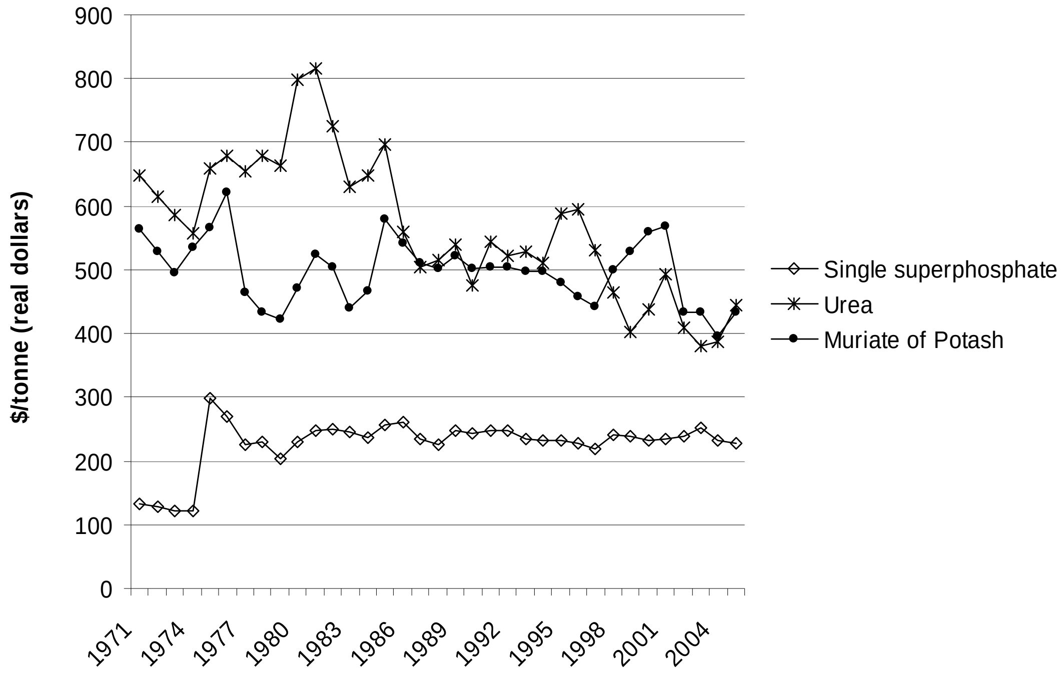
Note: No allowance for labour has been included including irrigation labour.

PASTURE Year 3			2005/06 dollar values
Pasture Yield (t DM/ha utilised)	17.0		
	units /ha	**$/unit**	**$**
Seed - Annual Ryegrass (kg)	30	$ 4.00	$ 120.00
Fertiliser (kg)			
- triple super	200	$ 0.65	$ 129.20
- potash	200	$ 0.61	$ 121.60
- Blend	400	$ 0.70	$ 280.00
- topdress – Urea	975	$ 0.63	$ 615.23
Contractor rates (hrs)			
- sowing	1	$ 53.55	$ 53.55
- fertiliser spreading (x 2)	0.1	$101.50	$ 20.30
- topdressing Urea (x 10)	0.1	$101.50	$ 101.50
Slashing (hrs)	0.2	$ 72.45	$ 14.49
Irrigation (ML)	7	$ 30.00	$ 210.00
Total variable costs ($/ha)			$ 1,665.87
Total variable costs ($ /t DM utilised)			$ 97.99

Note: No allowance for labour has been included including irrigation labour.

Appendix 3: Price Distribution Fit Statistics

Australian Fertiliser Prices Since 1971



Price distribution functions were fitted using the BestFit Version 4.5 (Palisade Corporation, 2004*a*). This software package uses three test statistics to rank the best fitting distribution functions from a library of functions (Palisade Corporation, 2004*b*). These tests include Chi-squared statistic, Kologorov-Smirinov (K-S) statistic and the Anderson-Darling (A-D) statistic for continuous sample data (Palisade Corporation, 2004*a*).

Potassium chloride – Potash
Price distribution function: Beta General

$$f(x) = \frac{(x - \min)^{\alpha_1 - 1}(\max - x)^{\alpha_2 - 1}}{B(\alpha_1, \alpha_2)(\max - \min)^{\alpha_1 + \alpha_2 - 1}}$$

where $a_1 = 4.29964$
$a_2 = 2.58943$
$\min = 0.5$
$\max = 0.92480$
B is the beta function.

Summary results: Cows

	Fit	Input data
Mean	0.76513	0.76443
Median	0.77049	0.77400
Std deviation	0.07325	0.07460
Chi-sq test	2.81	
A-D test	0.4171	
K-S test	0.1544	

Single superphosphate

Price distribution function: Inverse Gaussian

$$f(x) = \sqrt{\frac{\lambda}{2\pi x^3}} e^{-\left[\frac{\lambda(x-\mu)^2}{2\mu^2 x}\right]}$$

where $\mu = 0.12838$

$\lambda = 7.819024$

Minimum value = 0.25

Summary results: Single superphosphate

	Fit	Input data
Mean	0.37838	0.37838
Median	0.37734	0.37300
Std deviation	0.01645	0.01705
Chi-sq test	1.286	
A-D test	0.2673	
K-S test	0.1306	

Urea

Price distribution function: Weibull

$$f(x) = \frac{\alpha x^{\alpha-1}}{\beta^{\alpha}} e^{-(x/\beta)^{\alpha}}$$

where $\alpha =$ 2.9032

$\beta =$ 0.34245

Minimum value = 0.45

Summary results: Urea

	Fit	Input data
Mean	0.75537	0.75524
Median	0.75184	0.76800
Std deviation	0.11430	0.11593
Chi-sq test	2.81	
A-D test	0.2759	
K-S test	0.09858	

Diammonium phosphate - DAP

Price distribution function: Log Logistic

$$f(x) = \frac{\alpha t^{\alpha-1}}{\beta(1+t^{\alpha})^2}$$

with $t \equiv \frac{x - \gamma}{\beta}$

where $\alpha = 5.64144$

$\beta = 0.21503$

$\gamma = 0.30$

Summary results: Diammonium phosphate

	Fit	Input data
Mean	0.52656	0.52938
Median	0.51503	0.50800
Std deviation	0.07784	0.07695
Chi-sq test	1.286	
A-D test	0.2549	
K-S test	0.09142	

Industry & Investment

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An Economic Evaluation of the FutureDairy Complementary Forage Rotation System – Using Cost Budgeting

ECONOMIC RESEARCH REPORT NO. 44 (AUGUST 2009)

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