Effect of a carbon price on farm profitability on rain-fed dairy farms in south-west Victoria: a first look

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Abstract. In this study, the possible impact of different prices of carbon on farm profitability in two dairy farm businesses with different feeding systems was analysed. The feeding systems evaluated were a ryegrass pasture-based system (RM) and a complementary forage-based system (CF). The carbon charge was imposed on the systems as they currently operate and without the farmers making strategic changes in response to the tax. The study is a first-look approach in order to gauge the order of magnitude of a carbon charge on dairy systems if they were to continue to operate essentially under the same system following the impost of a cost of carbon emissions, and to gauge the likely size of incentives to respond. The main finding of this study was that net present value (NPV) of operating profit for each system over the five years was reduced by a price on carbon. The carbon charge of \$15/t CO_2-eq reduced the present value of the operating profits over the five years of operation by around 7% and 6% in the RM and the CF systems respectively. The carbon charge of \$25/t CO_2-eq reduced the present value of the operating profits over the five years of operation by around 11% in the RM and 10% in the CF systems. Farmers continually face rising costs of production, and respond accordingly. A price on carbon emissions, if ever applied to agriculture, would invoke responses to further increase productivity and possibly to seek offsets if genuine opportunities occurred.

Keywords: dairy farm, feeding system, carbon cost, operating profit.

Introduction

The dairy industry in south-west Victoria is based on rain-fed pasture supplemented by concentrates, by-products, hay and, occasionally silage (Fulkerson and Doyle 2001). In south-west Victoria, almost half of the pasture production grazed by dairy cows is produced in spring (September to November) (Doyle et al. 2000). The desirable calving time is usually adjusted to 4–6 weeks before the spring pasture peak to meet the increasing cow requirements at that time (Thompson and Poppi 1990). Pastures, in this region, grow between 6 and 12 t DM/ha per year (Malcolm et al. 1996, p. 142). The production, depending on the seasonal conditions, slows in January and February. Therefore, considerable supplementary feeding may be required to increase the total dry matter intake (Bargo et al. 2003). However, managing feed costs is an important component of dairy-farm businesses and one of the keys to increased profitability. One way to maintain the competitiveness of the dairy industry is to apply new feeding strategies that can offer high nutrient content with low cost (Doyle et al. 2000).

Whilst applying different feeding strategies is a key technology to pursue productivity and profitability improvements on Victorian dairy farms, the choice of feeding strategy has implications for climate change because different feeding strategies result in different greenhouse gas (GHG) emissions. Thus, the complete benefits and costs of changing systems are important questions. For instance, global agricultural GHG emissions have increased by about 17% from 1990 to 2005 (Smith et al. 2007). The Australian agricultural sector produced 87.4 Mt of CO_2-eq (16% of net national) GHG emissions as methane (CH_4) and nitrous oxide (N_2O) in 2008. Enteric fermentation contributed to the 64% of the total sectoral emissions or 55.6 Mt CO_2-eq GHG emissions (DCCEE 2010a).

Australia, as a signatory to the Kyoto Protocol, is required to reduce its increased GHG emissions (ABARE 2009). Kyoto commitments only last to 2012 and Australia is on track to meet these obligations as the projected Kyoto Target for agricultural emissions is to reduce emissions by 86 Mt CO_2-eq (0.4%) below its 1990 level (87 Mt CO_2-eq) (DCCEE 2010b). Both major political parties have committed to reducing emissions by 5% on 2000 levels by 2020. This is a challenge given that emissions are projected to be 22% higher in 2020 under a business as usual scenario. The federal government has the further goal of reducing emissions by 80% on 2000 levels by 2050 (The Parliament of the Commonwealth of Australia 2011).

The policy approach for abating agricultural emissions in Australia has been reconsidered so that a carbon crediting scheme might be adopted instead of an emission trading scheme. For this purpose, the design of the Carbon Farming Initiative (CFI) was published for consultation in 2010 (DCCEE 2010c). The CFI is an Australian Government legislative scheme that provides farmers, forest growers and landholders with credits for reduced or avoided GHG emissions produced in agricultural sector, or sequestration through changes to soil and land management practices, or systems biology (DCCEE 2010c). This new policy will require feasible abatement options to meet internationally consistent integrity standards. Some of the potential eligible abatement activities are listed as reforestation and revegetation, reduced CH_4 emissions from livestock, reduced fertiliser emissions, manure management, reduced emissions or increased sequestration in agricultural soils, avoidance of deforestation and reduced emissions from rice cultivation (DCCEE 2010c). The most plausible future scenario is that landholders may act as an offset provider to other sectors which would mean that they are paid to reduce their emissions rather than being taxed. The alternative incentives should have similar effects in respect to on-farm behaviour, but will have different impacts on operating profit. There is a range of input–output relationships over which the fundamental dairy systems that are analysed is likely to remain relatively unchanged. That is, whilst tactical changes will be made, strategic (medium term) changes will not be implemented.

If a price was placed on carbon emissions, Australian dairy farmers would seek mitigation strategies to reduce their GHG emissions. Some of the options that may help curtail emissions were listed in Lennox et al. (2008) as: (i) increased efficiency in different intensive feeding and house systems and reduced substitution for other inputs with high GHG emissions, (ii) nitrification inhibitors in intensive grazing systems, (iii) land use changes between farm systems and between farming and forestry systems, and (iv) native reforestation (by generating carbon credits). There is no doubt that fertiliser management plays an important role in reducing N_2O emissions from agricultural soils (Kerr and Sweet 2008).

A carbon price policy not applicable to the agricultural sector is about to be implemented in Australia. It is an interesting question as to how a price on carbon emissions applied to dairy farming would affect dairy farm profitability. In this study, two different scenarios of price on carbon and their impacts on farm are evaluated using farm system analysis. The two feeding systems examined are a predominately ryegrass pasture-based system (RM) and a complementary forage-based feeding system (CF).

In this paper, actual farm data from five years of a dairy farm trial were used. The trial was designed to compare the profitability of two alternative feeding systems. The farm feed system was adjusted tactically each year according to seasonal conditions, however decisions were made under the circumstance that there was no carbon tax to be considered. Hence, the first look: to see the magnitude of a carbon tax on emissions relative to annual operating profits of the two feeding systems. Knowing this magnitude indicates whether the alternative feeding systems have different implications for carbon emissions and carbon charges, and indicate the sort of incentive, if any, dairy farmers running these types of systems might have to change between systems as a result of a carbon tax. If the effect is significant on operating profit of the feeding systems, the analysis will also indicate whether strategic changes to the system will be likely to be needed.

In the next section, the data source and the approach taken in this study to compare the systems are outlined.

Materials and methods

The data used in this study were obtained from a dairy farmlet trial conducted from 2005 to 2009 at Terang, south-west Victoria (DemoDairy, Terang: 38°14′S, 142°54′E). The trial was established on 28.5 ha of grassland comprising greater than 90% perennial ryegrass (*Lolium perenne*), and was based on a modelling exercise described in Chapman et al. (2008a and b). The two different feeding systems compared were ryegrass max (RM), which consisted of pasture and pasture products; and complementary forages (CF), which provided extra feed by producing summer crop in summer and cereal silage in winter when the pasture availability was relatively lower. There were twenty paddocks which were each subdivided into two and allocated to the two farmlets on a ratio of 0.56:0.44 (RM: CF respectively) effective grazing area. Thirty-six Australian Friesian dairy cows were allocated to each farmlet, and were managed under rotational grazing (Hill et al. 2012). Some of the characteristics of the two farmlets are described in Table 1.

The systems of the research farmlets were designed to be representative of the dairy farms in south-west Victoria (Doyle et al. (2000); DPI (2009) and DPI (2010)), and, for analysis, the farmlets were scaled up to be typical sized operations for the region. The average herd size on the farmlets was thirty-six cows. For analysis, a scaled up representative farm of 288 cows was formulated.

To estimate the global warming potential (GWP) of the two systems, CH_4 emissions from enteric fermentation and N_2O emissions from urine and faeces, as well as from fertiliser use were calculated according to Australian method published by DCCEE (2010d). These methods used to estimate the GHG emissions in Australia reflect country-specific information, revised IPCC guidelines for national GHG inventories (1997) and emission factors, and they are believed to represent international practice (DCCEE 2010d). Methane emissions are calculated from feed inputs while N_2O emissions are calculated from two sources namely N_2O emissions associated with animal (urine and faeces) and N_2O emissions associated with fertiliser application. The production and transport of raw material or inputs such as purchased feeds, fertiliser production processes, extraction of sources or packaging and transport of the output off-farm have not been considered. Also not considered is the emissions related to land use under constant management practices, capital goods such as buildings and machinery (Cederberg and Mattson 2000; Chen et al. 2005), on-farm milking and cooling; and retail-stage activities such as refrigeration and disposal of packaging.

Whole farm approach was used to evaluate the impact of carbon charge on farm operating profit. Farm operating profit was calculated as described in Malcolm et al. (2005; pp. 29–31):

Gross Income (milk, livestock trading, inventory change) – Variable Costs (herd, shed, feed) = Total Gross Margin (1)

Total Gross Margin – Fixed Costs (also known overhead costs including depreciation, operating allowance) = Operating Profit or EBIT (earnings before interest & tax) (2)

Operating Profit – Interest and Long Term Lease = Net Profit (Return on the owner's capital) (also known net farm income) (3)

Feed costs are shown in Table 2, and milk prices in Table 3.

The prices of fat and protein for years 2005, 2006 and 2007 were derived from the base price, step ups, seasonal and productivity incentives. For 2009, 2010, district average cents per litre was used: this encapsulated the sum of the effects of base price plus step-ups and incentives.

The effect of a carbon charge on operating profit is assessed in several ways. First, the effect each year on the five years of annual operating profits of the two systems is assessed. Second, the overall effect over the five years is assessed. This is done by calculating the present value (PV) of the stream of five years of operating profits, with and without an annual carbon charge. Net present value (NPV) means adjusting the future benefits and costs of an investment to their equivalent values at present by using an opportunity cost rate (discount rate). The annual discount rate used is 5% (Armstrong et al. 2010) nominal reflecting the opportunity cost of the current capital in the system. Opportunity cost is described as the earnings from alternative investments. A positive NPV after discounting means the investment being analysed better performs than its opportunity cost. When making a decision among alternatives, the option offering a higher NPV is preferred (Malcolm et al. 2005; pp. 138–141).

The carbon prices used are \$15 and \$25/t CO_2-eq carbon emissions. A reference case scenario is simulated (*status quo*) where no policy is introduced for a consistent comparison of different price inclusions. The currency used is Australian dollars. In the following section the results of the analysis are presented.

Results

Five years of data were analysed to evaluate the impact of a carbon price on farm operating profit. The results were compared with a *status quo* where there was no price influence on carbon and the farm profit. The CF system produced a higher operating profit/farm than the RM system over the five years of operation, reflecting higher milk yields produced in the CF system relative to that in the RM system (cumulative NPV of \$1287000 versus \$1171500 respectively).

With regard to the impact of change on carbon price, a price of \$15 per tonne of CO_2-eq emissions reduced the mean operating profits of the two systems over the five years from \$272000 in the RM and \$297000 in the CF to \$254000 in the RM and \$279000 in the CF systems. This equates to 7% and 6% reduction in the mean operating profits of the RM and the CF systems over the five years of experimental trial respectively. The reduction in the operating profit was higher if the price imposed on carbon was \$25 (11% and 10% for the RM and the CF systems respectively). Amongst the five years of the experimental trial, change in operating profit as a result of imposition of a carbon price was the highest in 2005–2006 when \$15 reduced the operating profit by 12% and \$25 reduced the operating profit by 20% in the RM system. In the CF system, the greatest response in the operating profit towards a carbon price was observed in 2009–2010 when operating profit was reduced by 9% (\$15 scenario) and 16% (\$25 scenario).

Operating profits of the two systems under different price scenarios are presented in Figure 1a and b.

An obvious finding of this study was that overall net present value (NPV) at 5% discount rate of operating profit for each system over the five years decreased when a price on carbon was included. Using a discount rate of 5%, NPVs of the systems, without charges, were the highest in a no carbon price scenario ($1171000 versus $1287000 in the RM and the CF systems respectively). Including $15/t CO_2-eq reduced the NPV by $80000/farm and $79000/farm in the RM and the CF systems respectively (7% and 6%). This reduction was higher in a higher carbon price scenario ($25/t CO_2-eq) and was observed as $133000/farm and $131000/farm in the RM and the CF systems respectively (11% and 10% reduction relative to a no price on carbon scenario).

Discussion

In this study, the impact of a price on carbon on farm profitability was analysed with five years of farmlet data. This study used a whole farm model, considering different types of feeding systems. The operating profit was higher in the CF system compared to the RM system because the use of summer crops followed by winter cereal silage enabled more cows to be milked. The carbon charge of $15/tonne reduced the present value of the operating profits of the RM and the CF systems over the five years of operation by 7% and 6% respectively. The carbon charge of $25/tonne reduced the present value of the operating profits over the five years of operation by 11% and 10% in the RM and the CF systems respectively.

These results are comparable to other similar studies. Lennox et al. (2008) in New Zealand found that a NZ$25 price on carbon would increase the annual costs for dairy farmers by 5.9%. Hendy et al. (2006) indicated that a high carbon charge (NZ$50/t CO_2-eq) may reduce the dairy farmers' revenues by 11%. Hendy and Kerr (2005) reported that a tax of 25NZ$/t CO_2-eq has the potential to reduce the revenue of dairy farmers by 7%. Sin et al. (2005) reported a loss of NZ$15000 in profit out of average farm net trading profits of NZ$49000 in 2002–03 and NZ$85,000 in 2003–04 in a scenario where NZ$25/t CO_2-eq was implemented for an average dairy farm in New Zealand. These results are comparable to the effects of a carbon tax on Victorian dairy farmers investigated in this study. Any difference between different studies on the impact of a carbon charge on farm operating profit may be attributed to the management of the farm practices in the two studies. However, it is important to note that the current analysis considered neither indirect emissions such as fertiliser production nor emissions from other pollutants. Only the emissions of CH_4 from enteric fermentation, and N_2O from animals and fertiliser were considered. The study was restricted to agricultural GHG emissions in the south-eastern part of Australia and excludes emission leakage in other parts of the region.

The price scenarios for carbon used in this paper were experimental and although the current policy (CFI) published by DCCEE (2010c) focuses on issuing carbon credits instead of a carbon tax, this study applies a price on carbon. The carbon charge was imposed on the dairy systems as they currently operate in a 'first-look' approach to gauge the order of magnitude of a carbon charge on dairy systems if they were to continue to operate essentially the same system following the impost of a cost of carbon, and to gauge the likely size of incentives to respond. Hence, only relatively modest carbon prices of $15/t CO_2-eq and $25/t CO_2-eq were investigated. More significant carbon prices would cause substantial overhaul and revision of farm plans and of ways of doing business. Note that the carbon tax scheme to commence in 2012 has a starting price of $23/t CO_2-eq (Australian Government The Treasury 2011).

This study uses a whole farm approach to evaluate the impacts of change in one particular part of the farm on other parts of the business. This is because the introduction of more complex feeding systems to achieve higher milk yields per cow may impact negatively on profit, labour efficiency, pasture management and utilisation (García and Fulkerson 2005). A whole-farm analysis, which allows for an understanding of complex interactions, offers the opportunity to evaluate the consequences of change in feedbase or feed utilisation components of farm systems on other parts of the farm business especially on returns and risk (Doyle et al. 2010). It considers all the elements which potentially have a role in identifying and solving a particular problem studied (Malcolm et al. 2005, p. 8). Therefore, whole farm models of dairy systems can represent adequately the internal cycling of materials and their constituents. They also can predict the effects of change in the farm business by representing the exchange of materials and nutrients coming in and out between the farming system and its environment (Schils et al. 2007).

There are a growing number of farm studies that estimate GHG emissions from farm systems. It is not well-recognised that this information is a necessary but not a sufficient condition to judge impacts of GHG emissions and their control. Estimates of GHG emissions, often expressed per head or per hectare, are measures of technical efficiency; and partial measures too. They are not measures of economic efficiency. Economic efficiency measures require estimates of profit from whole systems. Indeed, using technical ratios can lead to logically opposite conclusions. For example, to reduce GHG emissions *per hectare* suggests a *lower* stocking rate while to reduce GHG emissions *per head* suggests a *higher* stocking rate. Technical estimates of GHG emissions from systems are no basis for policy decisions, neither on farm nor beyond farm. It is only when this technical information about GHG emissions from farm systems is incorporated into effects on farm profit that conclusions can be drawn about the GHG emissions and the attempts to deal with them.

Conclusions

This study compared possible impact of including dairy farming in a carbon pricing scheme. In particular, the effects of a tax on carbon emissions on the profits of dairy farmers *in the situation where the farmers do not make strategic changes to the system in response to the carbon tax*. With both feeding systems and no change in the system, a $25/ t CO_2-eq price on carbon reduced the 5 year cumulative annual farm operating profits by around 10–11% per annum, with marginally more effect on the RM feed system than on the CF feed system. Like all potential cost increases, such a potential change in costs would be incentive to increase productivity such as increasing size of the system to reduce average fixed costs per unit of output or possibility getting involved in an appropriate offset scheme.

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References

Armstrong DP, Tarrant KA, Ho CKM, Malcolm LR and Wales WJ 2010, 'Evaluating development options for a rain-fed dairy farm in Gippsland', *Animal Production Science*, 50(6): 363–370.

Australian Bureau of Agricultural and Resource Economics (ABARE) 2009, *Issues insights, across the issues, economic insights, agriculture and the carbon pollution reduction scheme (CPRS): Economic issues and implications*, March 2009, ABARE.

Australian Government The Treasury 2011, *Appendix B - Treasury Climate Change Mitigation Modelling — Assumptions*.

Bargo F, Muller LD, Kolver ES and Delahoy JE 2003, 'Invited review: Production and digestion of supplemented dairy cows on pasture', *Journal of Dairy Science*, 86: 1–42.

Cederberg C and Mattson B 2000, 'Life cycle assessment of milk production - a comparison of conventional and organic farming', *Journal of Cleaner Production*, 8: 49–60.

Chapman DF, Kenny SN, Beca D and Johnson IR 2008a, ‘Pasture and forage crop systems for non-irrigated dairy farms in southern Australia, 1. Physical production and economic performance’, *Agricultural Systems*, 97: 108–125.

Chapman DF, Kenny SN, Beca D and Johnson IR 2008b, ‘Pasture and forage systems for non-irrigated dairy farms in southern australia: 2. Inter-annual variation in forage supply, and business risk’, *Agricultural Systems*, 97: 126–138.

Chen G, Orphant S, Kenman SJ and Chataway RG 2005, 'Life cycle assessment of a representative dairy farm with limited irrigation pastures', *paper presented to fourth Australian conference on life cycle assessment*, Sydney, Australia, 23–25 February 2005.

Department of Climate Change and Energy Efficiency (DCCEE) 2010a, *National greenhouse gas inventory accounting for the Kyoto target, May 2010*, Commonwealth of Australia, Canberra, ACT.

Department of Climate Change and Energy Efficiency (DCCEE) 2010b, *Agriculture emissions projections*, Commonwealth of Australia, Canberra, ACT.

Department of Climate Change and Energy Efficiency (DCCEE) 2010c, *Design of the carbon farming initiative,* consultation paper, Commonwealth of Australia, Canberra, ACT.

Department of Climate Change and Energy Efficiency (DCCEE) 2010d, *National inventory report 2008 Volume 1, The Australian Government submissions to the UN framework convention on climate change*, *May 2010*, Commonwealth of Australia, Canberra, ACT.

Department of Primary Industries 2009, Victoria's dairy industry, Farm performance 2008–2009, Government of Victoria, Melbourne.

Department of Primary Industries 2010, Victoria's dairy industry, Farm performance 2009–2010, Government of Victoria, Melbourne.

Doyle PT, Stockdale CR, Lawson AR and Cohen DC 2000, *Pastures for dairy production in Victoria, second edn*, Department of Natural Resources and Environment, Kyabram, Victoria.

Doyle P, Jacobs J and Henry D 2010, *Dairy moving forward. a national research, development & extension strategy. feedbase and animal nutrition RD and E strategy.* Draft report to steering committee. Full report on five program areas, Dairy Australia, Canberra.

Fulkerson WJ and Doyle P 2001, *The Australian dairy industry*, Department of Natural Resources and Environment, Melbourne.

García SC and Fulkerson WJ 2005, 'Opportunities for future Australian dairy systems: A review', *Australian Journal of Experimental Agriculture*, 45(9): 1041–1055.

Hendy J and Kerr S 2005, *Spatial simulations of rural land-use change in New Zealand: the land use in rural New Zealand (LURNZ) model,* Motu manuscript, Motu Economic and Public Policy Research, Wellington, New Zealand.

Hendy J, Kerr S and Baisden T 2006, *Greenhouse gas emissions charges and credits on agricultural land: What can a model tell us?* Motu working paper 06–04. Motu Economic and Public Policy Research, Wellington, New Zealand*.*

Hill J, Chapman D, Tharmaraj J and Jacobs J 2012, Integrated pasture and crop systems for dairy production in south-east Australia. 1. Milk production, body weight and body condition score', draft manuscript, School of Agriculture and Food Systems, University of Melbourne.

Kerr S and Sweet A 2008, *Inclusion of agriculture and forestry in a domestic emissions trading scheme: New Zealand's experience to date,* Motu Working paper 08–04, Motu Economic and Public Policy Research, February 2008*.*

Lennox JA, Andrew R and Forgie V 2008, *Price effects of an emissions trading scheme in New Zealand*, Paper prepared for presentation at the 107th EAAE seminar "Modelling of agricultural and rural development policies", Sevilla, Spain, 29 January–1 February, 2008.

Malcolm LR, Egan A and Sale PWG 1996, *Agriculture in Australia: An Introduction*, Oxford University Press, Melbourne.

Malcolm B, Makeham J and Wright V (ed.) 2005, *The farming game. Agricultural management and marketing*, second edn, Cambridge University Press, Melbourne.

Schils RLM, de Haan MHA, Hemmer JGA, van den Pol-van Dasselaar A, de Boer JA, Evers AG, Holshof G, van Middelkoop JC and Zom RLG 2007, DairyWise, A whole-farm dairy model, *Journal of Dairy Science,* 90: 5334–5346.

Sin I, Brunton E, Hendy J and Kerr S 2005, *The likely regional impacts of an agricultural emissions policy in New Zealand: Preliminary analysis,* Motu working paper 05–08, Motu Economic and Public Policy Research, June 2005, Wellington, New Zealand.

Smith P, Martino D, Cai Z, Gwary D, Janzen H, Kumar P, McCarl B, Ogle S, O'Mara F, Rice C, Scholes B and Sirotenko O 2007, Agriculture, in B Metz, OR Davidson, PR Bosch, R Dave and LA Meyer (eds.) *Climate change 2007: mitigation. Contribution of working group III to the fourth assessment report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK and New York, NY, USA.

The Parliament of the Commonwealth of Australia 2011, *Clean energy bill, a bill for an act to encourage the use of clean energy, and for other purposes, exposure Draft* Available at: http://www.climatechange.gov.au/government/submissions/clean-energy-legislative-package/~/media/publications/clean-energy-legislation/exposure-draft-clean-energy-bill-2011-pdf.pdf Accessed 29 May 2012.

Thompson KF and Poppi DP 1990, Livestock Production from Pasture, in RHM Langer (ed.), *Pastures their ecology and management*, Oxford University Press, Auckland, pp. 263–283.

Warrnambool Cheese and Butter Factory Company Holdings Limited, 2005, 2006, 2007, 2008 and 2009, *Milk Prices*. Available at: http://www.wcbf.com.au/media/18843/2011-12_wcb_milk_prices.pdf Accessed 29 May 2012.

Appendix

Table 1. Characteristics of the two farmlet studies. (Numbers in parentheses reflect the change in systems in 2009–2010)

Characteristic	**RM**	**CF**
milk production (L/cow/year)	7622	7950
milk production (kg MS/cow/year)	581	598
average dairy area (ha)	16 (13.8)	12.4 (11.6)
average herd size	36	36
stocking rate	2.25 (2.6)	2.9 (3.08)
home-grown feed (pasture + pasture silage) consumption (t DM/ha)	8	8.1+3.2 (double crop)
concentrate feed consumption (t DM/cow/year)	1.6	1.8
% of feed consumed as concentrates	25	27

Table 2. Feed costs across the five years of the experimental trial

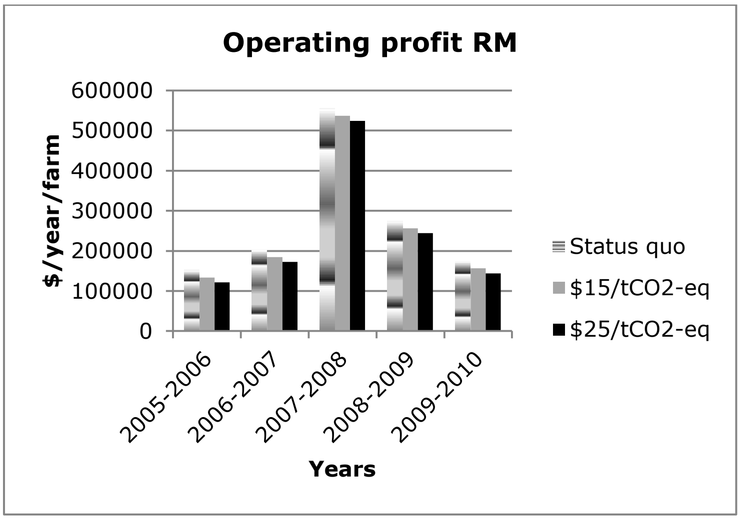
Feed types ($/t)	**05**	**06**	**07**	**08**	**09**
pasture	150	150	200	150	150
pasture silage	160	160	250	160	160
concentrates	200	250	350	200	200
purchased hay	150	150	250	150	150
purchased silage	180	180	250	180	180

Table 3. Milk prices used over the five years of experimental trial

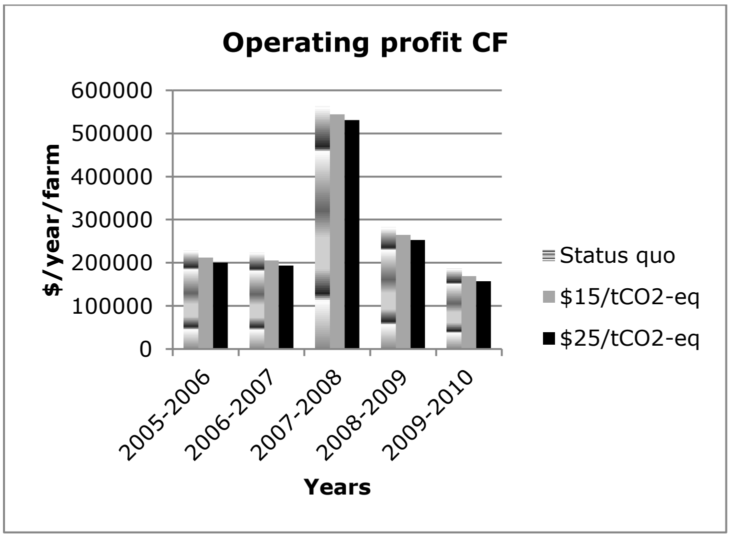
	05	**06**	**07**	**08**	**09**
butterfat ($/kg)	2.67	2.55	4.06	n/a	n/a
protein ($/kg)	6.46	6.34	10.15	n/a	n/a
milk price ($/L)	0.35	0.36	0.57	0.38	0.32
butterfat incentive ($/kg)	0.07	0.07	0.07	0.07	0.07
protein incentive ($/kg)	0.175	0.175	0.175	0.175	0.175

Source: Warrnambool Cheese and Butter Factory Company Holdings Limited.

Figure 1. Operating profits ($/farm) for different prices of CO_2-eq emissions



(a)



(b)

Developing potential adaptations to climate change for farming systems in Western Australia's Northern Agricultural Region using the economic analysis tool STEP

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Abstract. Climate change is expected to have a significant effect on agricultural production but less is known about its projected impact on the farm business. This paper provides a first attempt at an economic analysis of the impacts of climate change for broadacre farming systems and provides an insight into agricultural production areas in Western Australia at risk over the next 50 years. These risks have been assessed using the Simulated Transitional Economic Planning (STEP) model to investigate the impact on the farm business. Modelled future climate scenarios were incorporated into crop and pasture production models to examine the economic impact on the whole farming system. Uncertainties associated with climate and production projections were captured through the development of scenarios and sensitivity analyses were performed to encompass a range of potential outcomes for the impact of climate change on the farming systems of the northern wheat-belt.

Testing of this process showed that the current farming systems of the region may decline in profitability under climate change to a point where some become financially unviable in the long term. This decline in profitability is driven not only by the decline in crop yields from climate change but also from a continuation in the trend of declining terms of trade. With innovation and adaptation it may be possible to overcome these impacts on the region's farming systems even under severe (CSIRO Mk2) climate change projections. Potential profitable adaptations under climate change included a combination farming system of trade cattle, opportunistic cropping and carbon sequestration from oil mallee trees in the low rainfall area; investment in technology and genetically modified crops in the medium rainfall area; and in the high rainfall area a combination of increased crop area on the better soil types and the use of perennial pastures on the poor soil types. The findings are dependent on the accuracy and validity of future climate projections, crop yield estimates and the economic conditions used in the STEP model. Use of this process has improved understanding of the potential impacts of climate change and facilitated regional planning, decision making and the setting of research and investment priorities. However, additional fine-tuning of the analysis and further exploration of alternatives is necessary before policy decisions are made on the future of agriculture in Western Australia's northern wheatbelt.

Key words: Farming systems, climate change, STEP, economics

Introduction

Australia's changing climate is part of a global trend. However, despite general consensus on the causes and likelihood of climate change, projections of our future climate vary across Australia (Whetton et al. 2005). In addition the impact of climate change on agricultural production is likely to vary across regions (Howden and Jones 2004). Crop, pasture and livestock production will be directly affected by changes in average temperatures and rainfall, and by changes in the distribution of rainfall throughout the year.

The Northern Agricultural Region (NAR) of Western Australia is one area that faces large uncertainties over the possible impacts of climate change, especially with regard to responses at a farming system level. Characterised by warmer seasons and lower rainfall than other broadacre agricultural regions in the state, the north-eastern low rainfall area of this region is expected to suffer the greatest changes in productivity as a result of the shorter growing season and an unpredictable season start (late-April to mid-June). Combined with crop water deficits and high temperatures in the spring these conditions already limit wheat yield in the area (Kerr et al. 1992). While higher average temperatures and declining rainfall could transform traditional agricultural production in the NAR, we do not have a clear picture of;

(i) whether the current farming systems will remain viable under new climatic regimes, or

(ii) what adaptations can be made to our farming systems to ensure their sustainability and the cost of implementing these adaptations.

Mitigation strategies at a global and national level are aimed at reducing the extent of climate change but it is essential that local strategies are developed to adapt farming systems to the changing climate (Scheraga and Grambsch 1998). However, the ability of farming systems to adapt to climate change is currently limited by a lack of decision support tools to evaluate the impacts of climate change on regional farming systems and the transitional costs of future farming systems. This report discusses the possible effects of climate change on farming systems at a farm level, explores possible adaptive strategies to deal with these impacts and examines the transitional costs associated with moving towards these strategies.

Materials and methods

Study area

The northern agricultural region of Western Australia (latitudes 27.7 to 31.3°C) has a typical Mediterranean climate with most of the rainfall occurring in the winter months. The region is divided into three distinct zones based on annual rainfall and soil types, each with a characteristic farming system (Figure 1). These high (450-750 mm), medium (325-450 mm) and low rainfall (<325 mm) zones extend in bands inland from the west coast. The low and medium rainfall zones focus mainly on broadacre agriculture heavily reliant on the production of wheat. In the high rainfall zone farming systems are more variable. They have traditionally been based on livestock for meat and wool production but cropping has increased over the past 10–15 years and there is also a small growing horticulture industry.

Overview of process

The process used to investigate the impact of climate change on farming systems was to:

(i) Develop model farms representative of the major farming systems in the northern agricultural region of Western Australia

(ii) Establish current climate and future projections for a set of climate scenarios

(iii) Model the impacts of projected climate change on crop and pasture production

(iv) Assess the effect of the production changes on the annual surplus or deficit of the model farms over 50 years using the STEP model and perform sensitivity analyses

and

(v) Assess the financial performance of potential alternative adaptations in response to climate change using STEP.

Different methods to assess the effect of climate-induced production changes were developed and tested on the three farming systems presented.

Model farms for the northern agricultural region

Three model farms were developed to represent the major farming systems in each of the three rainfall zones.

The low rainfall farm, developed using soil type data from the north-eastern area of the region represented an average farm business in the low rainfall zone (<325 mm annual rainfall) (Clarke 1995). The 4,315 ha farm comprised 60% cropping and 40% volunteer pasture which supported a self-replacing merino flock. The cropping and livestock rotations reflected the current land use of local farming systems. Yields and variable costs were based on a survey of local farmers with the yields based on long-term averages for each soil type. Soil types ranged from higher yielding red loamy sands (wheat 1.8 t/ha) through to low yielding shallow, acidic or saline soils (wheat 0.8–1.2 t/ha). Other financial data were obtained from agricultural benchmark surveys (Bankwest 2003, 2005) and general financial estimates for cropping and livestock enterprises of Western Australia's northern agricultural region (Department of Agriculture Western Australia 2002, 2005). As crop yields fell below breakeven they were replaced with low-cost volunteer pasture.

The medium rainfall farm was based on a grower case study of a high production sandplain farming system typical of the medium rainfall zone (325–450 mm annual rainfall). The 3,500 ha farm comprised 80% cropping, in a wheat–lupin rotation, and 20% volunteer pasture supporting a self-replacing merino flock. Cropping 80% of the farm was considered the optimal enterprise mix for maximising profit while achieving good weed control in an environment where herbicide resistance is a serious threat to the sustainability of the system (Grima 2007). The crop yields were the long-term average yield for the soil type (wheat 2.5 t/ha, lupins 2.0 t/ha).

In the high rainfall zone (450–750 mm annual rainfall), the model farm was based on a grower case study of a mixed enterprise farm. The 5,000 ha farm comprised 55% cropping in a wheat-lupin rotation and 45% pasture for running trade wethers. Soil types ranged from high yielding gravelly loams (wheat 4.5 t/ha) through to lower yielding white/yellow sands (wheat 3 t/ha). The cropping phase ran on a five-year rotation (three wheat years with a lupin crop between each wheat year) before being put back into pasture for three to six years depending on the soil type.

Farm gate crop prices for the three farms were modelled at $250/t wheat and $240/t lupins over a 50-year period. These prices were the best estimates of future long-term average farm-gate prices at the time of the analysis as determined by consultation with regional economists (Rob Grima, Department of Agriculture and Food WA, pers comm. July 2008).

Modelling climate change in the test region

Climate scenarios were developed using the on-line OzClim program, available from http://www.csiro.au/ozclim/home.do.

The rainfall and temperature data generated for climate scenarios in OzClim were used to model the impact on future crop yields using a modification of the rainfall-driven French and Schultz (1984) equation. The equation was modified to suit each of the crops being modelled using previous estimates of water use efficiency (French and Schultz 1984; Hall 2002 Tennant 2001) and to reflect maximum yields from trials under ideal conditions. It was then further adjusted for excessive rainfall, soil capability class, and minimum and maximum temperatures (Van Gool and Vernon 2005; 2006; Vernon and Van Gool 2006). Van Gool and Vernon's (2005) wheat yield equations have been updated since publication and are shown below:

[1] (If $GR \leq 300$ mm) $MY = WUE1 \times (GR - WL) \times WAc \times LCc \times Mintc \times Maxtc$

[2] (If $GR > 300$ mm) $MY = WUE2 \times GR + YI \times WAc \times LCc \times Mintc \times Maxtc$

MY = mean yield
WUE1 = water use efficiency of 11.6 kg/mm
WUE2 = water use efficiency of 0.6 kg/mm
GR = growing season rainfall 1 April to 31 October, plus 20% of rainfall for 1 November to 30 March (The 20% accounts for initial soil moisture available to the crop)
WL = water loss. WL = 115 when GR ≥ 150 mm/year; WL = GR $\times$ 0.77, when GR < 150 mm/year
YI = 1635 kg (Yield at the intercept of two linear regressions of mean wheat yield versus corresponding rainfall record)
WAc = waterlogging constant (has a value of 1.0 for northern agricultural region where annual rainfall is below 700mm)
LCc = land capability class constant (Table 1a)
Mintc = minimum temperature constant (Table 1b)
Maxtc = maximum temperature constant (Table 1c)

WUE1, WUE2 and YI were calculated from linear regression of mean wheat yields obtained from 1995-1999 Co-operative Bulk Handling Limited grain receival data and corresponding Australian Bureau of Meteorology rainfall records (unpublished data).

This model is a useful tool for combining complex data and expert knowledge. However, it does not consider increased atmospheric carbon dioxide levels which may offset some of the negative effects of temperature on yield (Ludwig and Asseng 2006), climate variability or climate extremes which are likely to increase with climate change (IPCC 2007).

An alternative crop simulation model APSIM-Wheat incorporating atmospheric carbon dioxide levels and climate variability was also used as an additional scenario in the analysis of the low rainfall farming system. Farre and Foster (2008) used the APSIM-Wheat model to compare simulated crop yields at different locations in Western Australia for two 30-year periods representing the current (1975-2004) and future (2035-2064) climates. The yield changes predicted using APSIM-Wheat modelled for the low rainfall area were of the same direction but about one-third of the magnitude as those using the modified French-Schultz approach. Therefore, in the economic analysis of the low rainfall farm under climate change the effect of predicted crop yields modelled using both the APSIM-Wheat and modified French-Schultz methods were included (see description below).

Modelling the effect of climate on future pasture growth

Modelling pasture production under climate change is also critical for a clear picture of the likely impacts of higher temperatures and reduced rainfall on livestock operations. The growth and quality of pasture may be affected by changes in rainfall amounts and variability, temperature and carbon dioxide concentrations. It was assumed that there was minimal impact on livestock productivity from climate change.

For the low and medium rainfall farms management of livestock and pasture is secondary to crop management. Livestock were grazed on annual volunteer pastures and pasture growth was estimated using a simple modified French-Schultz equation developed for the area (Rob Grima, Department of Agriculture and Food WA, pers comm. February 2007):

PG = (GSR mm – 100 mm) x 28 kg DM/ha

PG = pasture growth
GSR = growing season rainfall from 1 April to 31 October
DM = dry matter (Pasture production is measured in tonnes of dry matter per hectare.)

Livestock numbers in the model farms were adjusted to match the pasture available.

For the high rainfall farm, which is more livestock-focused, it was more important to accurately match livestock numbers to the carrying capacity of its pastures under climate change. Therefore, the more sophisticated Sustainable Grazing Systems model (Johnson et al. 2003; Johnson et al. 2008) was used to calculate the annual and perennial pasture growth in response to different climatic conditions. The climatic factors driving the processes within the model are primarily solar radiation, temperature, humidity, rainfall and wind speed. The current climate for the high rainfall area was simulated using historical climate reference data for the period 1901 to 2008 inclusive from the Australian Bureau of Meteorology's SILO database (www.bom.gov.au/silo). The predicted future climate was generated in the on-line OzClim program (Version 3.0) (www.csiro.au/ozclim/home.do) using the latest version CSIRO Mk3 global climate model. A range of low, medium and high emission scenarios (scenarios B1, A1B and A1F1 in IPCC 2000) were investigated to scope the future pasture production for the area. Total growth for annual (ryegrass) and perennial (Rhodes grass) pastures was simulated on different soil types for the current climate and for the predicted future climate in the years 2030 and 2070 (Johnson 2009).

The difference in modelled pasture production between the current base climate and predicted future climate under each climate change scenario was calculated as a percentage change per annum. Livestock numbers in the model farms were adjusted to match the pasture available. The pasture requirements of livestock were calculated by assuming a Dry Sheep Equivalent will consume 1 kg of pasture per day. Pasture utilisation of the livestock on the model farm was calculated as:

> (pasture required for feed) / (total pasture available).

It is difficult to predict the potential impact of heat stress and climate extremes on livestock under climate change. For the purposes of this study, it was assumed that these effects were minimal through adaptations in management (e.g. provision of shelter and water), animal behaviour (animals seeking shade, feed) and species selection. Livestock were assumed to be more resistant to climate change than crops due to their mobility which allows them to seek shelter and access available feed (IISD/EARG, 1997). Using STEP to model the economic impact of climate change.

The economic impact of the production changes modelled for the farms under each climate scenario was investigated using the STEP model. STEP consists of Microsoft Excel spreadsheets that allow whole farm cash flow to be tracked through a transition from one farming system to another over a period of up to 50 years (Peek and Abrahams 2005).

The impact of climate change on the annual surplus or deficit was assessed over 50 years and compared to the current farming system without climate change impacts. Annual surplus or deficit was calculated as gross farm income net of total costs where costs included all capital, fixed and variable costs, taxation and personal drawings. To reflect improved efficiencies through normal advances in breeding, management and technology, the current farming system was modelled without the impact of climate change with an annual increase in crop yield each year. As the average yield increase of all crops in Western Australia over the last 20 years was 2% per annum (Stephens 2002) this value was used for the medium and high rainfall farming systems. Given the rainfall limitations of the low rainfall system, continued future yield improvements at the rate of 2% pa over the next 50 years was considered unrealistic. A rate of 0.5% was estimated to reflect a more realistic trend in yield improvements.

Declining terms of trade were included in the model to reflect the fact that input costs have been increasing at a faster rate than returns for more than 25 years (Mullen 2011). Hence, costs were increased at a rate of 3% per annum while returns were increased at only 2%.

A modified French-Schultz crop yield model projected changes in crop yield between 2007 and 2056. These were expressed as an annual linear percentage decline in yield for each climate scenario for each farming system and inserted into the STEP model.

To reflect real-life management the predicted decline in yield of the low rainfall farm was matched by modelled changes in farm management. Land was removed from crop production and increasingly devoted to livestock once crop yields fell below breakeven. The carrying capacity of pasture also declined under climate change but stock numbers were increased as the area of pasture increased. In addition, total input costs were reduced as less area was sown to crop. For the medium and high rainfall farms, which had higher crop yields and were modelled with a 2% annual increase in yield, the enterprise mix of the model farm was kept constant throughout the analysis. In addition the modelled effect of climate change on pasture production was negligible so livestock numbers were also maintained. In the climate change scenarios where crop yield declined input costs were reduced proportionately.

Future scenarios

With uncertainties in the accuracy of future climate and yield predictions, the financial viability of the model farms were further tested to scope the sensitivity of other possible future impacts under climate change on the farming systems. Scenarios tested included an alternative crop yield model and additional annual yield change scenarios to investigate the impact that additional variation in crop yield penalties had on the farming systems.

APSIM-Wheat was used as an alternative crop yield model to calculate future crop yield predictions for the low rainfall system (Farre and Foster 2008). APSIM-Wheat incorporates atmospheric carbon dioxide levels into crop yield calculations and models seasonal variability. Wheat yields were based on climate projections from a downscaled version of the later-released CSIRO Mk 3 global circulation model.

For the medium and high rainfall areas two annual yield change scenarios, 0% and 1%, were used to represent a combination of yield decline due to climate change and a level of yield increase due to advances in technology and management. Costs for these potential improvements were not factored into this analysis. These future scenarios were compared to the current system with no climate change at the current rate of crop improvement. All data into the model were validated through consultation with growers, researchers and/or agribusiness.

Sensitivity analyses

The relevance and strength of the input variables were assessed using sensitivity analyses to determine their impact on the potential outcomes. The financial performance of each model farm, under the CSIRO Mk2 climate scenario, was tested for sensitivity to:

(i) Crop price — a base long-term average farm-gate price of $250/t wheat, $240/t lupins was compared to future lower prices of $210/t wheat, $200/t lupin.

(ii) Terms of trade. In recent years the trend of declining terms of trade has slowed. To determine how better terms of trade would affect the financial viability of the model farms under climate change, currently declining terms of trade, where costs increase at a faster rate (3%) than returns (2%), were compared to projected future neutral terms of trade, where costs and returns both increased at the same rate of 2%.

The financial performance of the medium rainfall model farm was also tested for sensitivity to:

(iii) Crop yield — the current average yield (2.5t/ha wheat, 2t/ha lupins) was compared to a high potential yield (3.1t/ha wheat, 2t/ha lupins) and a low yield (2t/ha wheat, 1.5t/ha lupins), that is currently achieved by growers in the eastern edge of the medium rainfall zone.

In addition, the financial performance of the high rainfall model farm was tested for sensitivity to:

(iv) Livestock numbers — current stock numbers, utilising 24% of the pasture available, were compared to increased livestock numbers resulting in pasture utilisation rates of 35% and 50%.

(v) Cost of fertiliser inputs. In 2008, world fertiliser prices reached an unprecedented high. For the analysis of climate change impact on the high rainfall farm, fertiliser costs were based on June 2008 prices. Fertiliser prices continued to rise until the end of 2008 after which some fell to below the June 2008 levels. Hence current costs, based on June 2008 fertiliser prices, were compared to a 7.8% increase (using December 2008 prices) and a 1.6% decrease (February 2009 prices).

Testing potential adaptations to climate change using STEP

On-farm adaptations may play a role in reducing the impacts of climate change but their potential can be difficult to assess. STEP modelling provides a new approach to evaluate a potential adaptation by assessing the annual surplus or deficit of the model farm under a new or altered farming system. Using sensitivity analysis the production thresholds necessary for the farm to maintain an annual surplus can be determined. This process assists in highlighting the risks associated with implementing the new system and the knowledge gaps requiring research before trialling of the option can be considered. STEP was also used to compare the financial viability of different strategies of transition to a new system.

The current farming systems of the northern agricultural region were found to decline in profitability when modelled under the climate change projections of the CSIRO Mk2 scenario. Therefore, several potential adaptations to climate change were tested using STEP analysis.

Testing adaptations for the low rainfall farm

A combination farming system of a trade cattle pastoral alliance, oil mallee trees planted for carbon trading and opportunistic cropping was investigated as a potential adaptation for the low rainfall farming system. This adaptation used technologies and practices already in use by some farmers in the region.

Previous analysis identified a rapid transition phase strategy to a pastoral trade cattle alliance to be the most profitable (Megan Abrahams unpublished data). Under this scenario sheep were sold in the first year and replaced with trade cattle from pastoral regions. Opportunistic cropping operations occurred two in every ten years on the best cropping soil types achieving the current long-term average yields for each soil. Capital development and depreciation costs were reduced to reflect the lower frequency in use of cropping machinery.

Sensitivity to two crop prices (base long-term average farm-gate price of \$250/t wheat, \$240/t lupins and future lower prices of \$210/t wheat, \$200/t lupin) and two weight gains per head (120 kg and 180 kg) under conditions of declining and neutral terms of trade were tested. Two carbon prices (\$10/t CO_2 eq/ha and \$50/t CO_2 eq/ha) were also tested for each wheat price scenario and two fertiliser prices—base fertiliser input prices in July 2008 were compared with fertiliser prices reduced by 60% to 2007 prices. In this analysis cattle were stocked across the whole farm over winter with a stocking rate of 3 DSE/ha. This required an annual supply of up to 1,400 young steers at the start of winter or only 350 steers in a year where land was opportunistically cropped.

As the growth rate of the oil mallee trees and hence their potential to sequester carbon slows after about 30 years, this system was only tested over a 30-year period. During this period the oil mallee was assumed to maintain a constant growth rate (7 t CO_2 equivalent per annum per hectare). Additional future incomes from oil mallee products such as eucalyptus oil, wood pellets and activated carbon may also be possible but were not included in the analysis. The average annual surplus or deficit of the farm was expressed in today's dollar value by discounting at 8%.

Testing adaptations for the medium rainfall farm

Increasing crop area using genetically modified (GM) crops was investigated as a potential adaptation to overcome yield constraints on increased profitability of the medium rainfall farming system under climate change. The crop rotation was modified by replacing pasture with GM lupins and canola. This increased the crop area in the farming system where the profitability was threatened by annual ryegrass and wild radish weeds developing resistance to selective herbicides.

Pasture paddocks were removed from the rotation and replaced with GM crops tolerant to the non-selective herbicide glyphosate. It was assumed that the GM crops, Round-up Ready canola and lupins, were available for use in 2011 and integrated weed management was used in addition to herbicide use (Diggle et al. 2009).

STEP analysis was conducted on both (i) an immediate transition, in which the new GM cropping rotation was introduced over two years beginning in 2011, and (ii) a delayed transition, where introduction of the new GM rotation was delayed until 2016. The annual surplus or deficit of the farm under the transition strategies was compared to the current system under climate change.

Annual ryegrass resistance to the glyphosate herbicide is likely to develop after 22 years using this GM cropping rotation and weed control strategy (Diggle et al. 2009). After this time a new strategy would need to be adopted to manage herbicide resistance. Hence, the annual surplus or deficit of the farm for the GM system under climate change was investigated over a 25-year period. Average crop yields were used with the farm-gate crop prices at \$250/t wheat, \$240/t lupins and \$560/t canola. (N.B. Where wheat in the rotation was grown after another wheat crop, the price was reduced to \$245/t).

Testing adaptations for the high rainfall farm

To improve the profitability and longevity of the high rainfall system a combination strategy of increased crop area on soil types that maximise profit and perennial pasture area for livestock production on soil types that minimise input costs was investigated. This adaptation aims to reduce the cost of the current high input system on poor performing crop paddocks and improve the profitability on the poorest soils through increased livestock production.

Crop area on the farm was increased from 55% to 66% of the farm by replacing two pasture years with crop on the better gravel and loam soils. Perennial pastures replaced crops and annual pastures on the poorest sand soil types with livestock numbers adjusted to match the improved feed production.

Three transition phase strategies were tested to determine the most profitable timeline to convert the poorest sands to perennial pastures and increase livestock numbers:

(i) A fast transition, in year one - all 1,500 hectares of the poorest soil planted to perennials

(ii) A fast transition over the first two years, approximately half the area was planted in year one and half in year two while crop area was continued until perennials were planted.

(iii) A delayed transition to the new farming system over the first eleven years – one paddock planted to perennials each year until completed.

For all transitions excess livestock were sold prior to the establishment year when the perennials cannot be grazed. Additional livestock were bought once the perennials were established to retain a pasture utilisation rate of 24% across the farm. The cost of establishing the perennial pasture was $150/ha with an additional one-off cost of $20/ha for infrastructure, such as fencing and more water points to accommodate higher stock numbers.

Results

Modelled impact of climate change on crop yields

Climate scenarios for the low, medium and high rainfall areas of Western Australia's northern agricultural region projected an increase in minimum and maximum spring temperatures and a decrease in annual and growing season rainfall (Table 2).

Due to the negative effects of higher maximum temperatures and reduced growing season rainfall, crop and pasture production were also projected to decline. The total reduction in crop yield predicted under the CSIRO Mk2 and Hadley climate change scenarios between 2007 and 2056 was expressed as an annual percentage decline in yield for each farming system (Table 3). Pasture modelling predicted a small reduction in pasture growth but this had little effect on livestock numbers on the farms. The economic impact of the modelled change in climate on crop and livestock production for each representative model farm is described below.

Economic impact on low rainfall farming system

The economic modelling showed that the predicted impact of climate change on crop yields could make the current low rainfall farm financially unviable within a few decades. Annual yield declines of 1.5% for the Hadley climate scenario and 1.3% for the CSIRO Mk2 climate scenario modelled using the modified French-Schultz crop yield modelling approach caused the farm to fall into deficit within about 20 years (Figure 2). The reduction in the farm's annual surplus was driven by both the predicted yield decline under climate change and the current trend in declining terms of trade.

A lower annual yield decline of 0.4% has been predicted for the low rainfall area by the APSIM-Wheat crop model which incorporates yield impacts from atmospheric carbon dioxide and variability in interannual rainfall (Farre and Foster, 2008). Although the annual surplus of the farm under the APSIM-Wheat scenario is gradually reduced over time the farm is still profitable for almost the entire 50-year period (Figure 2).

When the current farming system was modelled without the yield effects of climate change the annual 0.5% yield increase from normal advances in breeding, management and technology maintained an annual surplus over the entire period (Figure 2). The graph shows this annual surplus to be increasing with time because the surplus has not been discounted to today's dollar value.

Stochastic effects were present in the graphs generated from the low rainfall farming system in difference to the smooth transitions graphed in the medium and high rainfall farming system. This reflects the higher risk profile of the low rainfall farming system and the greater sensitivity of low rainfall farm profitability to changes in crop yield and crop area which results from the yearly rotation of crop types on different land management units.

<u>Sensitivity analysis</u> The profitability of the low rainfall farm was tested for sensitivity to lower crop prices and improved terms of trade. Lowering crop prices by only $40/t markedly reduced the profitability of the low rainfall farming system which stayed in deficit after 7 years for the CSIRO Mk2 and Hadley scenarios and in 10 years for the APSIM-Wheat scenario (data not shown). Using the base crop prices, but with terms of trade increased to a neutral status, the farm remained profitable under the CSIRO Mk2 climate scenario for a further 10 years (data not shown).

Economic impact on medium rainfall farming system

Crop modelling for the medium rainfall farming system predicted an annual yield decline under climate change at the rate of 1% for the CSIRO Mk2 climate scenario and 1.1% for the Hadley climate scenario. The modelled effect of climate change on pasture production and consequently stocking rate was negligible. Therefore stocking rate was kept constant throughout the analysis. Where the annual yield declined at a rate of

1% under the CSIRO Mk2 scenario, the farm went into deficit in 2024 (Figure 3). In the event that climate change conditions are not as severe, or the annual yield decline was improved to 0% as a result of an improvement in technology and management the farm fell into deficit much later in 2047 (Figure 3). The annual surplus or deficit of the farm still declined even though long-term average yield remained constant due to declining terms of trade. At an annual yield increase of 2% and 1% the farm maintained an annual surplus over the entire 50-year period for average crop yields at the two prices tested and was able to overcome the negative impacts of declining terms of trade (Figure 3).

Sensitivity analysis The annual surplus or deficit of the medium rainfall farm under climate change was tested for sensitivity to changes in the key drivers of its profitability: crop price, yield and terms of trade.

The impact of lower long-term wheat and lupin prices caused the medium rainfall farm to go into deficit in 2008 under the CSIRO Mk2 (1% annual yield decline) scenario (data not shown). Analysis of breakeven yields showed that crop yields were at or just above breakeven in 2008 and the livestock enterprise was operating at a loss. With high input costs for fertiliser, fuel and herbicides this system was only just paying for itself at the crop prices of $210 wheat and $200 lupins. An annual reduction in crop yields of only 1% (i.e. 25kg/ha) immediately placed the farm in deficit. When a less severe scenario outlook was tested and the annual yield change improved to 0%, the farm still went into deficit in 2008 under lower farm-gate grain prices (data not shown).

The impact of higher potential wheat yields (3.1t/ha wheat, 2t/ha lupins) under the modelled 1% annual yield decline scenario (CSIRO Mk2) extended the financial viability of the medium rainfall farm by a further 14 years to 2038 (data not shown). Improvements in the terms of trade to neutral markedly improved the financial viability of the farm and it remained in surplus for a further 30 years under average yields (2.5t/ha wheat. 2t/ha lupin) (data not shown).

***Economic impact on* high rainfall farming system**

Even with the small annual yield declines predicted under both the CSIRO Mk2 (0.04% annual yield decline) and Hadley (0.07% annual yield decline) climate scenarios the farm went into deficit within 25 years (Figure 4). Declining crop yields combined with declining terms of trade caused the production of both lupins and wheat on the poorer soils to become unprofitable.

Sensitivity analysis The annual surplus or deficit of the high rainfall farm was tested for sensitivity to crop price, flock numbers, fertiliser input costs and terms of trade.

The high rainfall system was sensitive to reductions in the grain price. Due to the farm's high input costs a reduction in the price of wheat and lupins by $40/t caused the farm to almost immediately go into deficit in 2011 unless annual yield increases of more than 1% could be achieved (data not shown). With low grain prices the farm must achieve higher yields at the current input prices or purchase at low input prices to remain profitable.

Profitability of the high rainfall farming system was improved by maximising stocking rates and increasing pasture usage. When livestock numbers were increased so that pasture utilisation improved to 35%, the high rainfall farm remained in surplus for a further ten years (data not shown). With a further increase to 50% utilisation, the farm remained in surplus for the entire 50-year period of the analysis. Current practice for farms in this region is to run livestock at a pasture utilisation of between 20–30%. However, with good management some farms in the area have increased this value to about 50%. In addition, the sheep on this high rainfall farm are a trading flock and most were sold before the summer-autumn feed gap period thereby reducing the grazing pressure when less pasture is available.

The annual surplus or deficit of the high rainfall farm under the CSIRO Mk2 scenario was also tested for sensitivity to the cost of fertiliser inputs. With an increase in the cost of fertiliser of 7.8% across the farm, the farm went into deficit eight years earlier (data not shown). Lowering the cost of fertiliser inputs by 1.6% had little effect only extending the financial viability of the farm by two years. Fertiliser prices have since fallen further and in November 2009 were 40% below June 2008 prices.

Similarly, the high input costs of the system made the farm very sensitive to changing terms of trade. When terms of trade were improved to 'neutral' the financial viability of the farm under both the CSIRO and Hadley climate scenarios increased markedly (Figure 5). Hence, the decline in profitability of the high rainfall farm is driven mainly by declining terms of trade rather than the predicted yield reductions under climate change.

Potential adaptation for the low rainfall farming system

A combination strategy of a trade cattle pastoral alliance with opportunistic cropping and oil mallees for carbon trading may sustain the viability of the low rainfall farm but it is sensitive to crop price, liveweight gain, terms of trade, carbon returns and fertiliser price. Weight gain per head is a particularly strong driver of profit in the system and its management involves lower input costs and less risk in a poor season than increasing stocking rate.

In the current situation of declining terms of trade the combination farming system only remains viable at the higher weight gain for cattle (180kg) while receiving high wheat and carbon prices unless the terms of trade improve to neutral (Table 4a).

Increasing the frequency of cropping years improves the profitability of the farm (data not shown) as does lowering the cost of fertiliser inputs (Table 4b). World fertiliser prices were volatile during the time of the analysis and had markedly increased from the previous average long term prices. Testing the profitability of the combination strategy with fertiliser prices reduced by 60% showed an improvement in profitability (Table 4b). Under lower fertiliser prices and declining terms of trade the combination farming system now succeeded under high cattle weight gains (180kg), at both the medium and high crop price levels and both levels of carbon pricing. If the terms of trade improved to neutral the farming system under high cattle weight gains succeeded under all prices but the system only succeeded under low cattle weight gains while receiving higher crop prices. The combination strategy however is only one possible scenario for adaptation and analysis of environmental and other impacts needs consideration.

Potential adaptation for the medium rainfall farming system

Increasing crop area in the rotation using genetically modified crops was more profitable than the current system under the CSIRO (1% annual yield decline) climate scenario. An immediate transition to the GM adaptation resulted in an average annual surplus of $100,000 and extended the longevity of the system for a further ten years. Delaying the introduction of the GM crop rotation resulted in a loss of potential income with an average annual surplus of $66,000 per annum (Figure 6). In contrast, the current farming system under climate change had an annual surplus of only $36,000.

The sensitivity of the medium rainfall farm to profitability was increased during the transition to the GM crop rotation and this is illustrated by the stochastic effects present in the graph. This reflects the impact of yearly rotation changes of crop types and crop area on profitability during the transition to GM due to changes in crop input costs and crop price between the crop types.

While the GM crop adaptation aimed to lengthen the period of profitability of the farming system by delaying the development of resistance to selective herbicides it also allowed the farm to operate with a 100% cropping program. Increased wheat production together with the addition of canola in the rotation increased the potential income stream of the farm. As this cropping adaptation was more profitable than the current system delaying its introduction only reduced the profitability of the medium rainfall farm.

Potential adaptations for the high rainfall farming system

The combination of increased crop area on the good soils with increased perennial pastures and livestock on the poorer blackbutt sands significantly extended the viability of the farming system (Figure 7). The most profitable option for this strategy was to replace 100% of crop and annual pastures on the blackbutt sands with perennial pastures which resulted in an average annual surplus of $286,000. Profitability in this strategy was maximised by allocating crop area to soil types that maximised profit, pasture area to soil types that minimised input costs and grazing numbers matched to the increased feed production. However, the establishment costs of perennial pastures were not included in this analysis which will impact on the profitability as will the speed of transition to the new farming system.

The fast transition strategies to convert the blackbutt sands to perennial pastures and increase livestock numbers were the most profitable, but the one and two-year transitions involved a large initial outlay of money (Figure 8). These strategies carry higher financial risk as pasture establishment failure could be detrimental to the economic position of the property. Although the two-year transition would spread this risk to a small extent the drop in the farm’s annual income was more pronounced in comparison to the one-year transition strategy. This occurs because there is an extra year’s delay before stock numbers reach their full complement while pastures are establishing.

The 11-year transition may be the lowest risk approach for the farmer and will reach the same level of annual surplus as the quicker transition strategies in 2021 but returned the lowest average annual surplus (Figure 8). In this strategy the annual cost is reduced as only a small amount of land is being converted to perennial pasture each year. Stock numbers can be gradually built-up rather than purchasing large numbers at once. The risk of pasture establishment failure in a poor season will have less impact on the farm than for the quicker transition strategies.

Discussion

The low rainfall farming system

The predicted impact of future climate change regimes on crop yields could make the current low rainfall farming system of Western Australia's northern agricultural region financially unsustainable within 20 years. The crop dominant mixed farming system becomes an unsuitable option for the low rainfall under declining crop yields and rising input costs. Even when practical management changes are made by removing land from crop into livestock production the system eventually fails as the cost of production exceeds the income due to the trend in declining terms of trade. A key adaptation approach could be to move the focus away from a crop dominant system that is dependant on a traditional start-of-season rainfall break for profitability and move towards a farming system that is more flexible in responding to variable season types.

The combined trade cattle, carbon trading and opportunistic cropping system may be a viable alternative to the current low rainfall farming system. This alternative system removes high input losses from cropping in poor seasons and focuses on lower cost production enterprises that are farmed to seasonal conditions. The system responds better to seasonal conditions as livestock are no longer carried year round and instead utilises trade cattle (through a pastoral alliance) which are finished on winter/spring pasture. This maximises pasture use in the most productive part of the growing season and allows an increase in stock numbers and turnover as pasture no longer needs to be managed as a feed source over summer.

Opportunistic cropping employs existing practices to maximise returns in good seasons through planting crops on the best land only when good seasonal start conditions permit and avoiding large losses in poor seasons. While there is some initial expenditure in site preparation and planting for oil mallees few inputs are required once established and oil mallees offer an income stream through poor agricultural seasons. For oil mallees there is also a future potential for value-adding in the form of bio-energy and reconstituted wood products.

The biggest risk for the low rainfall adaptation is the cost of achieving the thresholds for success. The adaptation focused on incorporating existing practices and technologies which did not require a large degree of capital investment and avoided extra costs associated with training and adoption when changing to entirely new enterprises. For success in the trade cattle enterprise high weight grains of 120-180kg and stocking rates of 3 DSE need to be achieved in the low rainfall area. The risk in this adaptation is whether that weight gain and stocking rate can be achieved in the low rainfall area and the cost to the business in trying to achieve it. Achieving these levels will require more investment of time for labour in managing intensive grazing management practices and investing in new pasture types or animal genetics for higher levels of productivity.

With unpredictable starts to seasons any decline in crop yields will place further importance on the ability of the farm manager to make decisions to sow and interpret the season correctly. Correct interpretation of good seasons for planting will be a key area of importance to success. The cost of implementation is incorrect seasonal timing, poor commodity prices and high input costs. An opportunity cost is also created when oil mallee trees are permanently planted on highly productive crop land.

Management strategies which minimise risk in dry seasons are critical to ensure the long-term profitability of the low rainfall farm. With climate change forecasts predicting an increasing frequency of dry seasons (Pittock 2003), further research to develop and assess the viability of low input strategies for minimising losses in drought years is imperative and will facilitate the determination of appropriate policy and research agendas for this area. The STEP model has shown that there are possibilities for alternative farming systems in the low rainfall areas to overcome profitability declines whether or not they are climate change driven.

The medium rainfall farming system

The wheat-lupin rotation has been a profitable rotation on the sandplain soils of the northern agricultural region's medium rainfall area. However, if the effect of climate change on crop yield is as severe as the CSIRO Mk2 (1% annual yield decline) scenario suggests and input costs remain high, the medium rainfall farm may need to adapt to a more sustainable enterprise within the next 15 years. If yield losses can be minimised through improvements in management or technology, terms of trade and/or higher wheat prices then the medium rainfall farming system could remain quite profitable. In fact other risks such as the development of herbicide resistance, rising fertiliser and fuel costs, and increasing climatic variability may be more immediate threats than climate change alone.

The potential adaptation tested for the medium rainfall focused on increasing the proportion of crop area in the farming system through the use of new GM technology to improve crop yields in low profit areas. The addition of GM lupin and canola to the farming system provides an option for cropping where current profitability is threatened by weeds developing resistance to selective herbicides. The use of GM crops tolerant to non-selective herbicides minimises the use of selective herbicides in the farming system and extends the time before resistance develops. An immediate transition to the GM adaptation was the most profitable transition strategy as delay resulted in a potential loss of income.

For longevity, it is imperative that the use of GM crops is accompanied by the implementation of the appropriate weed control package. Failure to implement a component of this package will reduce both the profitability of the medium rainfall farm and the length of time until the development of resistance to selective herbicides. In the absence of further adaption however, the overall trend of declining yield will still cause the farm to become financially unviable at some point in the future.

The high rainfall farming system

The high rainfall farming system may not remain financially viable beyond the next 30 years if declining terms of trade continue along with the modest reductions predicted in crop yield from climate change. Profitability of the high input crop enterprise on low productivity soils declines as a result of high input costs constricting margin returns as crop yields reduce further under climate change. If losses can be minimised and profitability improved on these soil types then the high rainfall farming system could remain quite profitable.

The potential adaptation tested for the high rainfall farming system focused on increasing crop area on soil types that maximise crop productivity and improving the profitability of poor soils by planting perennial pastures for increased livestock production. While high input costs in the farming system are driven by fertiliser for crops the margin returns for the enterprise are also the largest. Increasing crop intensity and area on high yielding soil types is likely to increase the profitability and longevity in the farm.

Increased livestock production could be one of the key methods for farming systems to adapt to climate change. Livestock production is more resistant to climate change than crops because of mobility and access to feed (IISD/EARG 1997). SGS pasture modelling found that the quantity of pasture will only decrease slightly over the next 30 years which would leave stock numbers at current levels. Changing pasture type and management is likely to further increase pasture profitability through the ability to increase livestock production per hectare.

The most profitable transition strategy for this farming system was to increase crop area on productive soil types and embark on a slow transition of planting perennials on poorer soil types to improve livestock carrying capacity. This returned a slightly lower average annual surplus but carries lower risk as establishment and setup costs could be made gradually.

The potential costs of moving to this alternative farming system are small but include the risk of failure in perennial pasture establishment and the cost of purchasing additional livestock at market price each year that pastures are established. Further analysis of the high rainfall area however, should also include intensive agriculture options. Intensive agriculture enterprises, such as horticulture, currently exist in the southern part of the high rainfall area in close proximity to the state capital, Perth. As urban growth is currently pushing into traditional horticulture land it is expected that the horticulture precinct will push north into this area. The southern section of the high rainfall zone may become focused on intensive agriculture due to the availability of water and potential higher profitability compared to broadacre agriculture.

Conclusions

Climate change is expected to have some impact on the region's farm businesses. The farming systems that are currently in use are expected to decline in profitability to a point where some become financially unviable in the long term. However, the negative impact on farm profitability in the future is not only driven by a reduction in crop yields from climate change but also from a continuation in the trend of declining terms of trade.

The degree of impact on the future profitability of the region's farming systems is linked to rainfall. The low rainfall farming system is expected to be the most at risk from the impact of climate change and declining terms of trade. The profitability of this farming system is already challenged by management decisions on climate risk. However, with innovation and adaptation it is possible for the region's farming systems to overcome these impacts. For the low rainfall farming system this could involve a change to a more flexible farming system that can respond better to season types. For the higher rainfall farming systems innovation and adaptation could focus on technologies and techniques that improve yields and profitability.

This paper has outlined a process developed to investigate the long-term economic effects of climate change on farming systems and evaluate strategies to cope with the impacts. The key feature of the process is the use of STEP which is a tool to examine the financial effect of production or system changes on a farm business over time. Here, the use of STEP modelling has been extended to include the effects of climate change, using three main steps – (i) predicting the change in the future climate, (ii) modelling its effects on agricultural production and (iii) using STEP to estimate impacts on the annual surplus or deficit of a representative farm.

As with any analyses of this type around the issue of climate change our findings depend on the accuracy and validity of future climate projections, crop yield estimates and the economic conditions used in the STEP model. Uncertainties include the future commodity price, the direction of the terms of trade and the effect that new technologies, new markets and other factors may have in alleviating the impact of reduced yields on farm profitability. Variability was also not included in scenarios, but instead long-term average conditions were used in the analysis.

In addition, if agriculture is included in the Government's Carbon Pollution Reduction Scheme the profitability of potential options discussed in this report will need further analysis incorporating the costs of greenhouse gas emissions. However, this report highlights that STEP can be used to investigate the long-term economic effects of climate change on farming systems and may be a useful research tool for the development of strategies to cope with the impacts.

Acknowledgements

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References

Bankwest 2003, 'Bankwest benchmarks 2002/2003, Bankwest Agribusiness Centre, Perth Western Australia.

Bankwest 2005, 'Bankwest benchmarks 2004/2005', Bankwest Agribusiness Centre, Perth Western Australia.

Clarke M 1995, 'Pindar Tardun catchment management report', Department of Agriculture Western Australia, Unpublished report.

Department of Agriculture 2002, 'Gross margins guide 2003', Department of Agriculture, Western Australia, Miscellaneous publication 18/2002.

Department of Agriculture 2005, 'Gross margins guide 2005', Department of Agriculture Western Australia. (Replaces Miscellaneous publication 18/2002). http://www.agric.wa.gov.au/content/amt/agec/gross_margins_2005.htm (accessed 17 July 2012).

Diggle A, Peek C, D'Emden F, Evans F, French B, Grima R, Harburg S, Hashem A, Holmes J, Lemon J, Newman P, Paterson J, Penny S and Portmann P 2009, 'The implications of GM glyphosate resistant lupin', in S Penny, G Shea, B French, A Douglas, and J Paterson (eds.), *2009 Crop updates*, Department of Agriculture and Food, Western Australia, pp.186-191.

Farre I and Foster I 2008, 'Will wheat production in Western Australia be more risky in the future?' Agribusiness Crop Updates, Department of Agriculture and Food WA.

French RJ and Schultz JE 1984, 'Water use efficiency or wheat in a Mediterranean-type environment. I. The relation between yield, water use and climate'. *Australian Journal of Agricultural Research*, 35: 743-64.

Grima R 2007, 'Economic analysis of a high production yellow sand farm in the Northern Agricultural Region', Department of Agriculture and Food, Western Australia, Unpublished report.

Hall DM 2002, 'Impact of high yielding cropping systems on crop water use and recharge'. Final report summary prepared for the Grains and Research Development Corporation.

Howden M and Jones RN 2004, 'Risk assessment of climate change impacts on Australia's wheat industry', in *New directions for a diverse planet: Proceedings of the 4th International Crop Science Congress*, Sep 26 – Oct 1 2004, Brisbane, Australia.

International Institute for Sustainable Development and the Environmental Adaptation Research Group 1997, *Agriculture and climate change: a prairie perspective*. Institute for Environmental Studies, University of Toronto.

IPCC 2000, 'Special report on emissions scenarios', prepared for the Third Assessment Report of the Intergovernmental Panel on Climate Change, Geneva.

IPCC 2007, 'Climate change 2007: synthesis report', contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Pachauri RK and Reisinger A (eds.) IPCC, Geneva, Switzerland.

Johnson I., Lodge GM and White RE, 2003, 'The sustainable grazing systems pasture model: description, philosophy and application to the SGS national experiment', *Australian Journal of experimental Agriculture*, 43: 621-631.

Johnson I, Chapman D, Snow V, Echard R, Parsons A, Lambert M and Cullen B 2008, 'DairyMod and EcoMod: biophysical pastoral simulation models for Australia and New Zealand', *Australian Journal of experimental Agriculture*, 48: 711-728.

Johnson I 2009, 'Pasture growth rates in the Geraldton region of WA: growth rate analysis and climate change scenarios using the SGS pasture model'. Prepared by IMJ consultants for the Department of Agriculture and Food, Western Australia, March 2009, unpublished report.

Kerr NJ, Siddique KHM and Delane RJ 1992, 'Early sowing with wheat cultivars of suitable maturity increases grain yield of spring wheat in a short season environment'. *Australian Journal of Experimental Agriculture*. 32: 717-23.

Ludwig F and Asseng S 2006, 'Climate change impacts on wheat production in a Mediterranean environment in Western Australia'. *Agricultural Systems*, 90; 159-179.

Mullen, JD 2011, 'Public investment in agricultural research and development remains a sensible policy option'. *Australian Farm Business Management Journal*, 8 (2): 1-12.

Peek C. and Abrahams M 2005, 'Farming systems analysis using the STEP tool', *Proceedings of the agribusiness crop updates 2005*, Department of Agriculture and Food Western Australia.

Pittock B 2003, 'Climate change - an Australian guide to the science and potential impacts', Australian Greenhouse Office.

Scheraga JD and Grambsch AE 1998, 'Risks, opportunities, and adaptations to climate change', *Climate Research*, 10**:** 85-95.

Stephens, D 2002, 'National and regional assessments of crop yield trends and relative production efficiency: theme 5.1. land use change, productivity and diversification'. National Land and Water Resources Audit, Miscellaneous publication 12/2002, Department of Agriculture WA.

Tennant D 2001, 'Software for climate management issues, in 'Crop updates 2001', Department of Agriculture, Western Australia.

Van Gool D and Vernon L 2005, 'Potential impacts of climate change on agricultural land use suitability', Wheat resource management technical report 295, Department of Agriculture, Western Australia.

Van Gool D and Vernon L 2006, 'Potential impacts of climate change on agricultural land use suitability: lupins', Resource management technical report 305, Department of Agriculture, Western Australia.

Vernon L and Van Gool D 2006, 'Potential impacts of climate change on agricultural land use suitability: barley', Resource management technical report 302, Department of Agriculture, Western Australia.

Whetton PH, Mcinnes KL, Jones RN, Hennessy KJ, Suppiah R, Page CM & Durack PJ 2005, 'Australian climate change projections for impact assessment and policy application: a review', CSIRO marine and atmospheric research paper, 001, Aspendale Victoria.

Appendix

Table 1a. Land Capability Class constants for adjusting yield potentials on each soil capability class

Land Capability Class	**Land Capability Class Constant (LCc)**	
1	1.8	Higher than average yields
2	1.4	
3	1.0	Average yields
4	0.6	Lower than average yields
5	0.4	

Table 1b. Minimum temperature constants for adjusting yield potentials

September average minimum temperatures (°C)	**Temperature constant (Tc)**
>5.6	1.00
5.4 – 5.6	0.95
5.2 – 5.4	0.90
5.0 – 5.2	0.85
Trend continues to 4.0 °C	

Table 1c. Maximum temperature constants for adjusting yield potentials

August-October average maximum temperatures (°C)	**Temperature constant (Tc)**
<22.8	1.00
22.8 – 23.0	0.95
23.0 – 23.2	0.90
23.2 – 23.4	0.85
23.4 – 23.6	0.80
Trend continues until 24.8 °C	

Table 2. Comparison of the modelled base climate (1990) to climate scenario projections (2056) for the three farming systems of Western Australia's northern agricultural region

	1990 base climate		**2056 CSIRO Mk 2 projections**		**2056 Hadley projections**	
Model farms	Growing Season Rainfall (mm)	Average September Maximum Temp.(ºC)	Growing Season Rainfall (mm)	Average September Maximum Temp.(ºC)	Growing Season Rainfall (mm)	Average September Maximum Temp.(ºC)
1. Low rainfall	248	23.2	226	24.9	222	25.3
2. Medium rainfall	334	22.4	301	24.1	290	24.4
3. High rainfall	515	21.1	462	22.6	414	22.9

Table 3. Predicted annual crop yield decline over 50 years modelled using the French-Schultz and APSIM-Wheat methods under different climate scenario projections for three representative farms

	Predicted annual yield decline		
	French-Schultz crop model		**APSIM-Wheat crop model**
Representative farm	**CSIRO Mk2 climate projections**	**Hadley climate projections**	**Downscaled CSIRO Mk3 climate projections**
Low rainfall	1.3%	1.5%	0.4%
Medium rainfall	1%	1.1%	ND
High rainfall	0.04%	0.14%	ND

ND = not done

Table 4. The average annual surplus or deficit (today's value) of the farm over a 30 year period for different crop prices, carbon returns and weight gains per head at neutral and declining (↓) terms of trade (T of T) for (a) base fertiliser input prices in July 2008 and (b) fertiliser prices reduced by 60% to 2007 prices

Table 4a.

Cattle weight gain/head		**120kg**		**180kg**	
Crop price* $/t	**Carbon returns $/t CO_2 e**	**T of T ↓**	**T of T Neutral**	**T of T ↓**	**T of T Neutral**
$210 wheat $200 lupin	$10	*-$61,000*	*-$43,000*	*-$27,000*	*-$8,000*
	$50	*-$51,000*	*-$32,000*	*-$16,000*	**$2,000**
$250 wheat $240 lupin	$10	*-$48,000*	*-$29,000*	*-$12,000*	**$7,000**
	$50	*-$37,000*	*-$19,000*	**$3,000**	**$22,000**

Table 4b.

Cattle weight gain/head		**120kg**		**180kg**	
Crop price* $/t	**Carbon returns $/t CO_2 e**	**T of T ↓**	**T of T Neutral**	**T of T ↓**	**T of T Neutral**
$210 wheat $200 lupin	$10	*-$33,000*	*-$18,000*	**$4,300**	**$21,000**
	$50	*-$23,000*	*-$7,000*	**$21,000**	**$38,000**
$250 wheat $240 lupin	$10	*-$13,000*	**$3,000**	**$33,000**	**$50,000**
	$50	**$2,000**	**$20,000**	**$50,000**	**$70,000**

Note: Cattle at 3DSE/ha for 4–6 months. Pasture costs $22/ha.
Surpluses are shown in **bold**, deficits in *italics*. * Farm-gate price

Figure 1. Location of the representative model farms for the (1) low, (2) medium and (3) high rainfall areas of the northern agricultural region

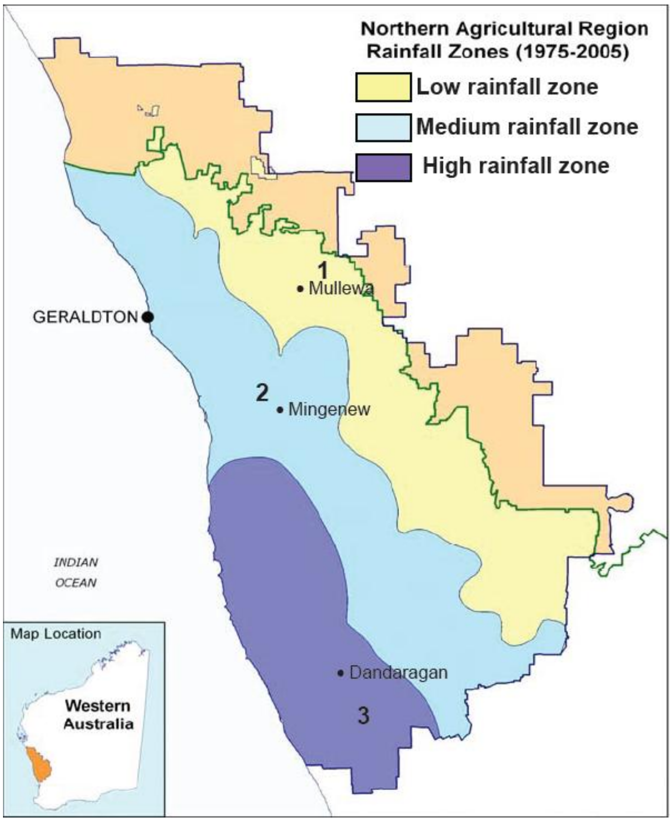


Figure 2. Annual surplus of the low rainfall farm for different climate change scenarios.

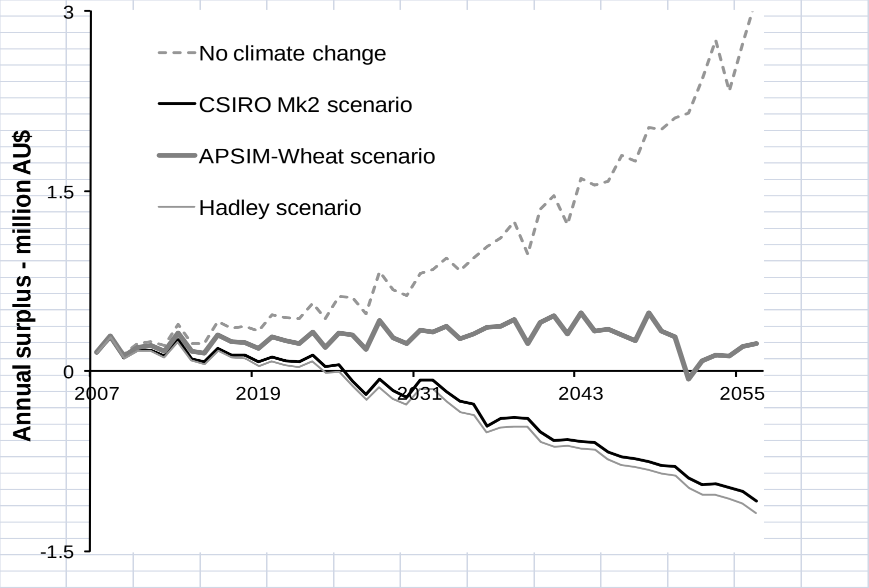


Figure 3. Annual surplus or deficit of the medium rainfall farm for different climate change scenarios

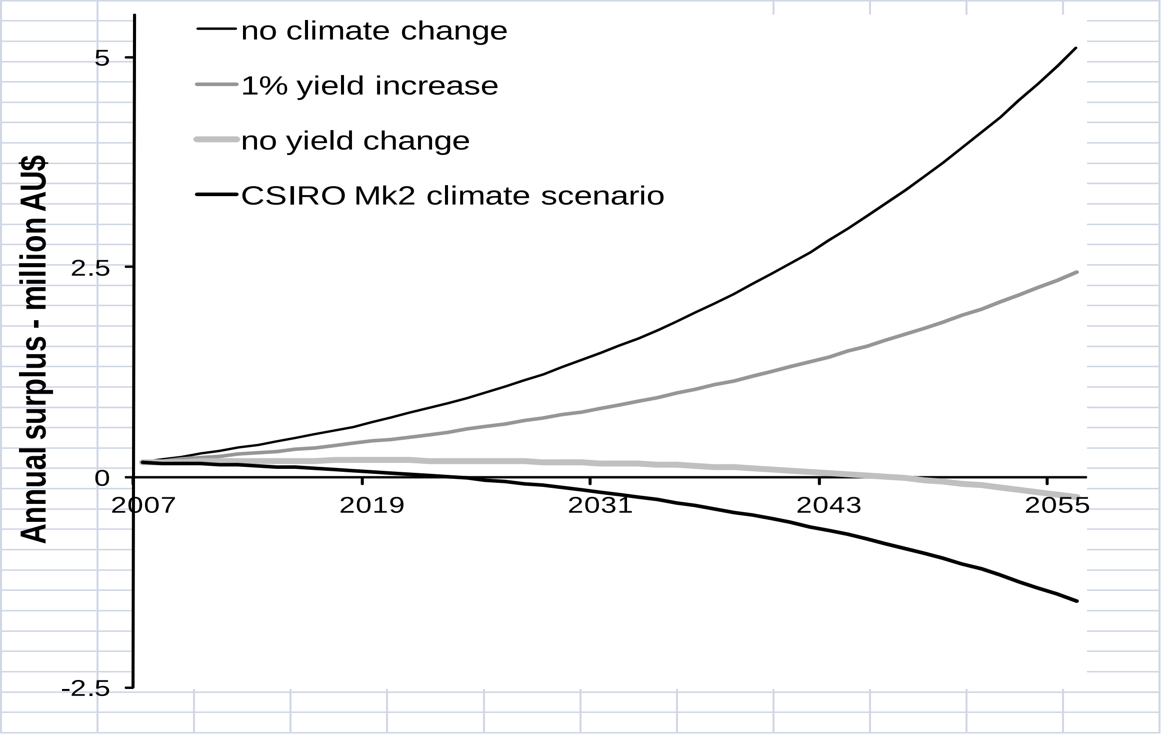


Figure 4. Annual surplus or deficit of the high rainfall farm for different climate change scenarios

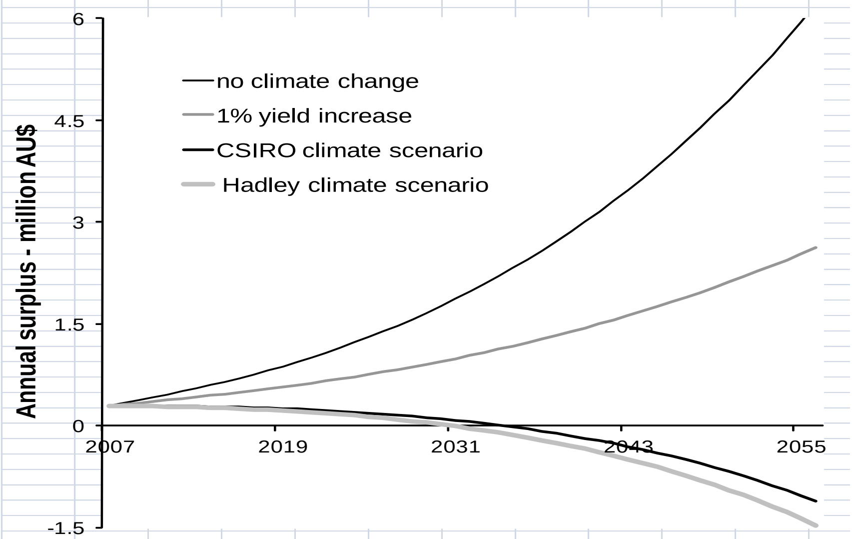


Figure 5. Sensitivity of the annual surplus deficit of the high rainfall farm under the CSIRO Mk2 (0.04% annual yield decline) scenario to terms of trade. Declining terms of trade (costs increasing at a higher rate than returns) were compared to neutral terms of trade (costs and returns increasing at same rate)

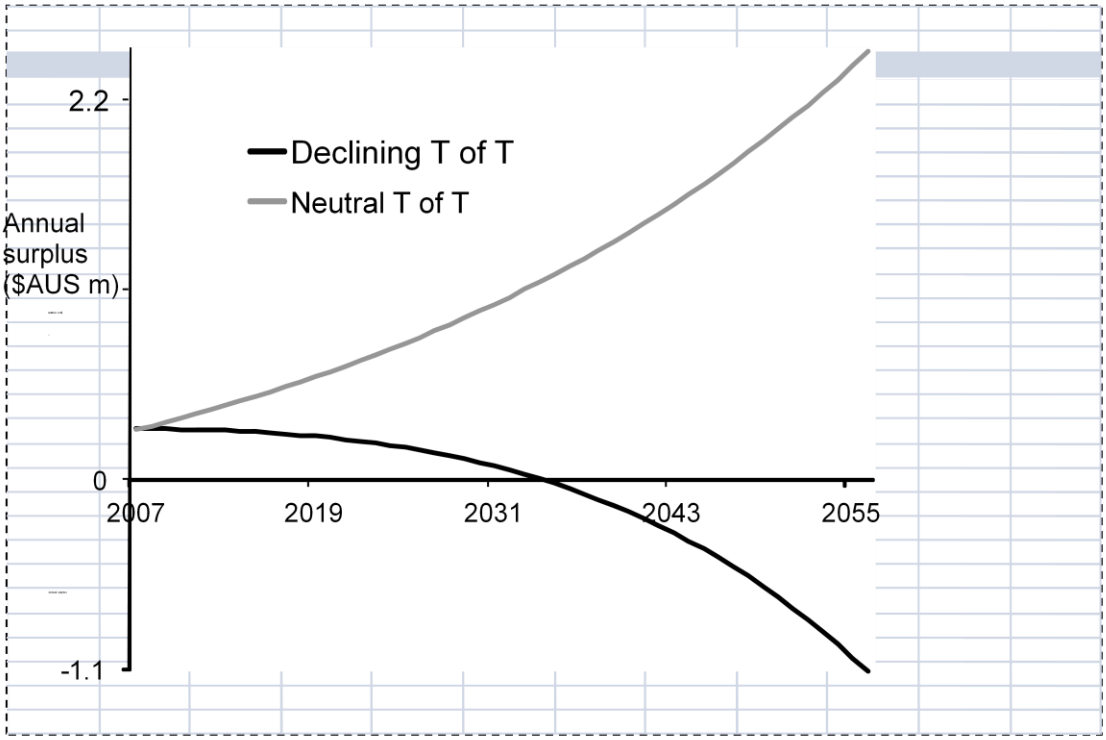


Figure 6. Annual surplus or deficit (today's value) of the medium rainfall farm for the current system and two GM crop transition strategies under the CSIRO (1% annual yield decline) climate change scenario. The average annual surplus over the entire 25-year period is also shown in bold type. (Crop prices were $250/t wheat, $240/t lupins, $560/t canola farm-gate)

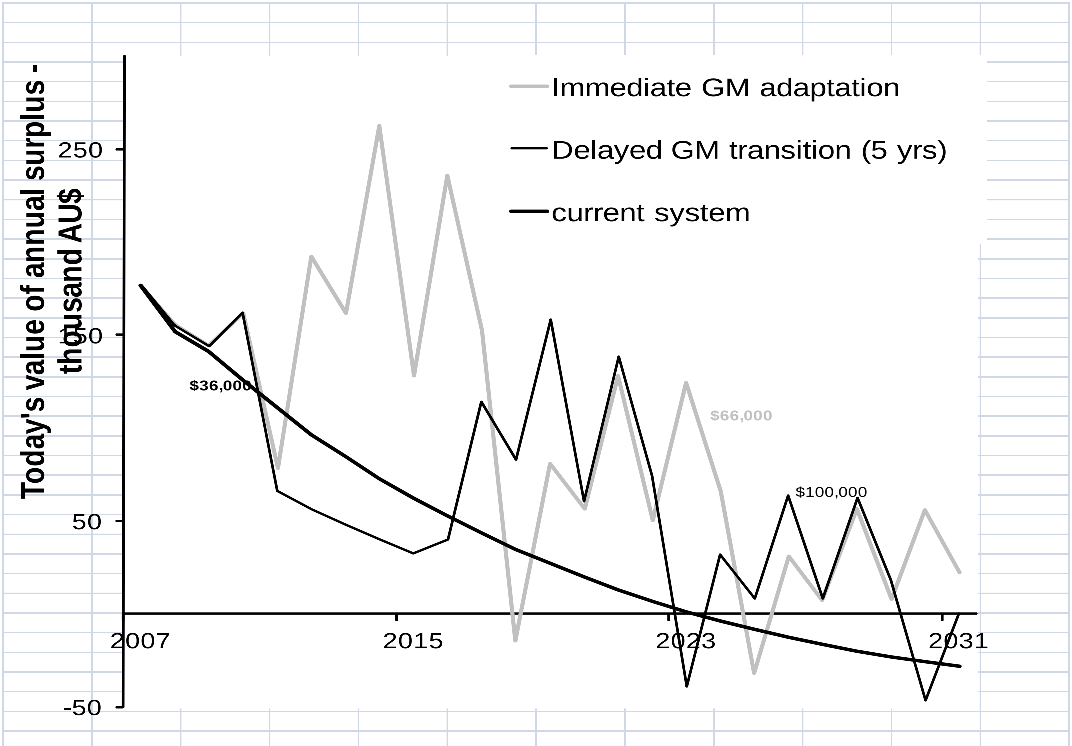


Figure 7. Annual surplus or deficit of the high rainfall farm with increased cropping on the good soils with or without increased perennials and livestock on the lower yielding soils. All scenarios are compared to the CSIRO Mk2 climate change scenario

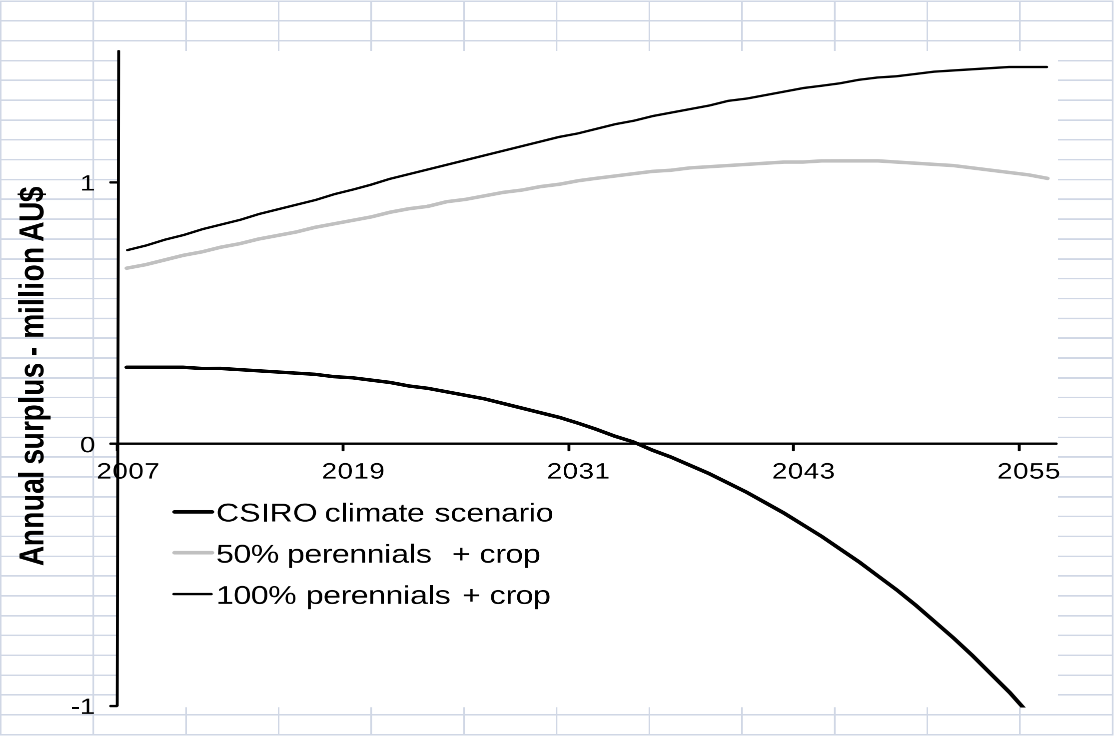
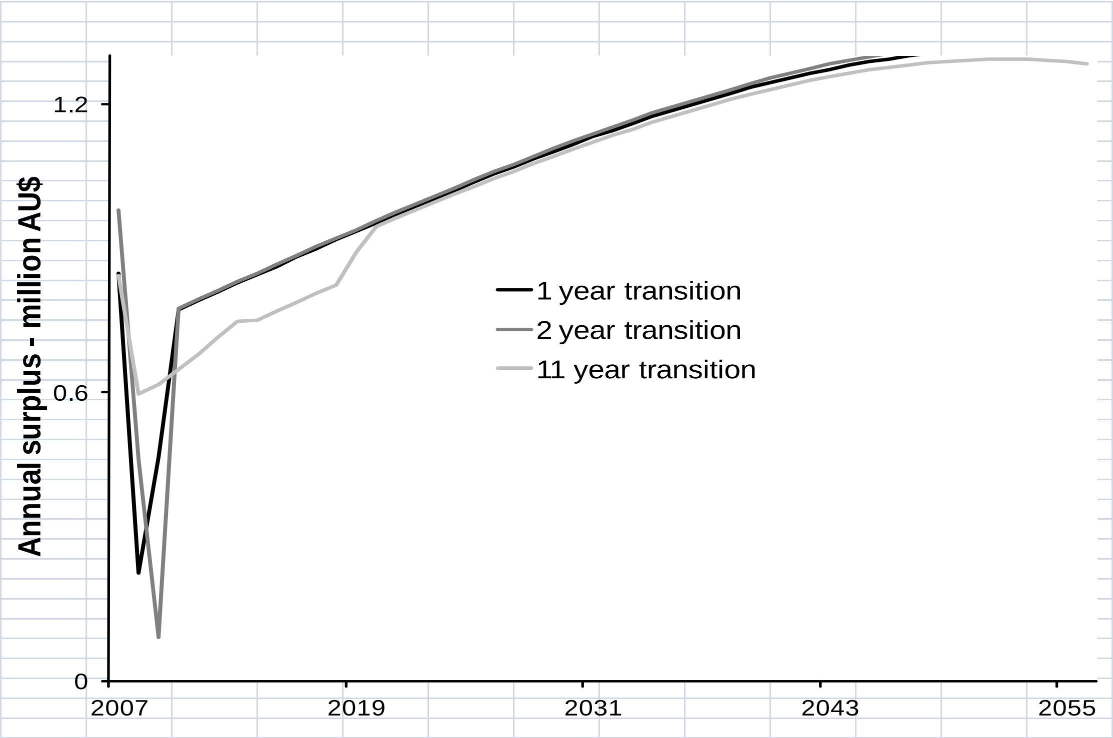


Figure 8. Annual surplus or deficit of the high rainfall farm during transition to increased cropping on the good soils and increased perennials and livestock on the lower yielding soils



Economic analysis of irrigation re-use systems in the Macalister Irrigation District of Eastern Victoria

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Abstract. Irrigation re-use systems are a common way of improving water use efficiency on irrigated dairy farms in the Macalister Irrigation District. A partial budget analysis of installing a range of irrigation re-use systems on an existing dairy farm was conducted using a case study approach. Two re-use dam sizes were tested – 6 ML and 9 ML. The analysis quantified the benefits of installing a re-use system through growing and consuming additional grazed pasture. There are also potentially other benefits of installing a re-use system both on and off farm, including improved irrigation management and reduced nutrient transfer from the capture area. The analysis found that irrigation re-use systems were almost always a good investment, regardless of the volume of water re-used or the amount of additional pasture consumed. The 9 ML dam had some economies of size, and therefore a lower pasture response per megalitre of water re-used was needed to meet the decision criterion (10% nominal internal rate of return). Only in the situation where both the value of pasture and percentage of water re-used were low ($100/t DM and 10% respectively), was the investment not justified on economic grounds. For a 6 ML re-use dam, a pasture price of $150/t DM and a re-use rate of 10% was still able to achieve a nominal internal rate of return of 12%.

Keywords: Dairy farming systems, economics, irrigation re-use system.

Introduction

Dairy farmers continually strive to use water more efficiently on their farms. One way to improve irrigation water use efficiency is to construct a water re-use system. Irrigation re-use systems capture water that runs off the end of each bay after irrigation. Re-use systems are also a way for farmers to collect nutrient rich water which may otherwise be lost from the property. Generally, a re-use system will comprise a capture dam, pump and a series of drains or pipes to channel water into and away from the dam. Runoff from irrigation and rainfall accumulates in the dam and can be pumped to locations around the farm.

The Macalister Irrigation District (MID) is located within the Gippsland region of Victoria, and covers an area of approximately 53,000 hectares (Southern Rural Water 2011). Around 33,500 hectares of this area is under irrigation, with irrigated dairy farming the predominant land use. It is estimated that approximately 30% of irrigators in the MID operate water re-use systems. Farms with high reliability water share allocations per hectare. This leads to a more secure irrigation water supply, and as a consequence they are less likely to have re-use systems (McAinch 2003).

Improved irrigation management leads to higher productivity, and reduces the environmental impact of irrigation by capturing water and nutrients before they leave the property. (G. Lamb [Department of Primary Industries] pers. comm. 2010). There are also a range of benefits of capturing irrigation water that extend beyond the farm boundary; for example, reducing the amount of nutrients, agrochemicals and pharmaceuticals that enter waterways where they can degrade natural ecosystems.

There are a range of costs and benefits associated with installing an irrigation re-use system.

Some benefits of re-use systems on dairy farms are:

- Additional water leads to increased pasture production and decreased reliance on purchased fodder
- Increased flexibility within the system
- Increased water use efficiency
- More flexibility in the timing and duration of irrigation
- Creation of a closed system (resources of water and nutrients remain on farm)

Some costs, disadvantages and risks of re-use systems include:

- Initial investment cost
- Increased repairs and maintenance costs (pump, motor and drains)
- On-going operating costs of using the system
- Loss of productive milking area
- Not a drought strategy (only get sufficient runoff in years with high allocations and average rainfall)

The aim of this analysis was to investigate the economic impacts of installing an irrigation re-use system on an irrigated dairy farm. For the purpose of this analysis, the assumed benefits of installing an irrigation re-use system were restricted to:

1. Additional perennial pasture available (t DM/ha) for grazing
2. The value of extra perennial pasture consumed ($/t DM)

It was expected that the installation of a re-use system in the MID would be a good investment when the quantifiable benefits were achieved.

Approach

Partial Budget

A partial budget, including a discounted net cash flow analysis, was used to investigate the economic feasibility of installing an irrigation re-use system on an existing dairy farm located in the Macalister Irrigation District. A partial budget considers the balance of economic costs and benefits of a proposed change affecting only part of the farm (Malcolm et al. 2005). The method for this analysis included use of a 10-year development budget as described in Malcolm et al. (2005). The measures used in assessing the profitability of re-use systems were nominal internal rate of return (IRR) for the extra capital invested and years for cumulative net cash flow to break-even. A description of these measures can be found in Appendix 1. The partial budget method was used because the adoption of a re-use system should make little difference to the overall way that the farm is managed. In the analysis that follows, a nominal IRR of 10% or greater was used to indicate a profitable investment. This was considered appropriate as re-use systems are a well established technology. Although variability in performance between years could be expected, it is considered a relatively low risk investment.

In consultation with a steering committee of farmers and industry specialists, costs for each major aspect of installing a re-use system were estimated (Table 1). Assumptions associated with these costs, along with other general assumptions are outlined below. Six scenarios were used to test the profitability of the system under a range of defined conditions; four have been reported here. However, it is unlikely that uniform conditions would occur over a 10-year period. Therefore, a sensitivity analysis was conducted to determine the minimum average pasture response per megalitre of irrigation water (t DM pasture consumed/ML) that was required to achieve a nominal IRR of 10%.

General assumptions

The following general assumptions have been made in the analysis:

- Before installing the system, irrigation management followed best practice as defined by the farmer steering committee.
    - 6 ML/ha irrigation water applied annually
    - 12-14 irrigations per year
    - 0.5 ML/hr flow rate
- Water re-use (irrigation and rainfall) was estimated annually and based on the total amount of water used. An annual rainfall of 450 mm was assumed.
- Dam size was limited to 1 ML for every 10 ha of titled area, in line with the Farm Dams Act (Farm Dams Act 2002).
- The dam was built to the maximum volume for each titled area i.e. if 90 ha were available; a 9 ML dam was constructed. All water re-used from the dam was returned to the paddock using flood irrigation.
- After installing the re-use system, it was assumed that the area collecting runoff on the farm was properly drained so excess water was captured by the re-use dam. Before installing the re-use system, all runoff water was assumed to flow to the lowest point of the farm and into the district drainage supply.
- The percentage of water re-used was assumed to be either 10 or 20% of total water applied. These values are estimated averages across years. Actual runoff will vary with season, time of year and irrigation practice.
- The pasture response per ML was averaged across seasons. It is recognised that responses vary across the season, and that the average will depend on a range of factors.
- Additional pasture consumed at grazing was valued as a substitute for purchased hay. Again, this would be expected to vary between seasons, so the values here have been used as an average across years.
- The value of additional vehicle use (and depreciation) to operate the system was considered minimal and has not been included.
- No additional labour was required to operate the system.
- Irrigation water and rainfall were assumed to be re-used at the same rate, for example, 10% of the water applied (either by rainfall or irrigation) ended up as runoff.
- Insurance costs for the pump, motor and fencing were excluded.

Construction Costs

Construction costs for the re-use system were based on five variables:

- The application and land survey fees
- Construction of the dam
- Installation of the pump
- Installation of the pipes
- Fencing of the system

Total System Installation Cost

Total system installation costs for a 6 ML and 9 ML dam are presented in Table 1. These are two common sizes installed on farms in the MID. If the dam is any smaller, the fixed costs would outweigh the benefits of the system. If the dam is much bigger than 9 ML, it becomes difficult to provide adequate drainage across the farm into the re-use system.

System Operating Cost

Maintenance and operating costs were included as $4/hour and $8/hour respectively of pump operation. The same sized pump was used for all scenarios and thus, maintenance costs varied proportionally with the volume of water re-used. The value of pasture lost as a result of building the re-use dam was estimated using the area expected to be lost from production, current pasture consumption and estimated value of the pasture lost (Table 2).

Benefits from installing a re-use system

The benefits of the re-use system were valued in terms of additional pasture consumed. The value of additional pasture to the farm system was based on the price of local pasture hay ($/t DM). The sensitivity of the analysis to changes in the value and quality of additional pasture consumed was also tested. Initially, pasture hay was valued at $150/t DM, and an average of 1 t DM pasture was consumed for every ML of water re-used. All additional pasture was assumed to be consumed by cows at grazing.

Results

The results for each scenario are presented in Table 3. The decision rule for the analysis was:

- >10% nominal IRR justifies the investment on economic grounds alone. This includes an allowance for paying interest, inflation and a risk premium.
- <10% nominal IRR requires non-economic benefits to justify the investment.

For both the 6 ML and 9 ML sized dams, the performance of the investment increased with the volume of water re-used. For example, scenario 6A (6 ML dam re-using 10%, pasture valued at $150/t DM) was an attractive investment under the initial assumptions, earning a nominal IRR of 12%. However, if the farmer was re-using 20% of water applied, installing a re-use system seemed even more attractive, earning an IRR of 29% for the extra capital invested (Table 3).

Sensitivity analysis

Pasture consumption required to justify the investment (nominal IRR of 10%)

The amount of pasture consumed (t DM) per ML of re-use water required to achieve a nominal IRR of 10% is presented in Table 4. As the value of pasture or the percentage of water re-used increases, the amount of pasture consumed per ML needed to achieve the desired returns, decreases. However, both fodder price and pasture response will vary between seasons. If a run of years of poor seasonal conditions occurred, it may be difficult to achieve a nominal IRR of 10% despite best management practices. However, it is unlikely that a low pasture price would occur consistently with a low re-use rate in the long-run.

Proportion of water re-use required for an IRR of 10%

The performance of an investment in an irrigation re-use system is highly dependent on the amount of water re-used (as a proportion of total irrigation water), the pasture response achieved and the value of the pasture to the farm (Table 5). When both the value of pasture and pasture response rate were low, a greater proportion of water needed to be re-used to produce enough pasture and achieve the desired nominal IRR of 10% (Table 5). Given that these scenarios were simulated under 'best practice' management, the re-used water is equivalent to water that would have previously flowed off the farm into the regional drainage system.

Discussion

Installing a re-use system would be a good investment on an irrigated dairy farm in the Macalister Irrigation District under most circumstances. The performance of the investment depended on three variables: 1) pasture response per megalitre of water re-used; 2) value of pasture per tonne of dry matter; and 3) the volume of water re-used. These variables are linked. For example, as the volume of water re-used increases, the pasture response per megalitre required to justify the investment, decreases. This increase in water re-used spreads the substantial fixed costs of the investment over a greater volume of water, decreasing the required pasture response rate. Situations where installing a re-use system is not a good investment occur when two of the three variables are low. For example, low pasture response and low pasture price.

The analysis also showed that economies of size exist when comparing a 9 ML dam on 90 ha with a 6 ML dam on 60 ha. This was because of the relatively high fixed costs associated with construction of the dam and the relatively low variable cost of pumping re-use water. As construction costs contain a large fixed component ($30,000 for pump, motor and pipes), they are only partly related to dam size, making a 9 ML dam relatively less expensive on a per ML storage basis than the 6 ML dam. This is further compounded by the additional runoff stored and re-used through a 9 ML dam. The greater volume further dilutes the initial construction costs, reducing the savings required to justify the investment. Therefore, re-using 10% of irrigation water was sufficient to justify the investment for a 9 ML dam but, not enough to justify the 6 ML system.

With both the 6 ML and 9 ML sized dams, it was clear that if low water re-use occurred, particularly with a low fodder price, a substantially higher pasture response was required to achieve the same economic returns (Table 5). Seasonal variations would be expected to affect the amount of water re-used and hence, the pasture consumption response.

In the analysis described above, it was assumed that the operator had the management skills to utilise additional pasture and hence reduce the amount of purchased fodder. Had this not been the case, the economic benefits from the re-use system would not be fully realised, and the re-use system may add little value to the farm system. If additional pasture cannot be consumed at grazing, then the cost of consuming the feed may offset some of the benefits of the re-use system. For example, in option 6A (Table 4) where additional pasture is valued at $200/t DM, accounting for conservation and feed out costs of $100/t DM reduces the marginal value of the additional pasture consumed to $100/t DM. Consequently, the pasture response required per ML of water to achieve the desired IRR of 10% increases from 0.7 t DM/ML to 1.4 t DM/ML.

Conclusion

A 10-year partial discounted net cash flow budget analysis has shown that installing an irrigation re-use system for pastures grazed by dairy cows would be an economically attractive capital investment in many situations. Provided the operator can utilise the additional pasture, installing an irrigation re-use system will most likely have a positive impact on farm profit.

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References

Farm Dams Act 2002, Water (Irrigation Farm Dams) Act 2002, State Government of Victoria, http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook.nsf/edfb620cf7503d1aca256da4001b08af/F2BF31C8EAF43D52CA256E5B00213FD4/$FILE/02-005a.pdf (Accessed 30 May 2012).

Malcolm B, Makeham J and Wright V 2005, *The Farming Game – Agricultural Management and Marketing*, 2nd Edition. Cambridge University Press, Melbourne, Australia.

McAinch J 2003, 'Benchmarking production water–use effectiveness on irrigated dairy farms', Department Of Primary Industries, Melbourne, Australia.

Southern Rural Water, 2011, 'Macalister' Accessed: 1 – 4 – 2011 from:

http://www.srw.com.au/page/page.asp?page_id=155#Top (Accessed 30 May 2012).

Appendices:

Appendix 1 – Definitions of economic measures

<u>*Internal rate of return (IRR)*</u> is the discount rate at which the present value of future expected benefits from the project will equal the present value of all the costs of the project. This measure is used to compare different investment options. For this analysis any option able to achieve an IRR of greater than 10% was considered worthwhile, with 10% being the expected return from another investment, such as investment on the stock exchange (i.e. the opportunity cost).

<u>*Years to positive net cash flow*</u> This is a measure of the time taken for the returns from an investment to pay for the investment's purchase. This occurs when the cumulative net cash flow becomes positive. It is not a measure of economic or financial benefit, simply the time taken to remove the debt and regain positive cash flow.

Table 1. Estimated installation costs for an irrigation re-use system

Size of re-use dam	*6 ML*	*9 ML*
Application fees	$ 3,500	$ 4,500
Construction of the dam	$ 42,000	$ 63,000
Installation of the pump	$ 20,000	$ 20,000
Installation of pipes	$ 10,000	$ 10,000
Installation of fencing	$ 900	$ 1,100
Total	$ 76,400	$ 98,600

Table 2. Annual operating cost for each option tested

Size of re-use dam	*6 ML*		*9 ML*	
Option	6A	6B	9A	9B
Water re-use rate (%)	10	20	10	20
Area of pasture lost (m^2)	1,500	1,500	2,250	2,250
Current pasture consumption (t DM/ha)	13	13	13	13
Value of lost pasture ($/year)	$300	$300	$440	$440
Total volume re-used (ML)	63	126	95	189
Pump capacity (ML/hr)	0.5	0.5	0.5	0.5
Annual operating hours	126	252	189	378
Annual operating cost	$1,030	$2,070	$1,560	$3,100
Annual maintenance cost	$500	$1,010	$760	$1,510
Total cost ($/Yr)	$1,830	$3,380	$2,760	$5,050

Table 3. Nominal internal rate of return (IRR) and years to positive net cash flow when installing an irrigation re-use system. It was assumed 1 t DM additional pasture was consumed per ML re-use water, and additional pasture was valued at $150/t DM

Size of re-use dam	*6 ML*		*9 ML*	
Option	6A	6B	9A	9B
Water re-use rate (%)	10	20	10	20
Total capital cost	$76,400	$76,400	$98,600	$98,600
Water re-used (irrigation + rainfall) (ML)	63	126	95	189
Annual net benefit in the steady state ($)	7,620	15,520	11,490	23,300
Years to positive net cash flow	9	4	8	4
Nominal IRR (%)	12	29	15	35

Table 4. The pasture response (t DM/ML) required to achieve a nominal internal rate of return (IRR) of 10% under different systems

	Pasture response (t DM/ML) to achieve a nominal IRR of 10%			
	6 ML dam		9 ML dam	
Option	6A	6B	9A	9B
Water re-use rate (%)	10	20	10	20
Value of pasture – $100/t DM	1.4	0.8	1.2	0.7
Value of pasture – $150/t DM	0.9	0.5	0.8	0.5
Value of pasture – $200/t DM	0.7	0.4	0.6	0.4

Table 5. Percentage of water re-used, as a proportion of total water used, required to achieve a nominal internal rate of return (IRR) of 10% at three pasture values ($/t DM), and different pasture responses (t DM/ML). The percentage of water re-used was based on the volume of water originally applied to the area

Pasture response (t DM/ML)	*Value of pasture ($/t DM)*	*Percentage of water re-used to achieve a nominal IRR of 10%*	
		6 ML dam	*9 ML dam*
0.5	$ 100	42%	35%
	$ 150	23%	19%
	$ 200	15%	13%
1.0	$ 100	15%	13%
	$ 150	9%	8%
	$ 200	7%	5%
1.5	$ 100	9%	8%
	$ 150	6%	5%
	$ 200	4%	4%

Economic analysis of irrigation modernisation connection options for a dairy farm in northern Victoria

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Abstract. Limited availability of irrigation water has placed pressure on farmers and water authorities to improve the efficiency of their operations. 'Modernisation' of irrigation infrastructure systems is occurring throughout Australia in order to improve system delivery efficiency and reduce water losses.

A case study farm was used to examine the economic impacts of investing in a range of on-farm infrastructure connection options to improve irrigation efficiency. The analysis determined the required incentive payment for each connection option along with the impact from additional pasture/saved water/saved labour for a selected option.

None of the irrigation upgrade options analysed were profitable investments for the case study farm business, without the payment of a substantial incentive. The amount of incentive required to ensure the farmer was no 'worse off' varied markedly between the options analysed. The options with low capital expenditure, but higher water losses, appear the most profitable in all water availability scenarios, particularly under low irrigation water availability.

Key Words: dairy, irrigation, water.

Introduction

The dairy industry is Victoria's largest rural industry, with a gross value of raw milk production of around $2.4 billion in 2008-09. In northern Victoria, the industry makes up one-third of the value of Victoria's milk production and generates significant flow on effects through downstream processing into export products, such as milk powder, butter and cheese (Department of Primary Industries 2011). ABARE (2009) estimates this regional economic multiplier effect to be in the order of 2.5 from the dairy industry.

The Victorian dairy industry uses more than half of Victoria's total irrigation allocation primarily to grow pasture as fodder for milk production (Linehan et al. 2004; Qassim et al. 2008). The recent drought conditions faced by irrigators in northern Victoria and southern New South Wales have resulted in a substantial decrease in the availability of irrigation water. Accelerated structural adjustment has taken place in northern Victoria due mainly to drought, low irrigation water allocations and fluctuating milk prices (Dairy Australia 2010).

Limited availability of irrigation water has also placed pressure on water authorities to deliver water more efficiently. Irrigation infrastructure upgrades are currently underway across most states in Australia to improve delivery efficiency and to reduce system losses. Water savings can be recovered through reducing leakage, seepage, evaporation and system inefficiencies by way of reconfiguring, rationalising and modernising irrigation systems. Investments are being made in automating channel regulators, renovating/replacing channels, rationalising obsolete infrastructure and installing more accurate meters. In some cases a shift between the public and private irrigation asset boundary occurs, with the public supply system retracting to larger channels and farmers taking ownership and control of smaller channel infrastructure.

Upgrading irrigation delivery infrastructure is often seen as 'the answer' to address the objectives of improved delivery efficiency for the water authority and improved water efficiency and profitability at the farm level. However, there are several 'conflicts' that can occur when upgrading irrigation infrastructure:

- increasing the sophistication of the delivery system will generally lead to an increased cost per unit of water delivered to the farm;
- transferring channels from the water authority to individual farmers will reduce the volume of water available for irrigation as the delivery losses are also transferred to the farmer; and
- replacing Dethridge wheels with more accurate meters is likely to reduce the volume of water delivered to many farms.

The aim of this project was to analyse the profitability of various irrigation connection options available to a case study farm in northern Victoria. Given these options involve the farmer taking over a section of the delivery infrastructure and the associated water losses, a key focus of the analysis was to determine the required incentive payment for these options to be attractive investments for the case study farm business. The impact of factors such as labour savings, and increased pasture production, that may occur through upgrading the irrigation infrastructure were also analysed.

Method

The approach comprises several key aspects, namely a steering committee, the use of a case study farm and spreadsheet modelling. The incentive required for the case study farm to be no worse off has been examined by imposing different scenarios on the case study farm without changing the current production system.

Steering committee

Considerable inputs were obtained from a steering group comprised of dairy farmers, consultants, a rural counsellor, a water industry representative, an extension officer, economists and scientists. The project steering group met at least every three months and provided overall direction on the systems to be analysed, the issues that needed to be considered and communication of the outcomes from the analysis. This ensured the analyses carried out were subject to rigorous questioning and a broad range of perspectives were considered.

Case study

A case study farm approach was chosen to examine the impact of a range of irrigation connection options. This approach was considered appropriate given the complexity behind the farm business management decision-making process (Malcolm et al. 2005). An in-depth examination of a small number of businesses is generally more beneficial than surveying a large random sample Crosthwaite et al. (1997). The options were developed with support from an irrigation surveyor in conjunction with the case study farmer. A total of four water delivery options were assessed and different scenarios investigated under each option. A fifth option where the area of perennial pasture is moved from one part of the farm to another is also evaluated. The analysis compares each option to the status quo where the farm irrigation network continues to be operated in its current state.

The case study farm is located in the Murray Valley Region of Victoria approximately 40km north of Shepparton on the Murray Valley No. 6 channel. The farm consists of six separate allotments or part allotments, which were originally soldier settler blocks. All allotments have at least one water supply outlet and the farm has a total of 12 outlets. An internal laneway system links each allotment to allow stock movement.

The land available for pasture or feed production is 213 ha (out of a total area of 250 ha) with a high reliability water share of 921 ML and a 640 ML groundwater pumping licence through a spearpoint.

The farm family have worked there since 1979 assuming most of the farm management responsibilities during the late 1980s from the previous generation. The business employs two full time equivalent members of staff, plus a casual employee every second weekend.

The irrigation system is border-check (flood). Three-quarters of the farm has been laser levelled and half is automated (with bay outlets opening and closing automatically). The high level of existing irrigation development and automation reduces the marginal benefits from the different connection options on this farm.

Modelling

<u>*Analysis of current farm performance*</u> The first stage of the analysis involved developing a performance profile of the case study farm. This profile provided a 'starting point' from which to look at marginal changes that would help determine the likely on-farm benefits from infrastructure upgrades. The methods used for farm management economic assessments are described in Malcolm et al. (2005). The three basic financial statements used to develop the business picture or starting point were:

- the profit and loss;
- cash flow; and
- balance sheet.

To get a measure of the overall performance of the farm business, physical and financial data for the 2007/08 season were collected from the case study farm through a personal interview. Due to the unseasonable conditions during that year estimates for the farm under more typical conditions were also made. For instance it would be expected that the amount of bought in feed required in a more normal year would be reduced. To represent a more average situation, total feed costs in the profit and loss were adjusted based on less bought in feed and a lower grain price. Equally milk prices were at record highs during the 2007/08 season and were adjusted to a more typical average price closer to $4.50/kg (milk protein + fat).

<u>*Analysis of options*</u> A partial budget over 20 years with discounted cash flow analysis was used to determine the likely return on investment for the irrigation connection options. The main measure considered was net present value (NPV). This approach is consistent with previous studies that have analysed irrigation technologies such as Armstrong (2007), which looked at the economics of automating flood irrigation on a

case study farm. As the options examined involved the farmer taking over a section of channel and the associated water losses (plus replacing Dethridge wheels with new meters), there will be ongoing losses over the life of the investment. Hence, it was important to determine the incentive payment required in order to 'break-even' at a set discount rate. This is highlighted in Figure 1. In addition, the effects of potential increases in pasture production, reduction in water use, and labour savings were examined for a selected scenario.

A 5% real discount rate was used across the options based on maintaining the existing average return on capital for the farm. For the farmer to be no worse off from the extra investment, the NPV of each option must equal zero at 5%. If the NPV is negative then the farmer will be worse off and requires an incentive.

The irregular nature of the stream of cash flow creates challenges when trying to analyse the investment with the set of standard indicators. This is because each option begins with a positive injection of cash in year zero as a result of an incentive payment, and is followed by a series of costs rather than benefits. Hence, costs that are incurred later in the period are discounted. This is opposite to most investment streams which begin with a payment (negative cash item) and are followed by a stream of positive returns.

The atypical cash flow pattern means the internal rate of return (IRR) was not considered an appropriate economic indicator. This can be explained by the phenomenon that under higher discount rates the NPV of the investment actually increases due to the calculation reducing negative values (costs) as well as positive values (benefits). As the reduction in negative values is larger than the reduction in positive values, the NPV increases and higher discount rates make the NPV value bigger, and lower discount rates make the NPV smaller. The relationship between the discount rate and the NPV is the reverse of what we see with "normal" investments.

The main measure considered in this study was NPV, specifically where it equals zero at a set real discount rate. Commentators generally agree that the NPV gives better guidance than the IRR alone particularly if the investments being considered have different shapes (that is, very different timing of costs and benefits). The higher-IRR-is-better rule can recommend the wrong investment if the cash flow pattern is atypical. The NPV is a better indicator to evaluate an investment over time in this case.

Options analysed

The following options were developed by an irrigation surveyor in conjunction with the case study farmer as part of a reconfiguration proposal. All options involved taking over (or replacing) 1.96 km of channel previously owned by the water authority and replacing Dethridge wheel outlets with electro-magnetic meters. A total of four water delivery options are assessed along with the different scenarios investigated under each option. A fifth option where the area of perennial pasture is moved from one part of the farm to another is also evaluated. The analysis compares each option to the status quo where the farm irrigation delivery infrastructure continues to be operated in its current state.

<u>Option 1</u> The minimum works needed to maintain the status quo production system of the farm. Connecting under option 1 involved taking over 1.96 km of water authority spur channel and piping some sections, reducing the number of outlets from 12 to 4 and replacing the remaining dethridge wheel outlets with high flow electro-magnetic (magflow) meters located on the backbone. Option 1 was assessed under a 43% water allocation (actual 2007/08 allocation in the Murray system) (1A), accounting for losses to spearpoint water (1C), excluding groundwater all together (1D), under an allocation of 100% of high reliability water share (1B) and including taxation (1E).

<u>Option 2</u> A Rob Rye designed pipe and riser system was assessed in Option 2 under a 43% irrigation water allocation (2A). One of the ways to reduce or eliminate water losses due to evaporation and channel leakage is through a pipe and riser irrigation system. The system replaces existing on-farm open channels (authority owned and farm supply) with a network of pipes and risers, which replace existing bay outlets (Figure 2).

<u>Option 3</u> A fully automated AWMA designed pipe and riser system was assessed in Option 3 under both a 43% (3A) and 100% water allocation (3B). Although the technical specifications are very different to the Rob Rye system as it allows for much larger flow rates of up to 20 ML per day, the AWMA system utilises the same base design as the Rob Rye system. However, the labour requirements of the AWMA system are dramatically lower.

<u>Option 4</u> Option 4 is a modification to Option 1, which looks at the impact from lining the on-farm channel with a PVC material to reduce leakage and seepage. Most of the same assumptions apply as Option 1.

However, extra capital costs occur during the construction phase and reduced water losses are assumed.

Option 5 Option 5 is also a modification to Option 1 and investigates the impact from moving the area of perennial pasture away from the existing area on farm 5 to farm 3. This strategy reduces the amount of time water is held in the open channel on the farm by using a pipeline to deliver the water to the perennial pasture and the open channel only to irrigate annual pastures. By doing this, the open channels can be emptied for several months (November – March), and water losses as leakage and seepage should be reduced. This option is assessed under both a 43% (5A) and 100% water allocation (5B).

The options are presented in Table 1 and were approved by the steering committee for the project and are considered a logical mix as they account for varying water allocations and groundwater availability.

Costs and benefits

A range of different cost categories are associated with connecting an irrigator to the modernised system. These are categorised into costs that are borne by the organisation modernising and costs borne by the farmer. Only costs borne by the farmer were included in the partial budget analysis (see Table 2).

Farmer costs include:

- Construction such as the actual installation cost of new channels, pipelines, pumps, land remediation and other structures. They also include survey, design, supervision, fencing and forestry costs.
- On-going costs, such as water losses (leakage, seepage, evaporation and reduced water through more accurate metering), new tariffs, and maintenance of new infrastructure.
- Non-construction costs, such as production downtime during construction.

Reduced water delivered through more accurate metering is a significant ongoing cost to the farmer in the first five years of the analysis period, but is removed from year five onwards when it is expected that all meters off the backbone will be replaced with the more accurate meters regardless of the connection option.

A modernisation connection may also result in a range of benefits to irrigated dairy farmers mainly as a result of higher and more consistent flow rates including:

- on farm water savings,
- pasture production benefits, and
- labour savings associated with automation.

Not all of these benefits apply to every farmer who connects. Many farmers have existing automated bay outlets, high flow rates and laser levelled paddocks.

In paddock water savings (i.e. those beyond the metered outlet) could be expected due to the soil type of the case study farm. However, the savings are likely to be small as the existing farm irrigation infrastructure is already well developed. The farm has an efficient re-use and groundwater pumping system along with laser grading and automation. In addition, the farmer already receives adequate flow rates due to proximity to the backbone supply. However, some water savings will result under certain scenarios that are an improvement rather than replacing like with like. For example, where a pipe and riser system is installed and there is an elimination of losses such as channel leaks and evaporation, where the piped system replaces the existing in paddock channel network. After consultation with the farmer, local water authority and steering committee these savings were estimated at 5% of metered water in a given year for all pipe and riser scenarios assessed (Options 2 and 3).

Water savings amount to between approximately 20–50 ML per annum. These were valued at the price of water available for trade on the temporary market, which was estimated according to the opportunity earning rate (8%) on the average capital value ($2,300) of a ML of high reliability water share in the Murray system at the time of writing, plus the base water authority charge of about $50/ML.

Hence, for an allocation of 100% of high reliability water share the temporary sales water price would be estimated as follows:

- $138 (opportunity cost) / 1 (allocation) + $50 (base G-MW price) = $188 / ML

Faster irrigation may reduce water logging. This in turn may lead to improved pasture quality and/or quantity. The slope and light soil types of the case study farm mean that prolonged water logging is unlikely to have a significant impact on pasture production. This, in addition to the relatively high levels of existing development and constant flow rates, as a result of the farm's proximity to the backbone, means that pasture production benefits have not been included in the initial analysis.

Labour and vehicle use savings are only assumed for two of the options assessed where an AWMA pipe and riser system with remote automation is installed. The benefits amount to between $3,800 - $7,000 per year.

Total system wide water savings are the major benefit from modernisation and are normally distributed between organisations that invest in irrigation upgrades including State and Commonwealth Governments and irrigators themselves. System wide benefits reallocated to irrigator's entitlements are not included in this analysis due to uncertainty around an actual water saving amount and that all irrigators will receive a reallocation regardless of whether their infrastructure is upgraded or not.

Sensitivity testing

The effect of varying on farm water losses on NPV for each option was tested in a sensitivity analysis for the case study farm. The impact on NPV of increasing and decreasing losses by 20% was assessed and visually represented using error bars.

Results and Discussion

Profitability and Incentives

The profitability and required incentive payment for a range of infrastructure investment options were determined. Without any incentive to connect, none of the selected options are profitable, each returning a negative NPV (Figure 3). Each option requires an incentive payment (equal to the negative NPV amount) or significant efficiency improvement (water savings, pasture production) in order for it to be a profitable investment decision for the case study farm. The lower the capital costs and the higher the benefits through efficiency improvements from the different options, the more likely a farmer is to undertake the investment with a smaller incentive. Figure 3 shows the profitability of each option including sensitivity to on farm water losses (the latter is described in the following section).

Option 3A and 3B (AWMA pipe and riser) and Option 2A (Rob Rye pipe and riser) require the largest incentive in order for the farm system to maintain current profit levels. These are the options with lowest irrigation water losses and the largest labour savings, but highest capital expenditure.

The options with low capital expenditure but higher losses appear the most profitable in all water availability scenarios, but particularly under low water availability. Option 5A and Option 1A require the smallest incentive in order to maintain a five% return on capital and therefore remain viable.

Variation in the estimated water losses appears unlikely to change the ranking of the three lowest ranked options. The AWMA pipe and riser system does not appear very sensitive to water availability as losses and labour requirements are minimal to begin with. This system becomes slightly more favourable when compared to the base system (Option 1A) under higher allocations or under a perennial rather than annual pasture system. Most options would change if the farm was a perennial-based pasture system, as there would be more individual irrigations and subsequently labour requirement, and water applied and lost. For example, this would make the difference between Option 2A and 3A greater as there would be additional benefits from labour savings resulting from the increased number of irrigations. Under a perennial system the incentive required for Option 3A would be less.

Water losses associated with operating a new channel can be mitigated by moving perennial pastures to areas of the farm where they can be watered from a pipeline. This reduces the proportion of the irrigation season that the open channel needs to be used thereby reducing seepage and leakage. This was shown in Option 5A, which was the most profitable of the options tested. A mix of water delivery systems, such as open channel and a piped system, may allow for flexibility and additional management options across the farm.

Sensitivity testing – on farm water losses

The least sensitive of the options are 2A, 3A and 4A. Options 2A and 3A are both pipe and riser systems whilst option 4A includes a fully lined channel. These are all options with few water losses to begin with and are profitable under higher water allocations. It is therefore logical that these are the options that are least affected by a change to the existing water losses in each partial budget. On the other hand, the most sensitive to changes in water losses are options 1B, 1C and 1D, where more seepage and leakage will occur when more water flows down the on farm channels (see Figure 3).

Sensitivity to value of labour savings, water savings and pasture production

The economic impact from potential labour savings, improvements in pasture production and water savings were also investigated for Option 5A. If 150 hours of labour savings result from implementing Option 5A, this is equivalent to a present value of $45,000 over the life of the analysis period which effectively reduces the incentive required to $379,000.

Alternatively, if additional water savings of 30 ML per ha are achieved through a more efficient farm irrigation system then the incentive can be reduced by a further $9,000.

An overall increase in pasture production of 0.1 t Dry Matter (DM)/ha has the greatest impact over the life of the project when compared to the benefits of labour and water savings. This assumes additional DM replaces conserved DM valued at a net conserved feed price of $150/t DM (supplementary feed market price of $250/t DM minus conservation cost of $100/t DM). An additional 0.1 t DM/ha resulting from Option 5A is equivalent to a present value of $63,000 over the life of the analysis period. This effectively reduces the incentive required.

It is important to note that all farms will be different. For example farms closer to the main backbone channels may only require meter replacement and therefore are likely to need less of an incentive to connect than a farm that is further from the backbone requiring more significant infrastructure upgrading.

Conclusion

None of the irrigation upgrade options analysed were profitable investments for the case study farm business, without the payment of a substantial incentive. The amount of incentive required to ensure the farmer was no 'worse off' varied markedly between the options analysed.

The options with low capital expenditure, but higher water losses, appear the most profitable in all water availability scenarios, particularly under low water availability. The systems with high capital expenditure and lower water losses, such as the automated pipe and riser, would require a much higher incentive to be attractive, even with high irrigation water availability.

The connection decision is complex and farmers will need to make well informed decisions factoring in future water losses. Benefits from productivity improvements will depend on the degree of existing irrigation development on individual farms. Those farms that are less developed will have more to gain from modernisation, providing the operators have the skills to capture the potential improvements. The method also revealed the importance to farmers of understanding the water cycle on their farms and the value of different water sources. Soil types and the ability to recycle water will be important factors affecting decisions by irrigators. There is also additional complexity related to structural adjustment issues and the investment of large sums of money in irrigation infrastructure that may not be utilised in the future.

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The analysis in this paper is the work of the authors and is not necessarily endorsed by the Department of Primary Industries, nor the State Government of Victoria.

References

ABARE 2009, 'Australian Dairy' 09.1, Australian Bureau of Agricultural and Resource Economics, Canberra.

Armstrong D 2007, *Economic Analysis of Automatic Flood Irrigation for Dairy Farms in Northern Victoria*, Department of Primary Industries, Ellinbank, Victoria.

Crosthwaite J, MacLeod N, Malcolm B 1997, 'Case studies: theory and practice in agricultural economics', presented to the 41st conference of the Australian Agriculture and Resource Economics Society, Jan 22-24 1997, Gold Coast, Queensland.

Dairy Australia 2010, 'Australian dairy industry in focus – 2010', Dairy Australia: Southbank, Victoria http://www.dairyaustralia.com.au/~/media/Documents/Statistics-and-markets/Australian%20Dairy%20Industry%20in%20Focus/2010/Australian%20Dairy%20Industry%20In%20Focus%202010.ashx Accessed 30 May 2012.

Department of Primary Industries 2011, 'Victoria's Dairy Industry – Summer 2011' http://www.dpi.vic.gov.au/agriculture/about-agriculture/publications-resources/industry-profiles-archive/dairy-industry/dairy-industry-profile-summer-2011 Accessed 30 May 2012.

Linehan CL, Armstrong DP, Doyle PT and Johnson F 2004, 'A survey of water use efficiency on irrigated dairy farms in northern Victoria', *Australian Journal of Experimental Agriculture*, 44(2): 131-136.

Malcolm B, Makeham J and Wright V 2005, *The Farming Game – Agricultural Management and Marketing*, 2nd edition, Cambridge University Press, Melbourne, Victoria.

Qassim A, Dunin F and Bethune M 2008, 'Water balance of centre pivot irrigated pasture in northern Victoria, Australia', *Agricultural Water Management*, 95: 566-574.

Appendix

Table 1. Summary of options analysed

	Water Allocations and Groundwater Availability				
	43% **(A)**	**100%** **(B)**	**43%** **+ (spear losses)** **(C)**	**43% excl ground water** **(D)**	**43% + TAX** **(E)**
Option 1 (min works)	1A	1B	1C	1D	1E
Option 2 (pipe & riser)	2A	-	-	-	-
Option 3 (pipe & riser auto)	3A	3B	-	-	-
Option 4 (lined channel)	4A	-	-	-	-
Option 5 (move perennials)	5A	5B	-	-	-

Table 2. Summary of the costs and benefits associated with the various options

	Reduction in water available for irrigation (ML)		Extra operating costs ($'000/year)		Capital Costs ($'000)	Benefits ($/year)
	(Year 1-5)	(Year 6-20)	(Year 1-5)	(Year 6-20)		
Option 1A (min works)	44	22	21	14	321	1,600
Option 1B (min works)	93	43	25	16	335	1,600
Option 1C (min works)	38	16	26	20	321	1,600
Option 1D (min works)	73	34	29	17	321	1,600
Option 2 (pipe & riser)	22	0	34	27	664	4,500
Option 3A (pipe & riser auto)	22	0	20	13	1,040	8,500
Option 3B (pipe & riser auto)	22	0	25	16	1,050	15,400
Option 4 (lined channel)	28	6	16	9	394	1,600
Option 5 (move perennials)	35	13	18	12	321	1,600

Figure 1. Cash flow with required incentive in order for farmer to be no 'worse off'

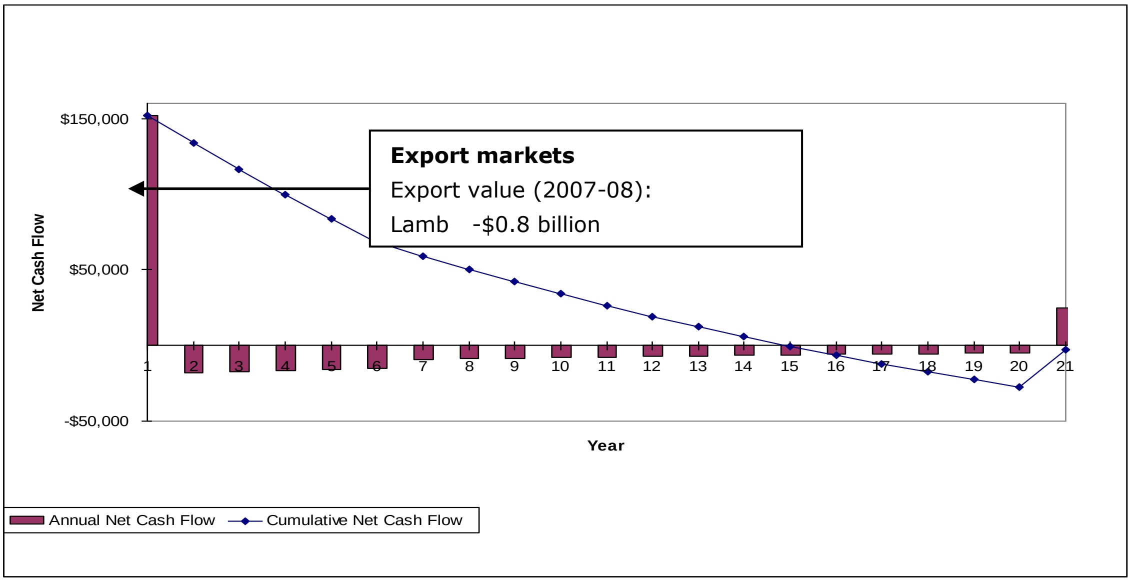
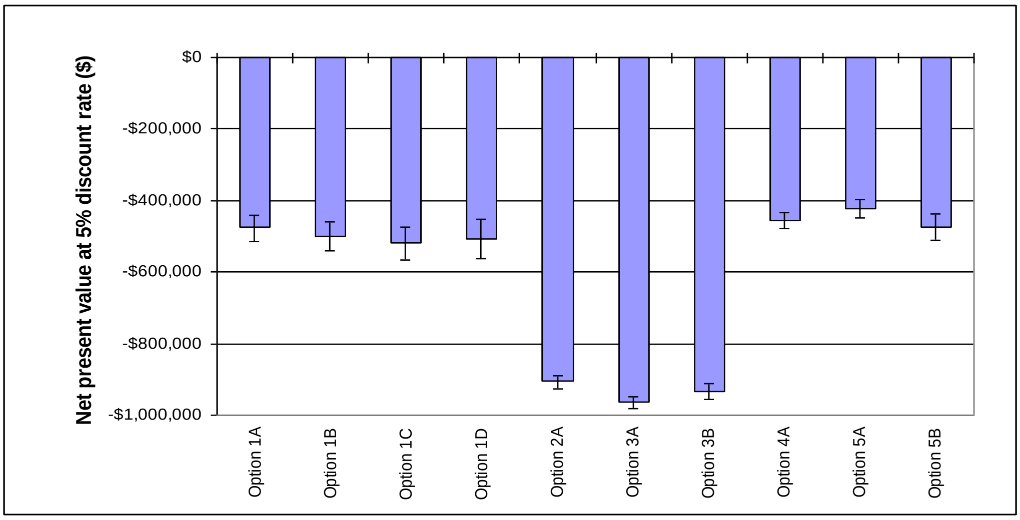


Figure 2. A riser irrigation outlet

Figure 3. NPV and sensitivity to water losses (error bars show the NPV sensitivity when water losses on farm are varied by +/- 20%)



An economic evaluation of automatic cluster removers as a labour saving device for dairy farm businesses

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Abstract. Automatic cluster removers (ACRs) are a popular device used for reducing labour requirements and improving conditions for workers and cows in the milking shed. An economic analysis was conducted on a range of milking sheds and herd sizes to determine whether the costs associated with the installation of ACRs can be justified on the value of the saved labour alone.

The analysis suggested that the technology could be a good investment in many Australian dairies, with a nominal internal rate of return (IRR) of up to 75%. The performance of the investment was dependant on being able to remove labour from the dairy after the installation of the devices. As the potential to make labour savings generally increases with shed and herd size, returns on investment also increased with these two factors.

While the cash labour savings are a major attraction to the adoption of new technologies, there are a number of costs and benefits that are difficult to quantify, but are important when considering an investment. These include herd health, occupational health and safety, worker comfort, and managerial control of the dairy shed.

Keywords: Cost Benefit Analysis, Partial Budget, Dairy Technology, Automatic Cluster Remover

Introduction

The labour associated with dairy farms in Australia is substantial. After feed costs, labour is the next largest expense on most Australian dairy farms, often up to 50% of overhead costs (Gilmour et al. 2010). Attracting and retaining quality labour is also often identified as a significant issue (Gilmour et al. 2010). One major requirement for labour is milk harvesting, which takes more than six hours per day on many dairy farms, and often requires more than one person (Moran 2002). The difficulty attracting and retaining skilled labour for milk harvesting is particularly challenging as the tasks rarely take place during normal business hours. Hence, there has been strong interest in labour saving devices for the milking shed. One such device is the automatic cup (or cluster) remover (ACR).

An ACR is an attachment on the normal milking cluster that measures the flow rate of milk from each cow in the milking shed. When the flow rate falls below a preset level, the ACR switches the vacuum off, and lifts the cluster into position to be reattached to the next animal (Stewart et al. 2002). These devices allow the clusters to be removed automatically without compromising the quality or quantity of milk harvested (Clark et al. 2004).

Automatic cluster removers are a popular labour saving technology in Australian dairies. A survey of Victorian dairy farmers found that almost 30% currently had ACRs, with the majority of those being in double-up herringbone dairies (Watson 2009). Of farmers planning on automating parts of their sheds, ACRs were the most popular first instalment, suggesting that farmers recognise the potential value of the technology.

Despite this apparent popularity, there is little economic analysis on the value of installing the technology. This paper describes an economic analysis of the installation of ACRs into the three most common milking sheds – the double-up herringbone, swing-over herringbone, and the rotary dairy.

Method

The value of installing ACR technology in a range of dairy sheds was tested. Swing-over dairies with 15 and 25 clusters were analysed, milking either 150 or 300 cows. Three double-up dairies, with 16, 28, or 50 clusters were tested. The smaller two sheds were analysed using either 150 or 300 cow herds, while the 50 unit dairy was tested with 300, 500 and 600 cow herds. A 50 unit rotary dairy was analysed using herds of 300, 400 and 600 cows. The labour requirements, time taken to milk, and potential savings for each dairy are listed in Table 1.

A partial budget projecting the discounted net cash flow over a 10 year period was used to analyse all systems. The method used the economic assessment of farm management changes described in Malcolm et al. (2005). This was a modified version of an economic analysis of other labour saving devices by Armstrong and Ho (2009). The nominal internal rate of return (IRR), the years to break even and the net present value (NPV) were used as the key economic measures.

A nominal IRR of greater than 10% was used as the criteria for judging the investment as worthwhile on economic grounds alone. A return of between 5% and 10% would require additional benefits for it to be considered a reasonable investment. Any returns below 5% per year were not considered sufficient to meet the opportunity costs of the expenditure.

It may not be possible to achieve these labour savings on all properties – so the sensitivity of the returns to labour savings was also tested.

Assumptions

The assumptions made in the economic analysis were made with the assistance of scientists and extension officers at DPI Ellinbank. All assumptions have been validated by a steering committee of farmers, consultants, scientists and economists in the Northern Irrigation Region of Victoria. The key assumptions are outlined below.

- Labour was costed at $25/hour
- It was assumed that ACRs would not reduce the time taken to milk, but would reduce the labour requirement during that time.
- Labour requirements and savings were recorded as an annual figure. For example, 1.5 labour units means two labour units were required for half of lactation, and a single labour unit milks for the rest of lactation.
- All cows have a 300 day lactation, and are milked twice per day.
- Milking time is a function of herd size, shed type and shed size.
- ACRs cost $1,700 per cluster, with $15 maintenance cost per cluster per year. Maintenance costs did not change with herd size.
- An automatic teat spray unit was included (at a cost of $6,000 per shed), and used the same chemicals as a hand spray.

Results and Discussion

Swing-over dairy

Automatic cluster removers could be justified by the value of labour saved alone in the 25 cluster shed, at both herd sizes (Table 2). The IRR ranged between 26 and 75%, with a strongly positive NPV. The technology allowed the shed to be run by one person for the majority of the year, saving almost a whole labour unit. The second person would be required only during peak periods.

The investment remained attractive (nominal IRR of 29%) if half of the expected labour savings could be made with the 300 cow herd. Intangible benefits would have to be valued by the operator to justify the investment with lower labour savings and a 150 cow herd (7% nominal IRR).

Similarly, the smaller 15 cluster shed required the larger herd size to justify the investment (nominal IRR of 13%). Labour savings were more difficult to find in this situation, as the shed can generally be milked by one labour unit without automated technology such as ACRs. The investment earned negative returns with both herd sizes when only half the expected labour savings could be achieved. Despite this, the investment may still be of value if other factors, such as worker comfort and fatigue are important.

Rotary dairy

Using the assumptions of this analysis, the installation of ACRs is a good investment in a 50-unit rotary dairy irrespective of herd size (Table 3). The savings were achieved by effectively turning a 'two person' shed into a 'one person' shed for the majority of the year (Table 1).

The return on investment increased with herd size, from an IRR of 20% with 300 cows to 59% with 600 cows. Both scenarios had the same initial set-up and annual repairs and maintenance costs. Milking the larger herd would take over two hours longer per day compared with milking the smaller herd. As labour savings were based on an hourly rate, a longer milking time would always result in higher cash savings, further diluting the cost of the investment, and increasing returns.

The sensitivity of the results to labour savings was tested (Table 3). Only the largest herd size tested (600 cows) continued to justify the investment on economic grounds alone when labour savings were halved, earning a nominal IRR of 21%. A nominal IRR of 9% when milking 400 cows was close to justifying the investment, and would probably require only minor intangible benefits for ACR installation to be worthwhile.

If a labour unit could only be removed from the milking shed for half the year, then the IRR dropped to a point where the investment could no longer be justified when milking 300 cows (IRR of 3%). Non-economic benefits would be required to justify automation when milking 600 cows (IRR of 9%).

Double-up dairy

The 8 cluster per side dairy was assumed to be operated with one labour unit for the majority of the year, allowing for few labour savings through automation. The other extreme was the 50 unit 'double-up', with 25 clusters per side, where a whole labour unit could be removed from the shed by installing ACRs.

The investment of ACRs appeared attractive in the majority of scenarios analysed (Table 4). The only option that did not justify automation on labour savings alone was the 16 unit dairy with the smaller herd size. The longer milking time of 300 cows was required to generate sufficient labour savings to offset the cost of the investment.

In the larger dairies (28 and 50 clusters), the installation of ACRs could be justified for all herd sizes analysed, as their installation meant that a labour unit could be removed from the milking shed for at least half the year. This would be a substantial cash and management saving to a dairy business.

Herd size became a more important determinant when only half the expected labour savings were achieved (Table 4). Installation of ACRs in a 28 unit dairy may be worthwhile when milking 300 cows, but not a smaller herd size. To justify the 50 unit double-up, milking more than 400 cows was required to justify on labour savings alone. With a 300 cow herd, intangible benefits of value to the owner-operator may be sufficient to justify the investment with half of the expected labour savings. It was not possible to generate sufficient cash savings with the 16 unit double-up dairy.

Intangible costs and benefits

Herd health *The effect of ACRs on herd health is debatable, and depends heavily on shed design and quality of staff. Automatic cluster removers do have the potential to reduce mastitis associated with over-milking, by stopping the vacuum when milk flow falls (Klindworth* et al*, 2003). There is a wide variety of ACR systems available, from the basic to the technologically advanced. For example, some ACR systems can detect flow per quarter, and shut down the vacuum one teat at a time – eliminating over-milking in a given quarter. When combined with electronic ID, the more advanced ACRs compare milk yield with yield for the same cow at previous milkings. An alert is raised if there is a substantial difference, for example, if the cups have been kicked off, leaving a cow only partially milked. It is important, when selecting an ACR system, to understand the costs and benefits of each of these options to find a system to best meet the needs of the farm in question.*

The important concern regarding herd health is more acute in rotary dairies. By removing the person at 'cups-off', the opportunity to detect inflamed or damaged teats is removed, making the early detection of mastitis more difficult. Picking up these diseases and problems early can be invaluable in maintaining a healthy herd and a low bulk milk cell count. In a herringbone shed, there is the opportunity to glance over the udders before cows are released, potentially identifying damage early. Some more advanced ACRs contain technology to identify and alert the milker to the symptoms of mastitis. However, these are significantly more expensive than the ones used in this analysis.

The change from manual to automatic teat spraying may also have an effect on herd health, depending on the way teats are currently treated after milking, and the efficacy of the automatic teat spray unit chosen.

In his 1984 survey of Western Australian dairy farmers, Olney found no significant difference in the somatic cell counts of farms before and after the installation of automatic cluster removers.

Increase managerial control of milking shed This is a point of real value for farm managers who regularly use relief milkers, or have trouble finding reliable staff. By using ACRs, a manager can ensure that cows are not over or under milked. By altering the cut-off point for the ACRs, the manager is able to find the optimal balance between time spent milking and the residual volume of milk in the udder. Once this level is set, the manager knows that the cows will be milked to the same level at every milking, irrespective of the staff member employed. Olney (1984) found that over half made greater use of relief milkers after the installation of the technology. For single calving herds, the ACR cut-off level can be altered to match stage of lactation.

The flow meters are inclined to drift over time in ACRs. It is recommended that the recorded and the vat milk volume are compared regularly. If there is a large difference, then the ACRs might require recalibration.

Improve worker comfort (lifestyle) Automation can make the task of milking easier, by removing some of the more laborious tasks, such as cup removal. In turn, labour can be better streamlined and tasks completed less strenuously. Klindworth (2003) recommends ACRs as a technology to reduce the stress or pressure placed on workers during milking. Automation can also allow an owner or manager to allocate more time to other aspects of the business.

It is noted that ACRs will do little to improve working conditions for employees if the shed is poorly designed or maintained.

Occupational health and safety (OH&S) During a typical milking in a non-automated shed, one labour unit often lifts and moves an accumulated weight of over 1 tonne. This is a significant OH&S issue that can be almost halved through the installation of ACRs

(Cowtime, 2006). Depending on the placement of the cups after removal, bending, reaching, and lifting can be minimised. This is of significant benefit to staff in terms of enhanced comfort and reduced fatigue. The farmers interviewed by Olney (1984) reported that making milking easier was just as important as saving labour.

On the other hand, there are some OH&S concerns when converting a shed to a single labour unit set up. If there is only one labour unit, then injuries may go unnoticed or unreported, or, if the injury is serious, there is no one present to render assistance.

Flexibility and risk management While ACRs can be used to reduce labour requirements, they can also be used to improve the productivity and flexibility of the available workforce. If an employee is ill, it is possible for the shed to be managed by a reduced number of people. It also allows managers to gear operations to the tasks that must be completed. When the milking shed is busy, such as during calving or as heifers are introduced, it can be geared up with more labour units. When milking is less busy, then staff can be assigned to other tasks around the farm.

Conclusion

Installing ACRs is an attractive investment for a number of herd sizes and shed designs and sizes (cluster numbers), if the labour savings used in this analysis can be achieved. However, the economic performance is very sensitive to labour savings. When only half of the potential labour savings can be achieved, attractive returns from investing in ACRs are limited to the larger herd sizes and respective shed sizes.

Whilst this is an economic analysis, on-farm decisions are often also based on a range of factors that are difficult to quantify. Technology such as ACRs may be installed in sheds where they might not provide a high return on the capital, but where they provide some other benefits in the management of staff, herd health, or lifestyle. These reasons may be as persuasive as the economics, and so should be analysed and considered on an individual basis.

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References

Armstrong D, Ho C 2009, 'Economic impact of switching to 'Once-A-Day' milking on a dairy farm in Northern Victoria', Australian Farm Business Management Network Journal, 6(1): 55-62.

Clark T, Cuthbertson E, Greenhall R, Hannah M, Jongman E, Shoesmith D 2004, 'Milking regimes to shorten milking duration', *Journal of Dairy Research,* 71: 419-426.

Cowtime 2006, *Automatic Cluster Removers (ACRs),* Cowtime Quicknote 5.2*,* National Milk Harvesting Centre, Department of Primary Industries, Ellinbank, Australia.

Gilmour D, Ryan M, Swann C, Shambrook D 2010, '*Dairy Industry Farm Monitor Project: Annual Report 2009/10'*, Victorian Department of Primary Industries and Dairy Australia, Melbourne, Australia.

Klindworth D, Greenall R, Campbell J (2003), *'Cowtime guidelines for milk harvesting'* Dairy Research and Development Corporation, Melbourne, Australia.

Malcolm B, Makeham J, Wright V 2005, *The Farming Game: Agricultural Management and Marketing,* Edn 2, Cambridge University Press, Melbourne, Australia.

Moran J 2002, 'Managing dairy farm costs: strategies for dairy farmers in irrigated Northern Victoria', Department of Natural Resources and Environment, Melbourne.

Olney G 1984, 'Automatic cluster removers in Western Australian dairies', *The Australian Journal of Dairy Technology*, 39(1): 49-50

Stewart S, Godden P, Rapnicki P, Reid D, Johnson A, Eicker S 2002, 'Effects of automatic cluster remover settings on average milking duration, milk flow, and milk yield', *Journal of Dairy Science,* 85: 818–823.

Watson P 2009, *CowTime Tracking Survey 2009*, Report completed for the Department of Primary Industries, Down to Earth Research, Frankston South, Australia.

Appendix

Table 1. Dairy size, efficiency and labour requirement by shed-type

	Swing-over		Double-up		Rotary	
Cluster Number	15	25	16	28	50	50
Cows/Cluster/Hour	7	7	5	5	5	6
Installation Cost	$31,500	$48,500	$33,200	$53,600	$91,000	$91,000
Annual Maintenance (per year)	$150	$250	$160	$280	$500	$500
Labour to Milk before ACRs (FTE)	1.1	2	1.1	2	3	2.5
Labour to Milk with ACRs (FTE)	1	1.25	1	1.5	2	1.5

Table 2. Labour savings and economic returns from ACR installation in a 'swing-over' dairy, with sensitivity to labour savings

'Swing-over'	Full potential labour savings				Half potential labour savings			
Cluster number	15	15	25	25	15	15	25	25
Herd size (cows)	150	300	150	300	150	300	150	300
Milking time (Hours)	1.5	3.0	0.9	1.8	1.5	3.0	0.9	1.8
Labour savings ($,thousands/year)	2.2	4.5	10.1	20.2	1.1	2.2	5.4	10.7
Years to break even *	>10	7	4	2	>10	>10	9	4
Net Present Value+ ($,thousands)	-16	0.0	24	96	-22	-13	-5	38
Nominal Internal Rate of Return (%)	-1	13	26	75	-9	-1	7	29

* Before Interest, +At 10% discount rate

Table 3. Labour savings and economic returns from ACR installation in a 'rotary' dairy, with sensitivity to labour savings

'Rotary'	Full potential labour savings			Half potential labour savings		
Cluster number	50	50	50	50	50	50
Herd size (cows)	300	400	600	300	400	600
Milking time (Hours)	1.1	1.5	2.2	1.1	1.5	2.2
Labour savings ($,thousands/year)	16.4	21.8	32.7	8.2	10.9	16.3
Years to break even *	5	4	2	10	8	5
Net Present Value+ ($,thousands)	26	64	144	-34	-3	41
Nominal Internal Rate of Return (%)	20	32	59	3	9	21

* Before Interest, +At 10% discount rate

Table 4. Labour savings and economic returns from ACR installation in a 'double-up' dairy

‘Double-up’	Full potential labour savings						
Cluster number	16	16	28	28	50	50	50
Herd size (cows)	150	300	150	300	300	400	600
Milking time (Hours)	1.9	3.9	1.1	2.2	1.3	1.7	2.5
Labour savings ($,thousands/year)	2.9	5.9	8.4	16.7	18.7	25.0	37.5
Years to break even *	>10	5	6	3	5	3	2
Net Present Value^{+} ($,thousands)	-12	9	6	67	43	88	179
Nominal Internal Rate of Return (%)	3	20	16	48	25	39	73

* Before Interest, $^{+}$At 10% discount rate

The roles of trust and commitment in the Australian Lamb Retailers/Wholesalers

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Abstract. The red meat sector is vital to Australian agriculture. It is a large contributor to the value of agricultural production and exports and also accounts for a significant proportion of rural and regional employment. Developments in the red meat sector also affect other industries, both upstream and downstream.

A supply chain management survey of the Australian lamb industry was conducted by distributing a mail questionnaire to lamb retailers and wholesalers. The objective was to establish a model explaining the supply chain performance indicator responsiveness of lamb retailers/wholesalers in terms of the trust and commitment. Multiple regression analysis was performed. Australian lamb retailers' antecedent cooperative behaviours (independent variables) were regressed on supply chain performance indicator responsiveness (dependent variable).

The result of this research confirmed that trust and commitment are positively correlated with lamb retailers' responsiveness. Trust and commitment are a crucial part of any long-term relationships or alliance in agribusiness firms.

Keywords: trust, commitment, lamb, supply chain management.

Introduction

Australia is among the world's largest producers of lamb, with 412,536 tonnes (carcass weight) produced in 2009-10, with a gross value of sheepmeat of around $2.9 billion. In 2009-10, around 45% of lamb produced in Australia was exported.

Australia is also a large exporter of live animals, particularly out of northern and western Australia. The value of total sheepmeat exports in 2009-10 was $932 million. The distribution of sheep within Australia provides a strong indication of the regional importance of the industry. The majority of Australia's 76.9 million sheep (as at June 2008) are located in New South Wales (34%), Western Australia (23%) and Victoria (22%).

Australia is second only to New Zealand as an exporter of sheepmeat. Although New Zealand has remained dominant, the proportion of world exports coming from Australia increased from 25% to 31% over the 10 years to 2006.

Consumption of lamb has also fallen over the same period from 15 kilograms to 10 kilograms a person. For lamb, less than 15% was exported in 1988-89, but by 2007-08 this had increased to 45%. This greater dependence on export markets means the Australian red meat industry is increasingly influenced by global factors.

The lamb sector in Australia is undergoing rapid change because of various changes that have led to improved meat quality. In this type of business environment, advanced supply chain systems have been observed to have dramatic impact (Finch 2006). Hence the research reported focused on analysing antecedent cooperative behaviour and measuring supply chain performance indicators of Australian lamb retailers/wholesalers.

The next section of the paper considers the relevant structure of the wholesaling and retailing sectors of the lamb supply chain. Some key components of the literature are then reviewed, and this leads to the development of a conceptual framework. The conceptual framework suggested various methods, and a model was then constructed to illuminate the most important aspects of the supply chain. Based on the modelling work, suggested improvements for the industry are presented and analysed.

Combining knowledge of the rapid changes taking place in the lamb industry with the supply chain management literature (de Ruyter et al. 2001; Morgan and Hunt 1994) led to the following question that the quantitative analysis sheds light on:

How do trust and commitment in trading partners affect supply chain practice and supply chain performance of Australian lamb producers?

Structure of Australian Lamb Retailers/Wholesalers

The domestic market is an important sector for the Australian lamb industry. The domestic processed lamb market utilised 34% of lamb (or 719,000 tonnes) in 2005. Of this around 68% by weight (or 488,920 tonnes) is sold through the supermarket and retail butcher outlets. Around 27% of lamb (or 194,130 tonnes) used domestically is sold through food services. The remaining 5% (or 35,950 tonnes) is marketed to the processing sector to be further transformed into other food products.

Supermarket and retail butcher outlets

The average number of weekly serves of lamb purchased at supermarkets and retail butcher outlets in 2005/06 was 25.6 million. Red meat had a 55% share of total fresh meat purchases at supermarkets and retail butcher outlets.

Woolworths is the largest lamb retailer in Australia (around 32% share of lamb purchased in 2005). Then, this is followed by retail butcher outlets (around 28%); Coles (around 19%); other supermarkets such as IGA, BILO and Franklins (around 17.5%); and other markets/deli (around 3.5%). Australia had more than 3,800 retail butcher outlets in 2007.

Coles, Woolworths and IGA supermarkets are described in the next section.

Woolworths Group Limited

The first store (the Woolworths Stupendous Bargain Basement, Sydney) was established in December 1924. Between 1930s and 1940s, Woolworths established 31 stores in Australia and 9 in New Zealand. Then during the 1960s and 1970s Woolworths pioneered the supply of a wide range of low price, quality merchandise to rural Australia - especially to remote areas such as Alice Springs and Darwin. During the 1980s, Woolworths became established as the "Fresh Food People" - with a commitment to deliver quality fresh food to their customers. In 1985, Woolworths acquired Australian Safeway. Woolworths had now become the market leader in grocery sales, serving up to 10 million customers per week. In just two years, profit rose from $8 million to $136 million. In 1993, the $2,450 million Woolworths' share float was the biggest in Australia's history. The 1,000 million shares on offer were quickly snapped up by more than 33,000 investors, many of them everyday Australians - including 19,000 Woolworths' employees (Woolworths 2012).

Now, the Woolworths Group operates over 3,000 stores throughout Australia and New Zealand. It has more than 180,000 staff, serving over 13 million customers Australia-wide, every week. There are over 750 supermarkets throughout Australia and New Zealand (Woolworths 2012).

Despite the size of Woolworths' supermarket operation, it has paid meticulous attention to its individual supply chains. This has reached the point of significant vertical contracts with lamb producers. It what has enabled Woolworths to announce recently that in NSW consumers can purchase Meat Standards Australia graded lamb. The research project reported here examined how far trust and commitment were instrumental in enabling this type of improvement.

Coles Limited

In 1914, George Coles (founder) established the first Coles Variety store in Collingwood, Melbourne after he travelled to the US to learn best practices in retailing in the early 1900s. In 1960, the first supermarket was opened in North Balwyn, Victoria. By 1973, Coles grew rapidly by establishing a supermarket in every Australian capital city.

Coles is a part of the Coles Group Limited - Australia's largest retailing group and one of the top 25 retailers in the world. Coles Group Limited has over 2,500 retail outlets throughout Australia. There are 741 supermarkets (Wesfarmers Limited 2012). Moreover, Coles Group Limited employs more than 180,000 workers (or 92,000 employees in the supermarkets) and serves more than 4.5 million customers every week (Coles 2012).

In order to provide the best quality lamb, Coles established a group of dedicated graziers (the name is "Colestock") in 1998. More than 75% of Coles meat is supplied by Colestock producers. Currently, there are more than 1,000 Colestock graziers in Australia growing prime quality meat for Coles. They are located across South Australia, Victoria, Tasmania, New South Wales and Queensland. Like Woolworths, Coles is paying attention to how to manage its lamb supply chains to deliver consistent meat quality to its customers. Again, we examine how trust and commitment have enabled this type of development.

IGA (Independent Grocers of Australia)

In 1988, IGA was brought to Australia by Davids Holdings when 10 stores initially became members of IGA. Currently, there are over 1,000 IGA stores in Australia (over 250 stores in NSW/ACT, over 200 stores in QLD, over 350 stores in Victoria and over 200 stores in Western Australia) (IGA 2007). Based on size, range and customer profile, IGA Distribution consists of three channels. The first channel is Supa IGA. This is a large format store (full and large supermarket range). The store primarily provides all of the grocery and fresh food in one location. The second channel is IGA. This is a medium format store (mid-sized supermarket range). The last channel is IGA X-press. This is a small format store which attracts a convenience market with a concentration on high service. This only accommodates grocery products. Hence less emphasis seems to be placed overall by IGA on meat quality, but they still deliver lamb to customers, and they can't be ignored in our survey.

Literature Review

Antecedent cooperative behaviour

Mutual trust and long-term commitment are components of successful partnerships among supply chain partners (Mirani et al. 2001). It is clear that no real collaboration can exist in supply chain relationships without meaningful trust and commitment.

Trust

There are several definitions of trust in supply chain relationships:

- Trust is a general expectancy that the word of an individual or organisation can be relied on (Rotter 1967).
- Trust is the willingness to rely on a trading partner in whom one has confidence (Morgan and Hunt 1994). Confidence in supply chain relationships requires consistency, competency, honesty, fairness, responsibility, accountability, predictability and dependability (Lamming 1996; Moorman et al. 1992).
- Trust is the degree to which partners perceive each other as credible and benevolent (Doney and Cannon 1997; Kumar et al. 1995) and is expected to have a positive effect on the degree of collaboration in supply-chain relationships.
- Trust is "the belief that a party's word or promise is reliable and that a party will fulfil his/her obligations in an exchange relationship" (Schurr and Ozanne 1985, p.12).
- Trust is "the degree to which the channel member perceives that its relationship with the supplier is based upon mutual trust and thus is willing to accept short-term dislocation because it is confident that such dislocation will balance out in the long-run" (Anderson et al. 1987, p.6).
- Trust is "one party's belief that its needs will be fulfilled in the future by actions undertaken by the other party" (Anderson & Weitz 1989, p.33).
- Trust is "the firm's belief that another company will perform actions that will result in positive outcomes for the firm, as well as not take unexpected actions that would result in negative outcomes for the firm" (Anderson and Narus 1990, p.3).

Based on the definitions above, there are various ways to build trust in relationships between lamb producers and processors or processors and lamb retailers. Trading partners should demonstrate reliability in their operations, consistently performing as promised and meeting expectations. In addition, trading partners need to fully and accurately share all information for the effective functioning of relationships.

Commitment

Commitment is characterised by long-term relationships which can be defined as the willingness of each partner to exert effort on behalf of the relationship (Lee and Kim 1999; Tomkins 2000). Commitment and trust are the dimensions of a business relationship that determine the degree to which each party feels they can rely on the integrity of the promise offered by the other.

Methods

A conceptual framework

There are two elements of this conceptual framework. First, trust and commitment are the two antecedents of cooperative behaviour (de Ruyter et al. 2001; Morgan and Hunt 1994) which influence supply chain performance indicators.

The second component is the selection of an appropriate performance indicator for the lamb supply chain. A number of indicators, including responsiveness, flexibility, and efficiency, were tested to discover the process by which trust and commitment influence lamb supply chain performance. It was discovered that responsiveness had the strongest relationship linking trust and commitment to competitive advantage.

It seems appropriate to use responsiveness (Aramyan et al. 2006; Gunasekaran et al. 2004; Li et al. 2002; Li 2002) for this purpose, given that what Woolworths and Coles have achieved in recent years is agility in supplying their customers with the lamb quality that they are demanding. It is essential to measure and evaluate the supply chain performance of the Australian lamb industry, particularly because of the complexity and multiple echelons of the businesses involved.

In the process of studying the particularities of this industry, the research forged a new understanding of the major difficulties for implementation of supply chain management in the Australian lamb industry context, and highlighted the types of issues that influence supply chain performance. This investigation led to the hypothesis:

A relationship exists between a performance indicator (which turned out to be responsiveness) and at least one of the explanatory variables – trust and/or commitment.

A supply chain management survey of the Australian lamb industry was conducted by distributing a mail questionnaire to lamb retailers and wholesalers. The survey asked participants in the industry to express their views on various aspects of the supply chain, with a focus on the antecedent cooperative behaviour discussed above. The objective was to establish a model explaining the supply chain performance indicators of lamb retailers/wholesalers in terms of the antecedent cooperative behaviour involving trust and commitment.

Results

The effective response rate to the survey was 16%. Cronbach's alpha (Cronbach 1951) was used to test internal consistency, and values of 0.60-0.87 were obtained. While 0.70 or above is desirable (Hair 2006), 0.50-0.60 is considered sufficient (Nunnally 1978). The majority of items in the survey were based on established scales that have already been subjected to tests of content validity (Aramyan et al. 2006). In addition, the pre-test confirmed that a group of industry experts viewed the scales used as acceptable.

Discriminant and convergent validity were assessed by using factor analysis (see Table 2). Again the results fell within the acceptable range. Finally, stepwise multiple regression analysis was performed. Australian lamb retailers' antecedent cooperative behaviours (independent variables) were separately regressed on the various supply chain performance indicators. These separate regression equations were compared, and the strongest and preferred relationship was selected, and is shown in equation 1, in which Resp is responsiveness, α and βs are constants, e_i is the disturbance term, and t–statistics are shown in parentheses.

$$Resp = \alpha + \beta 1 * Trust + \beta 2 * Commitment + e_i$$

$$\begin{aligned} Resp = 4.406 + {} & \underset{(2.172)}{0.421} * Trust \; + \\ & \underset{(5.095)}{0.669} * Commitment + e_i \qquad (1) \end{aligned}$$

Adjusted R^2 : 0.512

Discussion

The result of this research confirmed that trust and commitment are strongly related to lamb retailers' responsiveness. They are far stronger explanatory variables than any other the alternatives considered. Given that the regression results summarise the survey data, they indicate that those supply chain participants who completed the survey regard trust and commitment as being critical to ensuring the delivery of high quality lamb to customers.

Trust and commitment are a part for any long-term relationship. In terms of alliances in the Australian lamb supply chain, there are two categories:

1. Horizontal alliances are between functions at the same level in the lamb supply chains. Horizontal alliances are suitable for smaller agribusinesses, for example among smaller lamb retailers or wholesalers.
2. Vertical alliances are between functions and several groups at different levels in the lamb value chain. For example, between lamb retailers and processors.

Several researchers thought that trust as a multidimensional term, cannot be predicted by a single item or psychological construct (Deutsch 1960; Barber 1983; Lewicki et al. 1998). Definition of trust in this research context is retailers' confidence in the other relationship member's reliability, truthfulness and stability, and the belief that their actions are in the best interest of and will have positive outcomes for the trusting party. Trust is a key success factor in the aligned Australian lamb industry, which is engendered by information sharing and openness (Peterson et al. 2000).

Two dimensions of trust which are 'competence trust' and 'goodwill trust' (Nooteboom et al. 1997, Das and Teng 2001) seem to be relevant in the context of trust between retailers and processors or final consumers. Competence trust in this research study is the expectation of the capability and know-how of the trustee to meet their promise, agreement and/or obligation (Mayer et al. 1995). Goodwill trust can be classified into three dimensions which are responsibility (Barber 1983), dependability (Rempel et al. 1985) and integrity (Mayer et al. 1995). Goodwill is defined as the expectation of the other's moral obligations and responsibility in social relationships to demonstrate a special concern for others' interests above their own (Barber 1983, Ring and Van de Ven 1992).

Many studies have confirmed the importance of trust and commitment as an essential in the formation of relationships and partnerships (Blois 1999; Das and Teng 2001; Crotts et al. 2001; Lewis 2000). Several benefits of trust exist between retailers and other relationship members:

1. Mutual trust (Bowersox et al. 2000; Chu and Fang 2006) can stimulate increased cooperation between retailers and other relationship members. In this, they may learn that cooperation or joint efforts can cause outcomes that exceed those achieved individually. For example, the retailers need to provide relevant

information about the requirements of final customers such as high quality, taste, etc. to the processors during the transaction processes. If retailers cannot provide the information to other relationship members or there is no confidence in the information provided it may create conflict, as well as an ineffective communication channel, then it can hinder the trust-building process.

2. Peppers and Rogers (2004, p.43) confirmed that "trust encourages relationship members to work to maintain the relationship and to oppose the temptation to take short-term gains and/or act opportunistically. Trust of a seller firm is positively related to the likelihood that the buyer will engage in future business, therefore contributing to increasing the duration of the relationship. "The existence of trust allows, disputes or conflicts to be resolved in an efficient and amicable way. In the absence of trust, disputes are perceived as signals of future difficulties and usually bring about relationship termination".

Peppers and Rogers (2004) confirmed that trust is clearly useful and essential to those seeking to build a relationship between retailers and other parties. However, to build that relationship is not easy and it needs a concerted effort. The following factors are the main contributors to formation of trust (Peppers and Rogers 2004; Rix 2006):

1. Shared values, for example to strive to have fresh lamb in the stores that is of high quality and fulfils the food safety regulations and meets the requirement of the Australian meat standard (MSA), are fundamental to building mutual trust and commitment between retailers and other trading partners. Peppers and Rogers (2004) added that the extent to which trading partners in a relationship share beliefs and values, such as vision or goals, mission, policies and behaviour, will influence the ability to build mutual trust.
2. Quality communication and contact strategy is needed for parties to build trust in one another. Retailers should have an open, frequent formal or informal communication strategy. This will provide advance warnings of problems (Rix 2006). For example warnings about delay, backorder or product contamination problems should be given. Peppers and Rogers (2004) added that another main contributor to build trust and commitment is communication which needs to be frequent and high quality in terms of being accurate, valuable, relevant, timely, up-to-date and reliable. For example, retailers need to communicate with processors regularly and accurately about carcases weight requirement, muscle, fat, slaughter date, batch number, ear tag number, reference number, carcase serial number, health status information, time of delivery, ordering policies, and quality assurance information.
3. Other practical approaches to build trust and commitment are regular food services or supermarket visits, being flexible to these retailers' needs, keeping promises, social activities and special events for the customers. For example, what we have learnt from a working partnership between Coles and Australian Country Choice is the Australian Country Choice has regular visits to the Coles or BILO supermarkets to know what are the requirements and market situation in the supermarkets. In addition, they have social activities and special programs for the customers, for example Easter and Christmas events, etc. With this, Coles and BILO supermarkets are trying to maintain their relationships with their customers and hence they might exceed customers' requirements.
4. Retailers need to have involvement at all levels of management, including top management, when they build trust and commitment. In other words, trust and commitment have a greater chance of success when all management are actively supporting them.

Trust and commitment exist when lamb consumers are able to forecast accurately the retailers' future behaviour based on the information given. For example, at Coles, Woolworth, Franklins and BILO supermarkets price specials must really be specials and not just a step to higher future prices. Trust and commitment can be damaged by a single negative event (Slovic 1993). The customers' trust will be diminished if the supermarkets provide the wrong information about the price. For example, if the catalogue in the supermarket says the price of minced lamb per kg is $5.99 then the actual price label in the supermarket must be $5.99.

Quality of care for consumers and community exists if there is full commitment from retailers or supermarkets to customers, community and the environment. The main effort for retailers or wholesalers to build trust and commitment is to listen to customers and their concerns. For example, Woolworths has more than 720 stores across Australia and serves more than 13 million customers every week. It attempts to be fully committed by having the objectives: The best price, the freshest food ("For two decades we have promised our customers that we are the Fresh Food People and we are constantly working to source the best fruit and veg, 97% of which comes from Australian farms."), the friendliest service, healthy living, support of community groups (Woolworths 2012).

To create honesty and fairness, the retailers should operate consistently and honestly by reassuring the provision of high quality, clean, safe lamb products.

Conclusions

A supply chain management survey of the Australian lamb industry was conducted by distributing a mail questionnaire to lamb retailers and wholesalers. The objective was to establish a model explaining the supply chain performance indicators of lamb retailers and wholesalers in terms of antecedent cooperative behaviour.

The result of this research confirmed that trust and commitment have a strong positive correlation with lamb retailers' responsiveness. Trust and commitment are a crucial part of any long-term relationships or alliance in agribusiness firms.

References

Anderson J C and J A Narus 1990, 'A Model of distributor-firm and manufacture-firm working partnership', *Journal of Marketing Research*, 54: 42-58.

Anderson E and Weitz B 1989, 'Determinants of industrial continuity in conventional channel dyads', *Marketing Science*, 8(4): 310-323.

Anderson E, Lodish LM and Weitz BA 1987, 'Resource allocation behavior in conventional channels', *Journal of Marketing Research*, 24(February): 85-97.

Aramyan L., C. Ondersteijn C, van Kooten O and Lansink AO 2006, 'Performance indicators in agri-Food production chains', in CJM Ondersteijn, JHM Winjands, RBM Huirne and O. Van Kooten (eds.), *Quantifying the agri-food supply chain*, Springer, Netherlands,47-64.

Australian Bureau of Statistics 2008, Livestock and meat, Australia electronic publication, Sep 2008 (and previous issues), cat no. 7218.0.55.001 URL: http://www.abs.gov.au/ausstats/abs@.nsf/ProductsbyReleaseDate/B7E8721AFEEA3BC7CA2575130012A215?OpenDocument Accessed 21 June 2012.

Barber B 1983, *The logic and limit of trust*, Rutgers University Press, New Brunswick, NJ.

Blois K. 1999, 'Trust in business to business relationships: an evaluation of its status', *Journal of Management Studies*, 36(2): 197-215.

Bowersox DJ, Closs DJ and Stank TP 2000, 'Ten mega-trends that will revolutionize supply chain logistics', *Journal of Business Logistics Focus*, 21(2): 1-16.

Chu S-Y and Fang W-C 2006, 'Exploring the Relationships of Trust and Commitment in Supply Chain Management', *The Journal of American Academy of Business*, 9(1): 224-228.

Coles 2012, All about Coles, http://www.coles.com.au/About-Coles/Company.aspx Accessed 21 June 2012.

Cronbach L 1951, 'Coefficient alpha and the internal structure of tests', *Psychometrica*, 16: 297-334.

Crotts J, Coppage C and Andibo A 2001, 'Trust-commitment model of buyer-supplier relationships', *Journal of Hospitality & Tourism Research*, 25(2): 195-208.

Das K and Teng B 2001, 'Trust, control, and risk in strategic alliances: an integrated framework', Organization Studies 22(2): 251-283.

de Ruyter K, Moorman L and Lemmink J 2001, 'Antecedents of commitment and trust in customer-supplier relationships in high technology markets', *Industrial Marketing Management*, 30(Yang): 16.

Department of Agriculture, Fisheries and Forestry 2011, "Red Meat Export Statistics." http://www.daff.gov.au/agriculture-food/meat-wool-dairy/quota/red-meat/statistics2011 Accessed 21 June 2012

Deutsch M. 1960, 'The effect of motivational orientation upon trust and suspicion' *Human Relations*, 13: 123-139.

Doney PM and JP Cannon 1997, 'An examination of the nature of trust in buyer-seller relationships.' Journal of Marketing Research 61(2): 35-51.

Fletcher, S., Buetre, B and Morey, K (2009). The value of the red meat industry to Australia. Canberra, ABARE

Finch BJ 2006, Operations Now: Profitability, Processes, Performance, McGraw-Hill, New York.

Gunasekaran A, Patel C and McGaughey RE 2004, 'A framework for supply chain performance measurement', *International Journal of Production Economics*, 87: 333-347.

Hair JF 2006, *Marketing Research*, McGraw-Hill, New York.

IGA 2007, Independent Grocers of Australia URL: www.iga.net.au/igafresh/index.cfm?page_id=2298 Accessed 21 June 2012.

Kumar N, Scheer LK and Steenkamp J-EEM 1995, The effects of perceived interdependence on dealer attitudes', *Journal of Marketing Research*, 32: 348-356.

Lamming RC 1996, 'Squaring lean supply with supply chain management', *International Journal of Operations and Production Management*, 16: 183-196.

Lee J and Kim Y 1999, 'Effect of partnership quality on IS outsourcing: conceptual framework and empirical validation', *Journal of Management Information Systems*, 15(4): 26-61.

Lewicki RJ, D. McAllister and Bies RJ 1998, 'Trust and distrust: new relationships and realities', *Academy of Management Review*, 23(3): 438-458.

Lewis J 2000, *Trusted partners*, Simon & Schuster Inc. Washington, DC.

Li SH 2002, *An integrated model for supply chain management practice, performance and competitive advantage*, Doctoral Dissertation, University of Toledo.

Li S, Rao S, Ragu-Nathan TS and Ragu-Nathan B 2002, An empirical investigation of supply chain management practices, Proceedings of the 33rd Annual Meeting of the Decision Science Institute 2002, San Diego, CA.

Mayer R, Davis J and Schoorman FD 1995, 'An integrative model of organisational trust', *Academy of Management Review*, 20: 709-734.

Mirani R, Moore D and Weber JA 2001, 'Emerging technologies for enhancing supplier-reseller partnerships', *Industrial Marketing Management*, 30: 101-114.

Moorman C, Zultman G and Deshpande R 1992, 'Relationship between providers and users of market research', *Journal of Marketing Research*, 29: 314-328.

Morgan, RM and SD Hunt 1994, 'The commitment-trust theory of relationship marketing', *Journal of Marketing Research*, 58: 20-38.

Nooteboom B, Berger H and Noorderhaven NG 1997, 'Effects of trust and governance on relational risk', *Academy of Management Journal*, 40(2): 308-338.

Nunnally J 1978, *Psychometric Theory*, McGraw-Hill, New York.

Peppers D and Rogers M 2004, *Managing customer relationships*, John Wiley & Sons, Inc., Hoboken.

Peterson J, Cornwell F and Pearson CJ 2000, Chain Stocktake of some Australian Agricultural and Fishing Industries, Department of Agriculture Fisheries & Forestry – Australia, Canberra.

Rempel JK Holmes JG and Zanna MP 1985, 'Trust in close relationships', *Journal of Personality and Social Psychology*, 49(1): 95-112.

Ring PS and Van de Ven AH 1992, 'Structuring cooperative relationship between organisations', *Strategic Management Journal*, 13: 483-498.

Rix P. 2006, *Selling managing customer relationships*, Mc Graw Hill, North Ryde, NSW.

Rotter JB 1967, 'A new scale for the measurement of interpersonal trust', *Journal of Personality*, 35: 651-665.

Schurr PH and JL Ozanne 1985 'Influences on exchange processes: buyers' preconceptions of a seller's trustworthiness and bargaining toughness', *Journal of Consumer Research*, 11(4): 939-953.

Slovic P 1993, 'Perceived risk, trust and democracy', *Risk Analysis*, 13(6): 675-682.

Tompkins J 2000 'Beyond supply chain management', *Supply Chain Management Review*, (March/April): 77-82.

Wesfarmers Limited 2012, 'Coles' http://edit.wesfarmers.com.au/our-businesses/coles.html#coles Accessed 21 June 2012.

Woolworths (2012), Our Story. http://www.woolworths.com.au/wps/wcm/connect/Website/Woolworths/About+Us/Our-Story/ Accessed 21 June 2012.

Appendix

Table 1. Australian lamb/live sheep exports – by volume

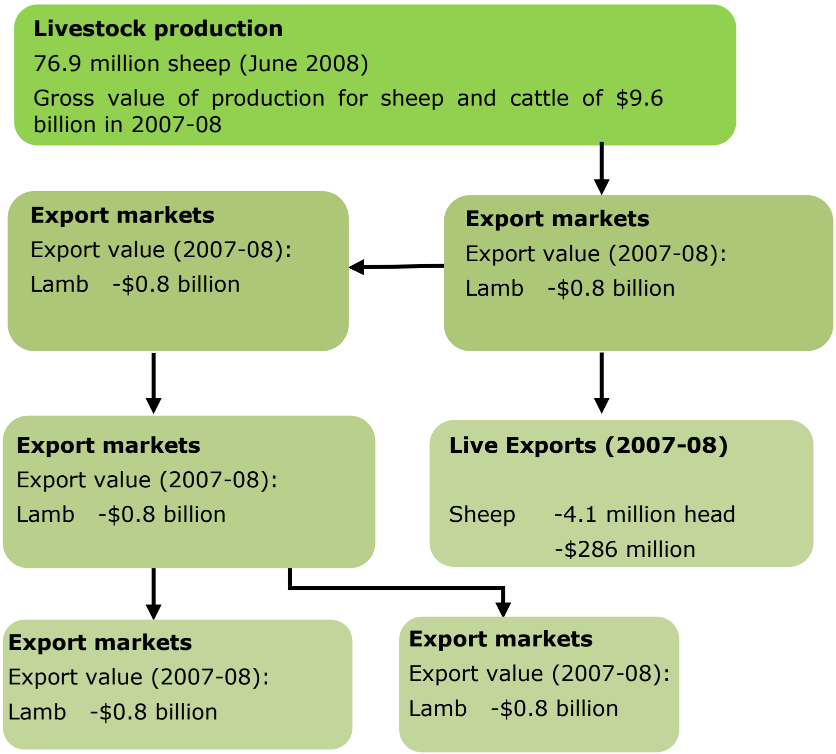
Products	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008
Lamb (kt)	99	115	109	98	112	123	143	150	163
Live sheep (‘000)	4,859	5,936	6,443	5,843	3,843	3,233	4,248	4,138	4,069

Source: Australian Bureau of Statistics 2008; DAFF 2011

Table 2. Factor Analysis

Elements	Components established	Factor Loading	Item deleted
Antecedent cooperative of behaviour	2 components	0.566	No items deleted
Supply chain performance	2 components	0.672	No items deleted

Figure 1. Australian red meat value chain framework



Source: (Fletcher et al. 2009)

Area response in wheat production: The Australian wheat-sheep zone: Comment

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Abstract. This paper points out some difficulties in the econometric estimation of the original paper and suggests procedures for overcoming these.

Keywords: lagged dependent variables, trending, small-sample bias.

Introduction

Rarely does an editor of a journal have the opportunity and the obligation to write in response to an article published in their journal. That is probably because events almost never conspire to throw-up the circumstances that have occurred in the current instance.

Relative to his peers, Culas (2011) is worthy of publication. The paper succeeds in highlighting the issues surrounding area response in Australian wheat production. It achieves its results using standard econometric methods. So what is the issue that is being raised in this comment? It is that there are some question marks surrounding these standard methods. In a nutshell, the issue is that where there are lagged dependent variables the estimation of the other dependent variables can be affected. While the particular circumstances of the Culas (2011) paper may mean that there might be little bias in the estimation, it is considered worthwhile to make clear the fundamental estimation issues because others may try to employ his methods in circumstances where they are not applicable. Hence, an important objective in this comment is to reveal the circumstances under which the methods are applicable.

The partial adjustment model

Culas (2011) employs a partial adjustment model of the general form:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 X_t + u_t \qquad (1)$$

He then applies ordinary least squares to the estimation. This is satisfactory as long as the error term (u_t) is well behaved, or white noise (Ramanathan, 2002) (in particular, the u_t are independently and identically distributed with zero mean and constant variance, σ^2), and the sample size is large enough (say greater than 30). This raises the first problem with Culas (2011), which is that the sample size seems to be 15 (i.e. annual data from 1991 to 2004), and we may expect some small-sample bias in the results, even without any of the autocorrelation issues discussed below.

The next situation to consider is where there is autocorrelated disturbances. Because u_t depends on u_{t-1}, Y_{t-1} (the lagged dependent variable) is correlated with u_t and applying OLS estimation will produce biased and inconsistent estimates. In addition, the usual tests for autocorrelation will be inapplicable. Ramanathan (2002, pp. 449-450) outlines an alternative estimation technique for overcoming these problems.

The relevant question for us is: are the disturbances in the Culas (2011) estimation likely to be autocorrelated? The paper itself does not provide enough direct evidence to make the judgement. Close examination of the results of the estimation reveals that, in the different versions of the model, the coefficient value of the lagged dependent variable range from 0.965 and 0.999 (Culas 2011, p. 47). That is, it is close to one, and this raises the possibility that the lagged dependent variable is squashing the effects of the other variables as observed by Achen (2001, p.14):

> *"In the presence of heavy trending in the exogenous variables and disturbances, lagged dependent variables will dominate the regression and destroy the effect of other variables whether they have any true causal power or not"* (original emphasis).

Hence, the issue about estimation problems devolves to whether the exogenous variables are heavily trending. The two variables to consider are the price ratio between wheat and wool, and the year. It would be expected that the price ratio is trending because of the secular increase in wheat prices and decline in wool prices over the study period. The year variable is by definition a trending variable. Hence, the Culas (2011) study seems to contain the circumstances outlined in the previous paragraph that Achen warns us to guard against.

Conclusion

The practical implications of this analysis are first, we should attempt to obtain a data set with more than 30 observations in order to reduce the problem of small-sample bias. Second, where there is a lagged dependent variable with heavy trending in the other exogenous variables, the model should be estimated using techniques applicable to the situation of lagged dependent variables and autocorrelation (Ramanathan 2002).

References

Achen CH 2001, 'Why lagged dependent variables can suppress the explanatory power of the dependent variables', paper presented at the American Political Science Association meeting, UCLA, July 2000.

Culas RJ 2011, 'Area response in wheat production: The Australian wheat-sheep zone'*, Australian Farm Business Management Journa*l, 8(1):43-49.

Ramanthan R 2002*, Introductory Econometrics with Applications,* 5th edition, South-Western, Mason, Ohio.

Area response in wheat production: The Australian wheat-sheep zone: Reply

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Abstract: This paper is my reply to the comment (Parton, 2012) on my original paper (Culas, 2011). The issues pointed out in the comment are the circumstances under which the econometric method that I employed is applicable. My reply suggests the econometric techniques that could be more appropriate in various circumstances.

Introduction

I take it as a privilege to receive a comment on my paper from the editor of this journal (Parton, 2012). I welcome the opportunity to further explain the methods I employed in Culas (2011).

The issues concerned are worthy of examination in order to obtain appropriate estimating procedures for econometric models. Parton raises some fundamental issues about employing estimation methods in circumstances where they are not applicable. This is mainly related to *"where there are lagged dependent variables the estimation of the other dependent variables can be affected" (*Parton, 2012, p.57)*.*

The other related issue is the presence of heavy trending in the exogenous variables and disturbances: *"are the disturbances in the Culas (2011) estimation likely to be autocorrelated? The paper itself does not provide enough direct evidence to make the judgement"* (Parton, 2012, p.57).

My reply to the issues is as follows:

Testing autocorrelation in the presence of lagged dependent variables

In the original paper, I considered a partial adjustment model of the general form:

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 X_t + u_t \qquad (1)$$

In which the dependent variable Y_t is a function of itself lagged one period and other exogenous variables X_t. This model was estimated as an AR1 regression by the Prais-Winston method to account for first-order autocorrelation:

$$u_t = \rho u_{t-1} + e_t \qquad (2)$$

An explanation for autocorrelation in the model is that the factors omitted from the time-series regression are correlated across periods. This may be due to serial correlation in factors that should be in the regression model. "*Failing to account for autocorrelation when it is present is almost surely worse than accounting for it when it is not"* (Greene, 1993, p. 424).

As I analysed a relatively small sample (1991-2004), the Prais-Winston method was favoured over the Cochrane-Orcutt method. The Cochrane-Orcutt method is more appropriate for estimating models with lagged dependent variables. However, as this procedure involves omitting the first observation in the dareta, a larger sample size is required (usually, over 30 degrees of freedom (d.f.)).

While there was no evidence of autocorrelation in the estimated model according to the Durbin-Watson Statistics (and also from the statically insignificant autocorrelation coefficients), provided the sample size is large enough (usually, over 30 d.f.), it is preferred that the Durbin *h-test* or Breush-Godfrey test should be used for testing for autocorrelation when a lagged dependent variable is present in the model (Greene, 1993, p. 428). Unfortunately, my sample size was not this large so I could not reach a definite conclusion about autocorrelation.

Estimating models with lagged dependent variables and presence of trending in the exogenous variables

The model was estimated with exogenous variables that are trending, such as the expected relative price between wheat and wool and the time-trend. It is a valid concern that when there is heavy trending in the exogenous variables and disturbances, the lagged dependent variable may dominate the regression and destroy the effect of other variables, whether they have true causal power or not (Achan, 2001). This means the lagged variables can artificially dominate the regression whether it has a great deal of explanatory power or not.

In fact, the model has been tested for different specifications as Regression 1, Regression 2, Regression 3 and Regression 4

(Culas, 2011, p. 47). In Regression 4, one of the exogenous variables (time-trend) was omitted. Leaving this out made little difference to the estimation of the coefficient on lagged dependent variable, which remained close to one (i.e., between 0.95 and 0.99) in all the regressions. Taken at face value this means that the area of wheat grown in the past predicts the future area very well.

The abovementioned results suggest that the presence of trending in the relative price does not invalidate the model. Hence, the estimates are valid, even though the model was estimated by the Prais-Wiston method that involves a GLS procedure. If the sample size had been larger, it would have been preferable to use the Cochrane-Orcutt procedure to minimize the effect of the lagged dependent variable in the regressions (Ramanathan, 2002, p. 450).

Conclusion

Parton (2012) has raised a valid point. This reply hopefully clears up the estimation methods that I followed in Culas (2011), considers the issues raised in Parton (2012) and provides some suggestions on the econometric methods that may be more applicable in the presence of autocorrelation, lagged dependent variables, and smaller sample size.

References

Achan CH 2001, 'Why lagged dependent variables can suppress the explanatory power of the dependent variables', paper presented at the American Political Science Association meeting, UCLA, July 2000.

Culas RJ 2011, 'Area response in wheat production: The Australian wheat-sheep zone', *Australian Farm Business Management Journal*, 8(1):43-49.

Greene WH 1993, *Econometric analysis*, Second edition, Prentice Hall, Inc. New Jersey.

Parton KA 2012, 'Area response in wheat production: The Australian wheat-sheep zone: Comment', *Australian Farm Business Management Journal*, 9(1): 57-58.

Ramanathan R 2002*, Introductory Econometrics with Applications,* 5th edition, South-Western, Mason, Ohio.