AFBM Journal
Agricultural Business Management and Farming Systems
volume 9
number 2
year 2012

ISSN 1449-5937 (Printed version)
ISSN 1449-7875 (Online version)

© Copyright Charles Sturt University

Contents

page

i  Contents
ii  Editorial Board
iii Foreword
iv  The character of AFBM Journal
iv  Instructions to authors

1  RA Villano, EM Fleming and PAA Fleming
   Variations in regional productivity in Australian wool production

13 Michael J Robertson, David J Pannell and Morteza Chalak
   Whole-farm models: a review of recent approaches

27 Alexandria Sinnett, William Dalton, Kristen M Pitt and Mark O Downey
   Economic analysis of early ripening system for table grapes

37 C Lewis, B Malcolm, R Farquharson, B Leury, R Behrendt and S Clark
   Economic analysis of improved perennial pasture systems

57 GJ Slaughter and S Mulo
   Strategies for investment in the Australian macadamia industry: Development and evaluation of an objective investment appraisal software model
Editorial Board

Chief Editor: Kevin A Parton, PhD, Professor
kparton@csu.edu.au

Scientific Editors:
Animal Systems & Technology  Sue Hatcher, PhD
sue.hatcher@agric.nsw.gov.au

Ecological Agriculture  Aaron Simmons, PhD
asimmons@csu.edu.au

Farm Economics  Bill Malcolm, PhD, Assoc. Professor
b.malcolm@unimelb.edu.au

Global Perspectives of Agriculture  Zhangyue Zhou, PhD, Assoc. Professor
zhangyue.zhou@jcu.edu.au

Management & Decision-Making  Roy Murray-Prior, PhD
r.murray-prior@curtin.edu.au

Social Issues of Farming  Judith Crockett, PhD
jcrockett@csu.edu.au

Sustainable Farming Systems  David R. Kemp, PhD, Professor
dkemp@csu.edu.au

Panel of Referees: Each scientific editor has an independent panel of
discipline-related referees who remain anonymous to
ensure a process of objective reviewing of the papers.
Foreword

In this issue of the *Australian Farm Business Management Journal*, there are a series of five articles that cover various aspects of farming as a business, and research related to the analysis of farm businesses. In the first paper, Villano et al. produce some clear evidence of the efficiency and adaptability to the environment of Australian wool production. They also examine the impact of advice from consultants.

The second paper (Robertson et al.) is a critical review of recent studies of whole farm modelling. The authors develop a typology of approaches and explain the strengths and weaknesses of each approach. Most of the models reviewed were specific to the context, and few were of general relevance. An important outcome of the review is to produce a set of guidelines for development of whole farm models. This will overcome problems such as lack of validation and poor documentation.

The final three papers analyse various aspects of innovations on farms. The first of these considers a trellis system to overcome some of the vagaries of the weather related to table grape production. It shows that there are worthwhile returns from this investment as long as there are premium prices for the fruit produced.

Next, Lewis et al. assess the investment in new perennial pasture systems in south west Victoria. This was shown to have good returns at various stocking rates. The analysis shows the impact of seasonal variability and failure to establish the pasture. Risk and return from the investment increased as stocking rate increased. The results may be of interest for producers across the high rainfall zone of eastern Australia.

The final paper is an appraisal of a whole farm financial model for macadamia farming, the *Financial Planner for Macadamia*. An important reason for presenting this model is that there are currently few tools available that are directly available to the industry. It uses a whole farm approach, has the ability to compare investments in the macadamia industry and applies sensitivity analysis. It passes a number of the critical tests suggested by Roberson et al. in the second paper in this issue.

The editorial team that put together this issue of the *Journal* is Kevin Parton, Donna Read and Kerry Madden.

Professor Kevin A Parton  
Charles Sturt University  
December 2012
The character of *AFBM Journal*

*AFBM Journal* is registered publication of the Australasian Farm Business Management Network (i.e. AFBMNetwork) and published by Charles Sturt University, Orange Campus, Faculty of Agriculture and Wine Sciences.

AFBMNetwork is a professional organisation supported by Charles Sturt University – Faculty of Science, Curtin University – Muresk Institute; Massey University – College of Sciences; The University of Melbourne – Institute of Land and Food Resources and Marcus Oldham College. Members from these organisations and the AFBMNetwork membership are the primary users of the *AFBM Journal*. However, independent and other organisational professionals are encouraged to publish in the *AFBM Journal*.

AFBMNetwork vision and mission statements actively encourage the design of farming systems matched to the environmental, social, economic and marketing conditions of Australasia. It promotes quality education, research, consultancy and extension to service the primary sector and its organisations. The *AFBM Journal* will therefore publish quality papers related to the areas of Animal Systems and Technology; Cropping Systems and Technology; Ecological Agriculture; Farm Economics; Global Perspectives of Agriculture; Business Management and Decision-Making; Social Issues of Farming and Sustainable Farming Systems.

The Department of Education Science and Training of the Commonwealth of Australia – Higher Education Research Data Collection (DEST-HERDC) defines that *the essential characteristics of a research publication* are as follows:

- substantial scholarly activity, as evidenced by discussion of the relevant literature, an awareness of the history and antecedents of work described, and provided in a format which allows a reader to trace sources of the work through citations, footnotes, etc
- originality (i.e. not a compilation of existing works)
- veracity/validity through a peer validation process or by satisfying the commercial publisher or gallery processes
- increasing the stock of knowledge

*AFBM Journal* support the above principles and while encouraging the publication of research results, useful to the professional farming related community, will undertake a stringent process of peer reviewing to ensure the quality of the papers published in the different issues of the Journal.

*AFBM Journal* is published online with free access for AFBMNetwork members and a wider audience. Subscription to two printed issues has a cost of A$100 and can be processed contacting the Chief Editor. Educational and research organisations pursuing a copy of *AFBM Journal* for library purposes should request it at kparton@csu.edu.au

Disclaimer: The views and opinions contained in the papers published in the *AFBM Journal* are those of the authors and do not necessarily reflect the views of AFBMNetwork or any of its supporting organisations.

Instructions to authors

Instructions for intending authors of papers to be submitted to the *AFBM Journal* can be downloaded from AFBMNetwork webpage. Papers must be submitted online to the following email address: kparton@csu.edu.au. Further enquiries must be addressed toward the same email address to the Chief Editor of the Journal, Professor Kevin A Parton.
Variations in regional productivity in Australian wool production

RA Villano, EM Fleming and PAA Fleming
School of Business, Economics and Public Policy, University of New England, Armidale, NSW, 2351
Email: efleming@une.edu.au

Abstract. We estimate total factor productivity in wool production spatially across benchmarked farms in four climatic areas in Eastern Australia. Estimates are decomposed into an environment-technology gap and technical efficiency relative to the production possibilities in each area. The environment-technology gap reflects the regional differences in the environment and variations in production technologies used in the wool enterprise. Significant gaps are found to exist between areas but they are relatively small in magnitude, emphasising the adaptability of the wool enterprise to environmental variability. Technical inefficiencies are also present in all areas but are larger among farmers who do not regularly receive consultancy advice in the benchmarking group. There is little variation in mean total factor productivity between the climatic areas.

Keywords: wool, efficiency, environmental-adaptability, consultancy.

Introduction
For most agricultural enterprises, a significant productivity gap would be expected to exist between producers operating in different agroclimatic areas of Australia. In this study we assess whether such a gap exists for wool production, which is arguably less sensitive to environmental conditions than many other forms of agricultural production. There has been a long history of successful adaptation to varied regional conditions that has taken place in the industry over the past two centuries.

The physical conditions have historically favoured wool production in wide areas of rural Australia given exogenous factors such as soil, climate, vegetation, location, pests and diseases (Williams 1973). In the early period of European settlement, the wool enterprise was well suited to managing the risks associated with agricultural production and marketing, saving scarce labour resources and avoiding the need for large amounts of capital expenditure. Limited labour supply and high land-labour ratios encouraged industries that did not rely on intensive labour use. Labour-saving production methods suited to a pastoral activity such as wool production were fostered rather than the more intensive activities found on small European-style farms that characterised farming systems in the early years of European settlement. The storability and high value-weight ratio of wool made it especially suitable as an export product in remote areas.

The production environment nevertheless varies considerably for wool producers in Australia as a function of spatial and temporal changes in natural resources, infrastructure, markets and institutions. Rainfall is often considered the major factor placing different limitations on production possibilities in agricultural production between regions. Other natural resource factors are also important, notably other climatic factors, soils, vegetation and topography. All of these factors may influence both the amount of wool produced and its quality.

The main factors influencing the volume of wool produced are the amount and quality of feed available, which vary spatially according to rainfall, temperature, humidity, frosts, soils, availability and palatability of pasture species, and pests among other factors (Bell 2006; Lewer 2006). Diseases such as blowflystrike, body lice, helminthiasis and bacterial diseases (Walkden-Brown and Besier 2006) also influence the condition of sheep and the amount of wool they produce, as well as its quality (and therefore prices that producers receive). Other major influences on wool quality are fibre diameter and staple length and strength (Yamin et al. 1999), and fleece rot and vegetable matter. All factors vary spatially. For example, vegetable matter tends to be a greater problem in mixed farming and pastoral areas (Fleet and Langford 2006), though chenopod shrublands found in large...
tracts of pastoral areas have a low grass seed burden (Lewer 2006). Fleece rot is more common in higher rainfall areas (Mortimer 2006). Disease risk factors include environmental variables such as temperature, rainfall, quantity and quality of pasture, toxicity and air quality (Walkden-Brown and Besier 2006). The natural environment for wool production also affects technology choice. Wool producers have long been adapting their production and marketing technologies to suit their operational environment as a result of experimentation, testing, and trial and error (DAFF 2001; Australian Government 2008). It means that the natural environment now exerts a less dominant influence on wool production because the various adaptations and innovations occurring in the industry have enabled wool producers to achieve greater control over their production process.

The question nevertheless remains whether wool producers are able to adjust their production technologies fully to the environment to bridge the productivity gap between a producer operating in a favourable agroclimatic system and one operating in a more difficult one. The often extreme difficulties imposed by adverse and diverse conditions for production may mean that no amount of adaptation has been sufficient to bridge this gap, and some processes may have actually widened the gap where environmental damage has occurred in a more challenging environment and easy productivity gains are made in a more favourable one. Furthermore, some factors work in opposite directions in influencing the value of a wool clip. For example, a reduction in fibre diameter can lead to a decrease in staple strength (Greef 2006).

In light of the prominence accorded to rainfall in influencing agricultural production, we assess the presence of differences in productivity between wool producers between four climatic areas in New South Wales and Victoria based on broad differences in rainfall regimes. We achieve this aim by measuring productivity, which is decomposed into the environment-technology gaps caused by spatial differences in the environment in which the wool is grown and technical inefficiency within these areas.

Study regions
The sheep production environment chosen for analysis covers most of New South Wales and parts of Victoria. It is divided into four climatic areas based on rainfall patterns:

- Northern New South Wales (CA1)
- South-Western New South Wales (CA2)
- Central and South-Eastern New South Wales (including a small part of North-Eastern Victoria) (CA3)
- South-Western Victoria (CA4).

CA1 comprises one Australian Sheep Region and part of another defined by Hassall and Associates Pty Ltd (2006) that are both predominantly self-replacing Merino sheep production systems operating in a summer rainfall climate. The regions are the elevated Armidale High Rainfall Sheep Region, which comprises mostly productive temperate pastures, and the flat to undulating New South Wales portion of the Northern Wheat/Sheep Region, which has lower rainfall, hotter temperatures and a greater emphasis on cropping. Soils, topography and climatic conditions vary across space in the area as a whole, and productivity potential is therefore diverse as demonstrated by DAFF (2001) and Walcott and Zuo (2003).

CA2 is part of the Central Pastoral Sheep Region (Hassall and Associates Pty Ltd 2006) in Western New South Wales, experiencing low winter rainfall. DAFF (2001) and Walcott and Zuo (2003) classify this region as having low to very low productivity potential for agricultural pursuits. Arid zone soils, native pastures and self-replacing Merino sheep production systems predominate (although the region is home to the highest proportion of wether-based enterprises). Rainfall tends to be extremely variable over time and across space, and lamb survival rates are low (Hassall and Associates Pty Ltd 2006).

CA3 comprises parts of two Australian Sheep Regions in New South Wales: the Eastern Wheat/Sheep Region and the Eastern High Rainfall Sheep Region (Hassall and Associates Pty Ltd 2006). It has evenly spread winter rainfall. The Eastern Wheat/Sheep Region has a wide range of annual pastures and winter and summer crops produced on both irrigated
and dryland farms (Hassall and Associates Pty Ltd 2006). In the Eastern High Rainfall Sheep Region, pastures are mainly productive temperate pasture species. Both regions have a greater preponderance of sheepmeat enterprises than the first two climatic areas. According to DAFF (2001) and Walcott and Zuo (2003), this region has consistently high productivity potential with pockets of very high potential.

CA4 corresponds to the region termed the Southern High Rainfall Region by Hassall and Associates Pty Ltd (2006), and has winter rainfall dominance. Pastures are typically improved, and grazing enterprises commonly comprise both wool and sheepmeat self-replacing production systems (Hassall and Associates Pty Ltd 2006). Environmental conditions tend to be favourable for wool production, indicated by the high to very high productivity potential accorded to it by DAFF (2001) and Walcott and Zuo (2003).

Conditions in CA1 make it difficult for average producers to bridge the productivity gap between themselves and the best-practice farmers on a regular basis. The physical features of CA2 are also likely to make it difficult for the best producers in this region regularly to bridge the productivity gap between themselves and the best producers in more favourable regions. Furthermore a substantial performance gap may exist between producers with and without access to irrigation facilities. On the other hand, the more favourable conditions for agricultural production in CA3 should make it easier for sheep producers to operate at consistently high levels of technical performance. Wool producers in CA4 should also find it relatively easy to operate at a high performance level. But because some producers do not pay for and receive regular consultancy advice technical efficiency is likely to be variable within regions.

Alternative classifications could have been chosen, such as an east-west orientation based on annual rainfall amounts. But we were constrained by the arrangement of the available data. In any event, our categories reflect to some extent variations in annual rainfall patterns.

**Adaptations to the wool production environment**

Evidence from studies of the Australian wool industry outlined below suggest that significant differences exist in production possibilities between wool-producing regions. The historical development of wool production and innovations within the wool industry appear to have enabled it to adapt to various production environments. The forms of adaptation and innovation to modify the environment are many and varied.

**Innovations in sheep breeding**

Variation in performance between sheep occurs as a result of their genes and the environment in which they are located. The main initial innovation in the wool industry was the introduction of Merino sheep on which the industry is still largely based. Even in the harsher environments, wool production still flourishes because of the suitability of Merinos to Australian production conditions, especially in areas with a hot arid climate. Merino sheep have proved adaptable to Australian production conditions chiefly because they ‘apply an impressive array of behavioural adaptations to their herbivorous mode of life’ (Colditz and Dart 2009, p. 2). Taylor (2006) provided a chronology of Merino breeding and genetics research in Australia from 1930 to 2000, which demonstrates that genetic improvements and selection of Merino sheep breeds and sires have long been a feature of research activities and management strategies to suit particular environments. They are exemplified by genetic selection for resistance to roundworms, blowfly resistance, dermatophilosis and fleece rot (Mortimer 2006), fleece weight and diameter (Taylor 2006), staple strength and style (Greef 2006) and body weight (Hinch 2006). An example of how genetic advances can help modify environmental impact is breeding for larger-framed Merinos that are better adapted to semi-arid rangelands (Lewer 2006), typified by the challenging conditions prevalent in CA2.

**Improving wool quality**

Farmers produce wool of varying quality and opt to produce wools of different wool diameter (microns), and therefore it is not a homogeneous product. These variations in wool quality influence the
prices received by the grower. Using their estimated model for wool micron, length and vegetable matter for auction sales in Australia and New Zealand for the 1986-87 selling season, Angel et al. (1990) demonstrated how prices vary when each pair of these attributes is considered. Vegetable matter content was found to affect finer micron wool more than broader micron wools, and the effect of micron on prices was far greater than the effect of vegetable matter on prices. These attributes vary spatially, but outcomes from the considerable research effort that has gone into improving wool quality, such as better measurement and description of objectionable fibres and improved processing to remove vegetable matter (Fleet and Langford 2006), are likely to have lessened the impact on productivity of these spatial variations.

Managing pastures and grazing intensity

Advances in the management of pastures and grazing pressure in the wool industry are epitomised by the introduction of improved pasture species, rotations, fertiliser application in hilly farming areas, aerial sowing, better use of native pastures, improved drought management, supplementary feeding and spatial diversification of properties owned to exploit regional differences in seasonal conditions. In particular, areas of sown pasture increased rapidly between 1950 and the mid-1970s (DAFF 2001). Irrigation has been used to improve pasture production, particularly in dry years (DAFF 2001) in areas of unreliable rainfall, but has been restricted to regions where the necessary infrastructure exists.

Hodgson (1990) provides a good summary of the science behind sheep grazing management and how grazing management systems vary according to the physical environment and pasture species. Scott et al. (2000), Chapman et al. (2003), Graham et al. (2003), Michalk et al. (2003), Sanford et al. (2003), Bell (2006) and Lewer (2006) analyse how different grazing methods improve the performance of animals, particularly sheep, in different parts of Australia that correspond to our four climatic areas.

Developing and managing on-farm water supply for livestock

The development and management of on-farm water supply for sheep has been a major factor enabling farmers to increase their productivity, especially in drier areas. Abel et al. (2006) observed that the ‘spread of water points across previously unwatered country simultaneously gave sheep access to more grazing while reducing stocking density by orders of magnitude’. Pasture usage is improved with more watering opportunities for sheep (Squires 1981). Fencing to separate flocks has been crucial in this process (Abel and Langston n.d.). The development of on-farm water supply has been particularly important in the Pastoral Zone (and therefore CA2).

Health management and animal husbandry

Sheep are susceptible to a range of infectious, parasitic, nutritional and neoplastic diseases, but have proved excellent animals for experimentation in physiological studies (Colditz and Dart 2009). An impressive stock of research results have accumulated, which has no doubt aided the adaptation of sheep to different environments. Traditional control measures of grazing management and chemicals have been augmented in recent times by breeding for disease resistance and the strategic use of nutrition, biological control and vaccination to control disease (Walkden-Brown and Besier 2006). Sheep husbandry skills and expertise have also accumulated over time, to similar effect. Examples of the broad range of advances in animal husbandry are more effective drenching regimes, modified timing of mating to suit seasonal conditions and aerial mustering on farms with difficult topography.

Environmental degradation

Modification of the grazing environment has not always been positive and led to a narrowing of productivity differences across space. Wool producers are facing a number of environmental challenges. Degradation in grazing areas has reduced the landscape function through soil erosion, loss of soil structure, loss of native species, woody weed infestation, scrub encroachment, feral animals, salinity, chemical residues, and loss of wildlife habitat and biodiversity (Abel and Langston n.d.; Gardiner et al. 1998;
Department of the Environment, Water, Heritage and the Arts 2002). It may have accentuated differences in productive capacity between regions by having differential effects on the natural resource base.

**Greater understanding of agroecosystems and better decision making by graziers**

As Abel and Langston (n.d., p. 22) pointed out in respect of the Pastoral Zone, biodiversity is a source of adaptive capacity – “resilience-in-waiting”. Ecological innovations and the accumulation of knowledge of the links between productivity and biodiversity, and the limits placed on sheep carrying capacity by environmental degradation, have therefore become more prominent features in graziers’ management programs in recent years. Early efforts to conserve the production environment entailed control measures to deal with pests and weeds. Biological control agents have had a substantial effect on the rabbit population since 1950, providing an obvious example of pest control in sheep production. It was initially achieved through the myxamotosis virus and, more recently, through 1080-based baits and the Calici virus. The construction of rabbit proof fencing and the fumigation and destruction of warrens have also played a role in controlling the population. More recently, conservation measures have been taken through programs such as sustainable grazing systems. Livestock have been excluded from degraded areas, weeds have been more effectively eradicated, and greater use has been made of perennial pastures and the maintenance of vegetation along drainage lines (Department of the Environment, Water, Heritage and the Arts 2002). Maintaining flexible and proactive farming operations has helped wool producers manage the environmental risks they face. Strategies include enterprise diversification and stocking rate changes in response to rainfall, spatial diversification and the strategic trading and movement in sheep, and weed and disease control (Abel and Langston n.d.; Lewer 2006; Stafford Smith and McKeon 1998; Howden et al. 2009). Use of decision support tools and remote sensing of feed on offer has helped sheep producers make better predictions about future production conditions, improving the sustainability of grazed pastures. The Department of the Environment, Water, Heritage and the Arts (2002) pointed out the value of measures such as the formal monitoring of vegetation and pasture condition, and monitoring water tables.

**Exploiting scale in farming operations**

Choosing the optimal scale of farming, and maintaining a flexible farming system to allow for variations around this scale according to climatic and market conditions, enables wool producers to maximise their productivity. It has long been a major factor influencing the productivity of grazing enterprises in Australia, with inexorable increases in the average size of broadacre properties (ABARE 2007). This has long been apparent in the Pastoral Zone where the disadvantage of low output per sheep per hectare has been offset by developing large properties (Davidson 1967). Abel and Langston (n.d.) also point out that property size is an important determinant of adaptive capacity.

**Development of supporting rural institutions and infrastructure**

Various forms of institutional support have assisted wool producers, particularly in terms of research and extension, as noted above, but also in facilitating the accumulation of human and social capital (Nelson et al. 2007). They include the role of the family farm and local support networks, structural adjustment programs, soil conservation programs and drought assistance. Abel et al. (2006) identified the importance for the pastoral system of ‘networks of properties held by pastoral families or companies, supporting services, communication and transport networks, abattoirs, and markets for wool and meat’. They also referred to the beneficial links to ‘a system comprising state and federal governments, lobby groups, voters, media, and the Australian and international economies’, arguing that pastoralists gained considerable access to external resources through exertion of their economic power and political influence. There is, however, a negative side to institutional intervention. Walker and Janssen (2002, p. 719) concluded that ‘command-and-control approaches to rangeland policy and management are bound to fail’.

Method of analysis and data
The method of analysis used is the stochastic metafrontier framework developed by Battese and Rao (2002), Battese et al. (2004) and O'Donnell et al. (2008). The metafrontier is a production function that envelops all individual group frontiers, which are boundaries of restricted sets of production technology. Battese and Rao (2002) use the term, metatechnology ratio, to describe the gap in performance between a firm in a group (in this study, a farm in a climatic area) and the best-practice firms forming the production frontier for all groups (the metafrontier). In view of the presence of environmental constraints in wool production, we call this ratio the environment-metatechnology ratio (EMTR) to reflect the fact that farmers are constrained in their production processes by the environment in which they operate, and use those processes based on technologies adapted to that environment. The EMTR measures the ratio of the output of the frontier production function for a particular region to the potential output that is defined by the metafrontier function, given the observed inputs (Battese and Rao 2002; Battese et al. 2004). Values lie between zero and one: the higher the values of the EMTR for the individual frontier of the climatic area, the closer it is to the metafrontier. The performance of farms relative to the frontier of their individual climatic area reflects their technical efficiency with in that environment, and is termed the TE-A. These values also lie between zero and one, with higher values indicating a higher level of technical efficiency. TE-M measures the individual farm relative to the metafrontier, and is the product of TE-A and EMTR. It provides a means to compare total factor productivity indices between farms and to measure mean total factor productivity across climatic areas in a manner analogous to the temporal measurement of change in total factor productivity as outlined by Coelli et al. (2005, p. 301).

The following three propositions are examined by estimating EMTRs and TE-As for wool producers in the four climatic areas:

1. Variations in EMTRs between climatic areas are expected to exist, with higher mean EMTRs in the more favourably endowed CA3 and CA4.
2. EMTRs of individual farms are expected to be more widely distributed in the more diverse climatic areas of CA1 and CA2.
3. TE-A scores of farms in CA4 are expected to be lower with higher variance, with higher TE-A scores for farms receiving consultancy advice.

We use farm-level data obtained over ten years from two benchmarking groups:

1. A commercial organisation, which provides consulting advice to all farmers in regions CA1, CA2 and CA3 and some farmers in CA4.
2. A government-based organisation, which collects benchmarking data from farmers in CA4 but does not provide any consultancy advice.

The unbalanced panel data set contains 1157 observations from 372 farmers covering the ten-year period from 1994/95 to 2003/04. The data set contains farm-level input and output data for farm enterprises. The wool output variable was calculated as the sum of implicit wool output and net trading profit or loss on adult sheep. Implicit output was obtained by dividing wool revenue in each year by the wool price index and the net trading revenue by the sheep price index. Both indices are published by ABARE (2007). The wool output was calculated per dry sheep equivalent (DSE) (that is, constant returns to scale are assumed) because data on farm area were unavailable for farms in the government-based benchmarking group.

Seven input variables were included in the estimated models: agistment, health, pasture, selling, shearing, labour and overheads. Overheads that were included were restricted to those that have a direct influence on wool production. All input variables were calculated as costs per DSE that were deflated by the index of prices paid by farmers (ABARE 2007). Information about the data set and variables are provided in Table 1, where the figures in parenthesis are standard deviations.

Results
We follow Coelli et al. (2005) and assume that all firms have access to the same technology in every period and that the
covariances between all error terms are zero. This enables us to treat the panel data as if they were from a single cross-section. We have confirmed this approach by including a time trend in the initial model which was found to be insignificant; thus, it was excluded in the final model.

A likelihood ratio test result justifies the estimation of a metafrontier production model, and a generalised-likelihood ratio test result suggests that the group frontiers are not identical ($p$-value = 0.0000).

Estimates of the metafrontier production function are presented in Table 2. The standard deviations of the metafrontier estimates were calculated using parametric bootstrapping as suggested by Battese et al. (2004). Apart from labour and pasture/feed, estimated coefficients of the stochastic metafrontier production function were found to be significant and of expected sign.

Estimated mean EMTRs, TE-As and TE-Ms are presented in Table 3 and their distributions are presented in Figure 1. The value of EMTR ranges from 0.20 to 1. The maximum value of 1 was observed in all climatic areas, which indicates that all four frontiers were tangential to the metafrontier at least at some point.

The mean EMTRs were found to be significantly different for all climatic areas. The results support the first proposition of higher mean EMTRs in the more favourably endowed CA3 and CA4 than those in CA3 and CA4. But, although the differences are significant, the variations in EMTRs are minor in magnitude, with a relatively small range in mean values from 0.72 in CA2 to 0.80 in CA3. CA1 and CA2 recorded relatively low mean EMTRs of 0.73 and 0.72, respectively. It implies, for instance, that wool producers in CA2 produce on average only 72% of the potential wool output than could have been obtained from the best production technology available and the most suitable environmental conditions for wool production in Eastern Australia.

EMTRs within climatic areas have low standard deviations relative to their means, indicating low dispersions for all areas (Table 3). They are more widely dispersed among farms in CA2, in line with the second proposition that EMTRs are more widely distributed in the physically more diverse climatic areas. Figure 1 shows that there are quite a few high individual EMTRs in CA2, indicating that at least some properties in the Pastoral Zone have been able to adapt fully to the most favourable production conditions. The most plausible explanations are that these properties are among the best fine wool producers in Australia and have regular access to adequate water supplies. In contrast, CA1 has very few observations on or near the metafrontier and, contrary to the second proposition, has the lowest standard deviation of EMTRs (Table 3). Higher mean EMTRs were found to exist in CA3 (0.80) and CA4 (0.77). The highest estimated mean EMTR in CA3 is consistent with the high productivity potential across the area. Variations in EMTRs within areas are attributable to the fact that not all producers take advantage of available production technologies. For example, Hinch (2006) reported uneven progress in adopting genetic advances in the sheep industry.

Turning now to the technical efficiency estimates, the TE-As represent what is feasible for farmers to achieve in each climatic area. Farms in CA1 and CA2 on average achieved higher technical efficiencies relative to their respective frontiers whereas their lower EMTRs indicate that they tended to be furthest from the metafrontier. The result of a statistical test indicates that the mean TE-As for CA1 and CA2 are not statistically different. Observations in CA1 are relatively closely grouped such that the mean TE-A score is high at 0.86. Both CA3 and CA4 have a substantial proportion of TE-A observations on or close to their respective frontiers and CA3 has a relatively high mean TE-A score of 0.80. Observations are relatively widely spread in CA4, with a mean TE-A score of only 0.74 despite having a substantial proportion of observations on or close to the metafrontier. This result is consistent with the third proposition that farms not receiving regular consultancy advice will have lower efficiency. A statistical test indicates that there is a significant difference in TE-A scores between those farms with consultancy advice and those that do not receive any advice, with the former having a higher mean technical efficiency. Variation in technical efficiency in CA4 therefore
seems to depend on whether paid consultancy advice is regularly received by farmers in the benchmarking groups. It is probable that the consultancy advice improves performance and/or higher-performance farmers are more likely to pay for consultancy advice.

**Conclusion**

Results reported in this paper show that productivity levels achievable by producers in challenging environments appear to be similar to those achievable by producers in more favourable environments, with only small, albeit significant, environment-technology gaps present between four selected climatic areas in Eastern Australia. Even within the climatic areas, farm-level EMTRs are tightly distributed around the mean. Thus, constraints on production imposed by the rainfall regime do not greatly restrict wool production. This result can be attributed to the various processes of successful adaptation to climatic conditions and the suitability of the Merino to a wide range of production conditions from the beginnings of the wool industry in Australia. The success of these farm-level adaptation processes, aided by the adoption of improved technologies, is due in large part to the research and development work carried out by the research and extension staff and consultants in the sheep industry. These processes have suited the varied environmental conditions in which wool is being produced, and have endowed producers with greater control over their environment. Environmental constraints appear to be as limiting within the delineated climatic areas as between them, due to a complex set of physical constraints in addition to rainfall and differences in adoption rates of available production technologies.

Farmers in Northern and South-Western New South Wales achieved higher technical efficiencies relative to their respective frontiers than farmers in Central and South-Eastern New South Wales and South-Western Victoria; but average producers in these regions tended to be furthest from the potential output achievable across all climatic areas. Another result of interest is the wider distribution of technical efficiency scores within the South-Western Victoria region than in the other three climatic areas. This finding is probably attributable to the absence of consulting advice to some sampled farmers in this region because farms receiving consultancy advice had significantly higher technical efficiency scores than those that did not.

**References**


Colditz I and Dart C. 2009, *The sheep*, ANZCCART Fact Sheet, University of Adelaide
DAFF 2001, Landuse change, productivity and development – historical and geographical context, Department of Agriculture, Fisheries and Forestry, Canberra.


Appendix

Table 1 Descriptive Statistics

<table>
<thead>
<tr>
<th>Items</th>
<th>CA1</th>
<th>CA2</th>
<th>CA3</th>
<th>CA4</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of observations</td>
<td>221</td>
<td>307</td>
<td>123</td>
<td>506</td>
<td>1157</td>
</tr>
<tr>
<td>Number of cross-sections</td>
<td>98</td>
<td>109</td>
<td>42</td>
<td>123</td>
<td>372</td>
</tr>
<tr>
<td>Wool income ($/DSE)</td>
<td>21.33</td>
<td>17.97</td>
<td>19.97</td>
<td>22.55</td>
<td>21.15</td>
</tr>
<tr>
<td></td>
<td>(7.069)</td>
<td>(4.91)</td>
<td>(5.97)</td>
<td>(11.53)</td>
<td>(9.05)</td>
</tr>
<tr>
<td>Agistment ($/DSE)</td>
<td>1.99</td>
<td>2.53</td>
<td>2.27</td>
<td>2.33</td>
<td>2.27</td>
</tr>
<tr>
<td></td>
<td>(3.23)</td>
<td>(4.69)</td>
<td>(3.61)</td>
<td>(2.35)</td>
<td>(3.20)</td>
</tr>
<tr>
<td>Health ($/DSE)</td>
<td>1.51</td>
<td>1.30</td>
<td>1.34</td>
<td>1.056</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>(0.74)</td>
<td>(0.74)</td>
<td>(0.92)</td>
<td>(0.62)</td>
<td>(0.77)</td>
</tr>
<tr>
<td>Pasture/Feed ($/DSE)</td>
<td>2.19</td>
<td>1.08</td>
<td>2.81</td>
<td>2.55</td>
<td>2.37</td>
</tr>
<tr>
<td></td>
<td>(1.29)</td>
<td>(1.72)</td>
<td>(1.67)</td>
<td>(1.23)</td>
<td>(1.50)</td>
</tr>
<tr>
<td>Overhead ($/DSE)</td>
<td>4.91</td>
<td>5.78</td>
<td>4.80</td>
<td>8.74</td>
<td>6.65</td>
</tr>
<tr>
<td></td>
<td>(1.76)</td>
<td>(2.78)</td>
<td>(1.90)</td>
<td>(5.90)</td>
<td>(4.59)</td>
</tr>
<tr>
<td>Shearing ($/DSE)</td>
<td>3.88</td>
<td>3.83</td>
<td>3.47</td>
<td>3.066</td>
<td>3.41</td>
</tr>
<tr>
<td></td>
<td>(1.23)</td>
<td>(1.24)</td>
<td>(1.16)</td>
<td>(1.093)</td>
<td>(1.20)</td>
</tr>
<tr>
<td>Selling ($/DSE)</td>
<td>1.97</td>
<td>1.84</td>
<td>1.89</td>
<td>1.90</td>
<td>1.90</td>
</tr>
<tr>
<td></td>
<td>(0.94)</td>
<td>(0.79)</td>
<td>(1.16)</td>
<td>(0.82)</td>
<td>(0.94)</td>
</tr>
<tr>
<td>Labour ($/DSE)</td>
<td>4.83</td>
<td>5.84</td>
<td>4.94</td>
<td>4.96</td>
<td>5.02</td>
</tr>
<tr>
<td></td>
<td>(2.29)</td>
<td>(3.58)</td>
<td>(2.00)</td>
<td>(3.53)</td>
<td>(2.99)</td>
</tr>
</tbody>
</table>
Table 2 Estimates of Parameters of the Metafrontier Production Function

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.539</td>
<td>0.042</td>
<td>12.79 a</td>
</tr>
<tr>
<td>Agistment</td>
<td>-0.034</td>
<td>0.008</td>
<td>-4.44 a</td>
</tr>
<tr>
<td>Health</td>
<td>0.053</td>
<td>0.035</td>
<td>1.54 c</td>
</tr>
<tr>
<td>Pasture/Feed</td>
<td>0.016</td>
<td>0.014</td>
<td>1.16</td>
</tr>
<tr>
<td>Overhead</td>
<td>0.250</td>
<td>0.043</td>
<td>5.87 a</td>
</tr>
<tr>
<td>Shearing</td>
<td>0.076</td>
<td>0.039</td>
<td>1.96 b</td>
</tr>
<tr>
<td>Selling</td>
<td>0.215</td>
<td>0.032</td>
<td>6.78 a</td>
</tr>
<tr>
<td>Labour</td>
<td>0.035</td>
<td>0.037</td>
<td>0.96</td>
</tr>
</tbody>
</table>

Note: This is an abridged version of the translog model.

a, b, c indicate significant at 1, 5 and 10% levels, respectively.

Table 3 Estimated EMTRs, TE-As and TE-Ms

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Region</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment-metatechnology ratio (EMTR)</td>
<td>CA1</td>
<td>0.73</td>
<td>0.10</td>
<td>0.31</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>CA2</td>
<td>0.72</td>
<td>0.17</td>
<td>0.20</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>CA3</td>
<td>0.80</td>
<td>0.12</td>
<td>0.35</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>CA4</td>
<td>0.87</td>
<td>0.13</td>
<td>0.27</td>
<td>1.00</td>
</tr>
<tr>
<td>Technical efficiency with respect to the regional frontier (TE-A)</td>
<td>CA1</td>
<td>0.86</td>
<td>0.08</td>
<td>0.33</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>CA2</td>
<td>0.86</td>
<td>0.09</td>
<td>0.54</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>CA3</td>
<td>0.80</td>
<td>0.13</td>
<td>0.30</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>CA4</td>
<td>0.74</td>
<td>0.15</td>
<td>0.09</td>
<td>0.94</td>
</tr>
<tr>
<td>Technical efficiency with respect to the metafrontier (TE-M)</td>
<td>CA1</td>
<td>0.63</td>
<td>0.11</td>
<td>0.23</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>CA2</td>
<td>0.62</td>
<td>0.16</td>
<td>0.17</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>CA3</td>
<td>0.64</td>
<td>0.14</td>
<td>0.16</td>
<td>0.94</td>
</tr>
<tr>
<td></td>
<td>CA4</td>
<td>0.57</td>
<td>0.15</td>
<td>0.08</td>
<td>0.91</td>
</tr>
</tbody>
</table>
Figure 1  Distributions of EMTRs, TE-As and TE-Ms by region

Northern New South Wales (A1)

South-western New South Wales (A2)

Central and South-eastern New South Wales (A3)

South-western Victoria (A4)
Whole-farm models: a review of recent approaches

Michael J Robertson¹, David J Pannell² and Morteza Chalak²

¹CSIRO Ecosystems Sciences and CSIRO Sustainable Agriculture Flagship, PMB5, PO Wembley Perth WA (6913) Australia

Corresponding author: Michael.Robertson@csiro.au

²Centre for Environmental and Economics and Policy, School of Agricultural and Resource Economics, University of Western Australia, Crawley WA (6009) Australia.

Abstract. There is a wide variety of approaches to whole farm models (WFMs) including purely biophysical models as well as models that combine biological and financial elements. Our study was motivated by the notion that researchers may benefit from guidelines on the choices they must make about modelling approach, when they are interested in moving to the whole-farm scale in order to understand the impacts of management changes on farm businesses. This paper reviews 53 studies published in Agricultural Systems, including the recent development of WFMs for developing country situations. We document current approaches and develop a typology, and describe strengths and weaknesses of various approaches. Models differed in the extent to which they accounted for resource constraints, endogeneity of input levels, spatial heterogeneity, interactions between activities, inter- and intra-annual variability, and risk. Models varied in objective (profit, environment, household food security), audience and whether they used real or representative farms. We found many studies did not provide a new insight into a farming system that has general relevance outside the specifics of the case being examined, did not use sensitivity analysis or validation, and were unclear on the objective of the work and the target audience. In response to this we consider issues around the communication of this type of research, proposing guidelines for the publication of WFM papers that are well documented, clear and useful.

Keywords: whole farm systems modelling, economics, optimisation, simulation, risk, sensitivity analysis, validation.

Introduction

In recent times there has been a proliferation of whole-farm models (WFMs) to address a multitude of questions in agricultural systems. Janssen and van Ittersum’s (2007) review of WFMs concentrated on mechanistic normative models. Normative approaches try to find the optimal solutions and alternatives to the problem of resource management and allocation rather than trying to model the actual behaviour of the farmer (so called “positive” approaches). Mechanistic (as opposed to empirical) approaches use mathematical programming and existing theory and knowledge to encapsulate the processes on farms in an idealised sense. Mechanistic normative models can use constrained optimisation and this is the class of model than Janssen and van Ittersum focussed on. They did not cover non-optimisation models nor did they address issues of spatial explicitness, representativeness, and coupling with biophysical simulation models. They also focussed on industrialised countries and since their review there has been a number of WFMs produced for developing country situations (e.g., Giller et al. 2006; Tittonell et al. 2009). Hence, it is timely to review recent trends.
model construction and solution, delays until model completion, model opaqueness).

We review recently published papers on WFM with the aim of providing insights into these choices. We document current approaches and develop a typology of models. Strengths and weaknesses of various approaches are described. In addition, we consider issues around the communication of this type of research, proposing guidelines for the publication of WFM papers that are well documented, clear and useful.

**Methods**

Papers using WFM published in the journal Agricultural Systems between 2006 and 2011 were read and classified according to a range of criteria shown in Table 1. All reviewed papers post-date those included in the survey of Janssen and van Ittersum (2007).

In classifying papers, the following categories were used:

1. Constrained resources. The mix and level of production activities in the model is constrained by the availability of resources, such as labour, machinery and finance.

2. Endogeneity of input levels. Levels of inputs, such as fertiliser, labour and fuel, are set endogenously to optimise the model's objective function.

3. Interaction of activities over time. One activity, such as cropping, interacts with another, such as grazing, on the same area of land. For example, nitrogen fixation by a legume pasture may increase the yield of cereal crops in subsequent years.

4. Interaction of activities over space. One activity, such as cropping, interacts with another, such as grazing on another part of the farm. For example, the production of manure by livestock is used as fertiliser on crops.

5. Spatial separation of activities. For example, forage production for hay, grain production, and grazing occur on separate land use units.

6. Spatial heterogeneity. Land use units have different production levels, inputs and profit margins, often as a function of soil type or topography.

7. Dynamics. Within-year dynamics are represented through sub-periods of the year, often to account for variation in feed supply and demand in livestock-related activities. Between-year dynamics are included through representation of inter-annual variability in activities such as crop production. Related to this is the extent to which a WFM focuses on tactical (e.g., within season enterprise and production method selection) versus strategic decisions (e.g., multi-year enterprise selection, flock or herd structural decisions).

8. Real versus representative farms. Models run on real farms may require a high level of detail, while representative-farm models may be a summation of local knowledge or farm surveys and hence an amalgam of synthetic and actual data on farm characteristics.

9. Audience. The aim of the model is to inform the settings of farm policy (e.g., levels of farm subsidies), research prioritisation (e.g., selecting those technologies with largest impact on whole-farm profit), or farm management (e.g., decisions made by farmers and their advisors of a strategic or tactical nature).

10. Objective. These are the key outputs or performance indicators for the model, and in the case of optimisation models are the objective function. Objectives might be financial (e.g., profit maximisation, risk minimisation), social (e.g., objectives related to the farm household), or environmental (e.g., minimise nutrient losses, greenhouse gas emissions, or energy consumption).

11. Variation accounted for. This refers to both variation in production (e.g., as a function of season), prices and costs and the reporting of model output.

12. Timeframe. For non steady-state models this category represents the number of years represented in a single solution of the model.

A total of 53 studies utilising 42 models were analysed. Studies based on smallholder agriculture in less developed countries (LDCs) comprised 21% of the 53 studies. All studies were of the type described by Janssen and van Ittersum (2007) as “mechanistic normative”. Normative approaches try to find the optimal solutions and alternatives to the problem of resource management and allocation rather than trying to model the actual behaviour of the farmer (so called “positive” approaches). Mechanistic (as opposed to empirical) approaches use mathematical programming and existing theory and knowledge to encapsulate the processes on farms in an idealised sense.

We concede that the selection of one journal for the review of literature will exclude many WFM studies from our survey. The scope of Agricultural Systems (“...an international journal that deals with interactions - among the components of agricultural systems, among hierarchical levels of agricultural...
systems, between agricultural and other land use systems, and between agricultural systems and their natural and social environments”) ought not to have excluded any particular type of WFM paper. Ultimately the aim of the study was to arrive at some general insights and principles derived from this cross-section of the literature on whole-farm modelling.

Results

Representation of resource constraints can make important differences to the evaluation of the impact of technologies and management practices. Models differed in terms of whether they accounted for resource constraints, such as labour, machinery and finance. Those models with an economic emphasis (often based on optimisation) evaluated the impacts of resource constraints explicitly (68% of the studies examined, Table 1), while those with a biophysical emphasis (often based on simulation) did not. Omitting such constraints from the analysis may result in the benefits of interventions being over-estimated. Of course, simulation modellers can consider whether any particular management strategy violates a specific resource constraint, but this is a relatively cumbersome process, and is rarely done in practice. Others argue that the implications for resource use can be handled by using outputs of resource use (e.g., labour) as a criterion for comparison of scenarios ex-post (Lisson et al. 2010).

Models differed in the degree to which they accounted for within-year and between-year variation. Models with livestock activities tended to focus on within-year dynamics (28%, Table 1) because of the need to reconcile feed supply and demand on a seasonal basis (Bell et al. 2008a), whereas those with an emphasis on crop production included only between-season variation (8%). Only 8% of studies accounted for neither within- nor between-season variation while 43% of studies accounted for both. The approaches that were used ranged from fully-dynamic simulation models (often daily time step) (e.g., Chapman et al. 2008) to those that represented a single year without intra-year dynamics (e.g., Yiridoe et al. 2006).

A total of 13% of models accounted for price variation only, 17% for seasonal variability only and 21% for both (Table 1). When prices were varied it was done so through changing baseline values up and down by arbitrary percentages (e.g., Byrne et al. 2010). None of the reviewed models used an assumed or actual distribution or sequence of prices, although there are examples where this has been done previously (e.g., Kingwell 1994). Many of the reviewed models were based on mean yield or price values, based on a sequence of years but ignoring variation from the mean (e.g., Huhtanen et al. 2011).

A common reason for modelling at the whole-farm level is to examine inter-enterprise interactions and optimal enterprise mix. A number of models were applied to mixed crop-livestock systems (49%), and most treated them as discrete enterprises (74%) operating on separate parts of the farm (Table 1). The notable exception is the MIDAS model (Kingwell and Pannell 1987) based on Australian mixed farming, where there is close temporal and spatial integration of crop and livestock production. This review found eight studies using MIDAS, all applied to mixed crop-livestock issues in Australia. Studies mostly concentrated on the evaluation of new plant options for the farm feedbase (shrubs, perennial pastures, annual pasture, and perennial grain crops) (O’Connell et al. 2006, Bell et al. 2008b, Gibson et al. 2008, Bathgate et al. 2009, Doole and Weetman 2009, Byrne et al. 2010, Monjardino et al. 2010), but also looked at new rotational options (Robertson et al. 2010). Household models in LDCs also linked crops and livestock because of the need to account for livestock utilising crop residues and the use of manure on croplands (e.g., Giller et al. 2006, Lisson et al. 2010, Parsons et al. 2011; Rufino et al. 2011).

Half of the reviewed models represented spatial heterogeneity in land-use units within the farm, including associated heterogeneity in productivity and suitability to different crop and livestock activities (Table 1). Amongst the industrialised agriculture applications, spatial heterogeneity is a notable feature of the MIDAS model where, depending on the version, up to 8 land management units (or soil types) can be specified for a farm. This emphasis in MIDAS is undoubtedly due to the heterogeneous nature of the soil-landscape system found on large farms (>3000 ha) in Western Australia, where MIDAS originated (Kingwell and Pannell 1987). The lack of spatial heterogeneity in other whole-farm models in industrialised settings is probably a function of relatively small farm size. The only other model where spatial issues were a prominent feature was NUANCES (Giller et al. 2006) where human-induced gradients of soil fertility in relation to the farm homestead on smallholder farms in Africa must be accounted for when addressing whole-farm
resource allocation and soil fertility interventions. Studies varied in terms of whether modelled farms were based on real farms (e.g., Evans et al. 2006) or synthesised representatives of a population (e.g., Crosson et al. 2006). Most studies (75%) used representative farms (Table 1), and farm surveys were used commonly to specify what was representative. Surprisingly, few models varied key characteristics of the representative farm in sensitivity analyses (e.g., O’Connell et al. 2006). Where real farms were used, parameters were often obtained from farm surveys. For example, Claessens et al. (2009) used farm surveys to assess the regional impact of a scenario by aggregating the impacts on each whole-farm up to a district or regional level. The objective of the models was either expressed as the objective function in optimisation models or as the main reported output in non-optimising models. Unsurprisingly, the objective was predominantly profit (industrialised studies) or food security (smallholder in LDCs), although a significant number also included energy (e.g., Ahlgren et al. 2009), natural resources (e.g., Belhouchette et al. 2011) or environmental measures (e.g., Happe et al. 2011), labour (e.g., Parsons et al. 2011) and 8% of studies accounted for risk (e.g., Mosnier et al. 2009) (Table 1). Household models built to address issues for smallholder farmers in LDCs (21% of studies) all had a model objective of maximising food security. All models built for industrialised agriculture had maximising profit as the objective and a significant number (21%) had profit and some measure of environmental impact, such as energy use, greenhouse gas emissions, soil carbon levels or nutrient losses (e.g., Nousiainen et al. 2011). Only one had a "social" objective (maximising labour use, Cittadini 2008). Significantly, only one study had risk reduction as part of the model objective function (Lien et al. 2007). The modelling studies nominated their target audience or end-user of the model results as prioritisation of research (45%) (e.g., Bathgate et al. 2009, Affholder et al. 2010), government policy that was unrelated to research prioritisation (22%) (e.g., Thornton et al. 2006, Matthews et al. 2006, Happe et a. 2011), farm management guidelines and recommendations (16%) and 18% of studies had more than one target audience (e.g., van Wijk et al. 2009) (Table 1).

Discussion
The insights gleaned from this review lead us to identify three dominant types of WFMs in use. The types are a mix of methodology, scope and target domain. Inevitably there is some overlap.

A typology of whole-farm models

Static optimisation in industrialised agriculture This approach represents the biological, physical, technical and managerial relationships of a farm and allocates available resources and recommends decisions in order to maximise the objective function of whole-farm profit, subject to resource, environmental and managerial constraints. This class of model was reviewed thoroughly by Janssen and van Ittersum (2007). All of the studies reviewed here used a comparative-static framework, which means that the dynamics of changing from one state to another are not captured. Both intra-year and inter-year dynamics can be represented (e.g., Kingwell et al. 1993), although they are assumed to be the same in every cycle of production. This is not to say that economic optimisation models are incapable of representing a sequence of years (as opposed to a cycle), but all reviewed studies did not do so, presumably for reasons of model simplicity. In the simplified approaches used, year-to-year variations in weather were not explicitly described, and nor were variations in price. However, these models can be run with a range of parameter values to assess the influence of different production levels on the profit-maximising mix of enterprises and the level of farm profit.

Strengths of this approach are that interactions between production activities within a year and between years can be considered in enterprise selection, that spatial heterogeneity of enterprise technology can easily be represented, that resource constraints are represented, and that the optimal integrated package of management practices can be determined. The output includes the marginal values of resources and the level of improvement needed in each practice for it to enter the optimal solution. Examples of this approach include Crosson et al. (2006), Francisco and Ali (2006) and the MIDAS studies listed above. Models are commonly based on representative farms within a defined region. Optimisation approaches are ideal for ex-ante research evaluation (Pannell 1996) because they allow easy assessment of how new practices or technologies are likely to best fit into the farming system. Their main weakness is that...
they use the representative farm approach, with the result that the relevance of results to any particular farm is not completely clear. They also require biophysical relationships to be represented in a relatively simplified form. **Household models in developing world agriculture** These have the objective function of improving food security and need to account for unique features of smallholder farms such as: household food requirements, the contribution of off-farm income, the ownership of livestock as a significant capital and cultural “asset”, the utilisation of communal lands, and the economic implications of home consumption of farm production versus market purchase (Thornton and Herrero 2001, Giller et al. 2011). Notable models are IMPACT (Herrero et al. 2007), NUANCES (van Wijk 2009), the model of Parsons et al. (2011), and IAT (Lisson et al. 2010). Spatial heterogeneity is often accounted for (e.g., soil fertility gradients and variable land types). As economic performance of smallholder households is highly dependent upon resource constraints, accounting for resource endowments of farmers (draft animal power, cash to purchase inputs, labour for farm activities) is an important feature of these models, often informed by farmer surveys (e.g., Tittonell et al. 2009). Both optimisation (Yiridoe et al. 2006, Giller et al. 2006) and non-optimisation (Thornton et al. 2006; Lisson et al. 2010) approaches have been used and short (Lisson et al. 2010) and long-term (Giller et al. 2006) effects are accounted for. A variety of approaches are used to generate the technical coefficients. Some household models used process-based simulation models to generate appropriate input–output coefficients which are then fed to the farm model (Lisson et al. 2010), some link simulation models together (Parsons et al. 2011), while others used summary functions derived from more detailed models (Chikowo et al. 2008). The strengths of these household models is that they account for resource endowment of smallholder farmers and the economic implications of home consumption of farm production versus market purchase, which are both unique features of agricultural households in LDCs. These features are also associated with a significant weakness of such models: because there is large heterogeneity in resource endowment and degree of reliance on off-farm income, in addition to biophysical variation (farm size, soil type mix, mix of activities) this poses a particular problem for configuring a representative farm. It is also difficult to represent non-financial or food security objectives such as the keeping of livestock for cultural purposes. On top of these weaknesses is the considerable challenge of collecting quality data to parameterise such models in data-sparse environments. **Biophysical simulation** In this class of model, resources (e.g., labour, expenditure on inputs) are supplied exogenously, often informed by surveys of real farms and hence no constraints are imposed apart from those imbedded in the biophysical functions. More detailed specification of management options is possible, and they often do account for year-to-year variability in weather. They do not seem to have been applied to spatially heterogeneous situations, perhaps due to the increased complexity of the computational task, although there is no theoretical reason why they could not be. Good examples of this class of model are Guimarães et al. (2006), who examined the impacts of variation in production performance of linked dairy-beef production systems on farm financial performance, and Chapman et al. (2008) who examined the impact of feedbase composition on dairy farm production and economic performance. Moore et al. (2011) used simulation to inform a budgetary approach to the analysis of water-use efficiency at the whole-farm scale. The strengths of this approach are that it supports comprehensive and detailed representation of biophysical processes and allows seasonal variability to be dealt with relatively easily (Donnelly et al. 2002). The main drawbacks of simulation approaches are that resource constraints on production activities (e.g., labour, machinery, finance) are not imposed and that optimisation is not used, with the result that the strategies examined may not be the most relevant to farmers; and that it is relatively difficult to represent spatial heterogeneity of resource quality, particularly soil types, across the farm. **Emerging approaches** In our survey of the literature we detected three emerging approaches to whole-farm modelling that are worthy of highlighting. In the first approach, static optimisation and dynamic simulation are used jointly to overcome limitations with the use of either approach alone. The static optimisation models can be used to define farm configuration subject to resource constraints, and this “optimal” configuration is then used to set the realistic boundary.
within which the biophysical model can be used to deal with variability (e.g., stocking rates, rotations, input levels). Whitbread et al. (2010) provides an example of this approach with smallholders in Africa. They show that this “soft coupling” of the dynamic with static optimisation modelling methods offers promise in being able to address issues of uncertainty in farm systems within a realistic resource-constrained scenario. It combines the best elements of each by (i) using the sophisticated modelling capacity that is available through platforms such as APSIM (Keating et al. 2003) to realistically represent the key drivers of the farming system (Chikowo et al. 2008), and (ii) use the household survey approaches to enhance the understanding of resource constraints and flows (Herrero et al. 2007; Tittonell et al. 2009).

The second approach involves the use of WFM’s with farm surveys to assess regional-scale issues, such as the potential scale of adoption of a new farm practice. This approach avoids the limitations inherent in a single-model configuration by being representative of a wider population of farms or farmers. For example, Claessens et al. (2009) used farm survey data and a simple farm model to assess ex ante the economic viability of adopting dual-purpose sweet potato in one district in western Kenya. In a simple ‘representative farm’ analysis, typical or average values of costs and returns would be used to evaluate whether the alternative practice (in this case dual-purpose sweet potato) was likely to be profitable. The significant limitation of that type of analysis is that it is difficult to generalize the analysis to represent the population, particularly where there is a substantial degree of heterogeneity in the farming conditions or context. The methodology of Claessens et al. (2009) was designed to take spatial heterogeneity into account by using the available data to represent the bio-physical and economic heterogeneity in the population.

A third emerging approach is that using multi-criteria approaches, although we found little use of it in our survey. Janssen and van Ittersum (2007) reported that nine out of 48 studies in their survey used multi-criteria approaches, and argued the case for such modelling approaches where decision makers are faced with multiple, often conflicting, objectives of which profit maximisation is only one. It is noteworthy that, in our survey of 53 studies, only one (Francisco and Ali 2006) took a multi-criteria decision making approach. However, a number of studies that had profit maximisation as their core objective also recorded levels of other variables (e.g., environmental) that might be of concern to decision makers.

Model “validation”

Janssen and van Ittersum (2007) argued that a WFM and its outcomes should closely match reality and they found in their survey of studies that half carried out some sort of comparison of modelled with actual farming practices. The fact that “validation” is not carried out more frequently is not surprising considering the lack of datasets to calibrate and validate WFMs (Thornton and Herrero, 2001). Model “validation” of representative-farm models poses additional challenges, given the variation that occurs in the real world. Such a comparison will only ever be approximate because of the myriad of uncontrolled factors operating in the survey dataset that will not be accounted for in the model configuration. Another issue is deciding which model outputs to compare with actual data. A model may closely match reality for one measure but differ greatly for other measures.

A more intuitive approach is the use of “sensibility” testing, which has been applied in crop simulation modelling in recent times (Holzworth et al. 2011; Huth and Holzworth 2005). In this approach model output is tested against expert opinion and common sense and the credibility of the model evaluated against its ability to mimic reality. While this is a subjective process, it is potentially more robust than any objective process that is subject to the flaws listed above. A key feature of sensibility testing is sensitivity analysis of key technical coefficients, which allows a test of the robustness of the model (Pannell 1997).

The audience for WFMs

Our survey indicated that the overwhelming justifications for whole-farm modelling remain research prioritisation and informing policy, these being the aims for 45% and 21% of reviewed papers, respectively (Table 1). A less common audience has been farmers (17%, as discussed below).

The experience of the MIDAS model in Western Australia, as described by Pannell (1996), is instructive for developers of other WFMs who aspire to informing research prioritisation. Since 1984, MIDAS has had a strong influence on agricultural researchers and research managers in the Western Australian Department of Agriculture and
Food and in several national research centres in Australia (the Centre for Legumes in Mediterranean Agriculture, the Cooperative Research Centre for Plant-Based Management of Dryland Salinity, and the Future Farm Industries Cooperative Research Centre). The model has (a) brought together researchers (of various disciplines) and extension agents who otherwise would interact little; (b) allowed scientists and extension agents to assess the economic significance of particular biological or physical information; (c) influenced the thinking of researchers and extension agents about the whole-farm system; and (d) highlighted a large number of data deficiencies and allowed prioritization of research to overcome them. Pannell (1996) lists strategies and practices which may be beneficial to others undertaking similar modelling efforts.

Apart from the Western Australia experience to the best of our knowledge there have been no other cases where major impacts of WFMs on research prioritisation have been documented. Sterk et al. (2006), in a reflection of the use of whole-farm design models with decision makers in six case studies, list ingredients that favoured success: an emphasis on learning rather than providing answers, a desire for change on the part of participants, and local relevance of the models. The role of researchers involved in the process was seen as critical and need to be involved with decision makers from the initial problem definition stage. The intended audience should have a guiding role determining the capabilities and outputs of the model, rather than being used by modellers to attempt to find niches for an existing model that was developed according to the judgements and preferences of researchers. These findings mirror those found by the APSRU group in Australia when exploring the role for computerised decision support for cropping farmers (Carberry et al. 2002). The experiences of Sterk et al. (2006), Carberry et al. (2002) and Pannell (1996) emphasise the primacy of the human dimension of model design, use and communication rather than the technical capabilities of such models. There is a need for more studies reporting on attempts to engage decision makers with the models (be they farmers, researchers or policy makers) in order to advance our understanding of the most effective way to generate and communicate model output as an input to decision making.

Farm managers were the main intended audience for only 17% of studies in our survey. For reasons well-discussed by McCown et al. (2006a, b), we believe that complex WFMs will remain largely irrelevant to directly informing management decisions of individual farmers. The quote of Dillon (1979, p11), reproduced by McCown et al. (2006a), describes five reasons why this is so:

“There is no conceptual difficulty in formulating static production economics in terms of a utility-maximising criterion, nor in conceptualising its logic for non-physical processes. The difficulty lies in application. First, data are not available to be able to specify the relevant production processes (both physical and non-physical) to any significant degree – particularly if we recognise the uniqueness of individual farms. Second, the farm system is dynamic, not static, both in the broad as a purposive organisation in a changing environment and also through the pervasive role of biological time-dependent growth processes in its technical subsystem. Third, even if data were available to specify the required production processes adequately, the task of analysis even under perfect information would be both too complex and too costly for either farmers or computer-aided professionals. “Non-optimising” modes of behaviour have to be used. Fourth, the problem of uncertainty has to be handled. Again this is pervasive in agriculture due to the stochastic vagaries of climate and markets especially, but also because of uncertainty about technology, policy and people. While technologies have been suggested to handle such uncertainty, their cost on anything approaching an individual farm basis makes them impractical. Fifth, even if farmers faced the same judgements about the probabilities they faced, they would still have different preferences and so need different prescriptions for utility maximisation across their individual multiple goals.”

An interesting attempt to engage with smallholders in Indonesia using a WFM is described by Lisson et al. (2010, p.491):

“...rather than employing an automated optimization strategy, a creep budgeting approach was selected, involving re-specifying various input and
output variables in a systematic manner to explore the system response to these changes. That is, the decision-maker ‘creeps’ around the economic response surface in a systematic fashion to examine whether there is a shift towards or away from a more optimal solution. In this way, the use of ‘what-if’ questions provides smallholders, researchers and extension specialists with important insights into how the economic position of the farm household system will respond to different activities.”

In the approach of Lisson et al. (2010), resource constraints relevant to the farm household, such as the supply of and demand for labour, are accounted for exogenously, and probably subjectively, by the farmer. Malcolm (1990) pointed out the irony that relatively simple modelling methods like this may be more suitable than complex models for capturing the full complexities of real decision making.

**Dealing with risk in WFM**

Risk, defined as unpredictability of the economic consequences of actions, is widely seen as an issue of critical importance to farmers, and hence conventional wisdom states that it ought to be included in WFM. In our survey, 53% of studies accounted for price, weather or both forms of variability. Risk is seen to matter because most farmers are “risk averse” (Binswanger 1980; Bardsley and Harris 1987; Abadi Ghadim and Pannell 2003) – they are prepared to sacrifice some expected income in order to reduce their exposure to risk. Our survey indicated that few WFM studies (22% of our sample) represent both main types of risk (price and yield) and even fewer (8%) explicitly represent the risk attitudes of farmers. Those that did include risk attitudes either represented risk aversion based on standard expected utility theory (e.g., Mosnier et al. 2009) or included risk minimisation as part of the objective function (e.g., Francisco and Ali 2006).

Given the above observations, the question arises as to whether WFM studies that fail to include risk and/or risk attitudes are fatally flawed. There are several factors that determine the net benefits of including risk and/or risk attitudes in these models: (a) the importance and relevance of risk to the issues that the model is being used to address; (b) the risk attitudes of the relevant population of farmers; (c) whether the purpose of the model is to predict farmer behaviour or to advise farmers; (d) the sensitivity of results to their inclusion; and (e) the costs of including them. In relation to risk attitudes, Pannell et al. (2000) argued that inclusion of risk aversion in models used to advise farmers is likely to provide minimal benefits, at least in developed countries. Because most farmers have low to moderate degrees of risk aversion (issue b), and because of the phenomenon of flat payoff functions (Pannell 2006), the benefits from improving the quality of recommendations by including risk aversion (an aspect of issue d) are often remarkably small while the costs in terms of model development, use and interpretation (issue e) are non-trivial. The benefits may be greater in developing countries where risk aversion is likely to be stronger.

Where the aim is to predict farmer responses, rather than advise farmers themselves, the benefits of including risk aversion may be greater, as farmer responses to risk can be significant even where the benefits in utility terms from doing so are not great. On the other hand, modelling experience shows that the sensitivity of results to inclusion of risk and risk aversion in whole-farm models is often less than the sensitivity to the inclusion of accurate biophysical relationships or accurate parameter values, such as expected prices and yields (Pannell et al. 2000).

Pannell et al. (2000) and McCown et al. (2006a) both concluded that the most important aspect of risk to be modelled is not farmers’ aversion to risk, but rather their short-term tactical responses to variation in weather and prices. There can be major benefits from responding to particularly favourable or unfavourable weather or prices, through pursuit of opportunities or avoidance of losses. The growing number of WFM studies that consider the dynamic and tactical features of farming (e.g., Kingwell et al. 1993; Donnelly et al. 2002; Mosnier et al. 2009) could be seen as a sign of the growing recognition of the value of WFM in analysing such features of farming systems.

If risk attitudes are important enough to include, then what matters for whole-farm decision making is aggregate risk at the whole-farm level. Hence it seems likely to be ill advised to include only price or yield risk and not both, and yet 32% of surveyed studies did that.

**Towards criteria for publishing papers on WFM**

The proliferation of WFM (42 models in 6 years of Agricultural Systems) raises the issue of whether criteria for judging the
scientific merit of WFM studies are well established. Many of the studies reviewed for this paper were case studies with limited applicability outside the specific situation concerned. A similar phenomenon in crop simulation modelling prompted Sinclair and Seligman in 2000 to publish a paper in Field Crops Research on criteria for acceptance of scientific papers on crop modelling. They argued that even though manuscripts on crop modelling may describe modelling efforts of practical perspective with local interest, they may not necessarily present an analysis of general, scientific interest.

We propose that six criteria are used to judge the merits of manuscripts reporting on studies developing or using whole-farm models.

Firstly, the study should provide a new insight into a farming system that has general relevance outside the specifics of the case being examined and / or propose a new technique for modelling that improves upon deficiencies in currently-used methods. In the case of general relevance there needs to be clarity regarding the magnitude, causation and breadth of the applicability of findings. Readers need to know how important the findings are. (e.g., What percentage change in farm profit occurs? How food shortage frequency is affected?) Readers need to know why the WFM findings are novel and the main factors contributing to the findings. Are the findings applicable to other farm types or farming regions? For some issues it may be worth publishing findings that convey "old truths" rather than "novel findings" or "new insights", particularly where "bandwagon" issues are emerging and where there are claims of a new paradigm. An example of a study that meets the criteria of relevance and new technique is that of Kingwell et al. (1993). In their study a discrete stochastic programming model of dryland wheat-sheep farms in Western Australia was described and used to identify tactical adjustments to climate and to calculate the value of those tactical adjustments. The study both described a novel approach to the question and generated novel insights to the value of accounting for tactical adjustments in WFM.

Secondly, studies should include a clear statement of the objectives of the work and a use for the results. If the objective of the work is to develop a better modelling technique, then the audience is modeller developers. If objective is to apply a model to address a whole-farm issue, then the various possible audiences interested in research prioritisation, policy evaluation, or guidelines for farm management should be highlighted. The case for treatment of the issue at the level of a whole-farm or household (as opposed to a field or region) should also be justified.

Thirdly, studies should nearly always include some component of sensitivity analysis. Our survey indicated a notable lack of sensitivity analysis in many studies. Sensitivity analysis (particularly to price, production levels, and farm configuration) should preferably be based on some empirical evidence of the range of feasible values to be varied. This could be obtained from farm surveys, historical records of prices, costs and production values, or simulated values of production in response to changes in biophysical settings (e.g., season, soil type, management). Where information is available on price probabilities then this should also be incorporated, e.g., rather than say high and low prices it may also be worthwhile to indicate that the "low" price is the 25th percentile price and the "high" price is the 75th percentile price. An example of the use of sensitivity analysis from our literature survey is the study of Byrne et al. (2010), who used a linear programming approach (MIDAS) to evaluate the factors influencing potential scale of adoption of a perennial pasture in a mixed crop-livestock farming system. In sensitivity analysis they varied commodity prices (standard, low and high values), relative productivity of the perennial pasture, mix of suitable soil types on representative farms, and type of livestock enterprise (meat or wool-producing sheep).

Fourthly, a criterion for any paper on WFM should be that there is some degree of "validation" against actual farm practice or outcomes (as suggested by Jannsen and van Ittersum 2007). As noted above there is a conspicuous lack of attempts to validate model outputs. The exact form which validation takes needs to be flexible and dependent upon data availability and the number of model variables that can be evaluated. As argued above we see merit in some combination of subjective ("sensibility testing") and objective methods (comparisons with farm surveys, etc). One example of an attempt to "validate" model output was the study of Robertson et al. (2010). They compared surveyed areas on farm of broadleaf break crops (canola, pulses) with economically-optimal areas predicted by a WFM. In the cases where

there was agreement between surveyed and predicted areas this provided “validation”, while those cases where there was a discrepancy generated a fertile discussion about possible explanations.

A fifth criterion is the need for an explicit statement of what inputs are exogenous or endogenous to the model. If different farmer types are being modelled, the assumptions of resource endowments must be clearly stated. This is a particularly important feature for WFM s in LDC s, where resource endowment has a large influence on the impact of interventions on household outcomes. The study of Titttonell et al. (2009) is a good example of how to couple typologies of farmers varying in resource endowment with a WFM to evaluate the impact of various interventions to intensify the farming system.

Finally, a criterion must be documentation of the source of technical coefficients. Jannsen and van Ittersum (2007) noted this was missing from many of the studies they reviewed, as did we. Many journals allow the publication of online supplementary material, so the constraint of space for publication of voluminous tables of model coefficients is now irrelevant. The study of Parsons et al. (2011) is a good example of how this can be done. It provides a model description supplemented by 14 tables of model coefficients, a number of which are derived from expert opinion.

We are conscious that if our six criteria are followed by journal editors this could easily lead to the practical issue of accommodating all these tasks (especially documenting coefficients, sensitivity analysis and validation) within an editorial word limit. There will be a need to achieve the required balance between informing readers of novel findings whilst ensuring these findings stem from a clearly and fulsomely detailed WFM. One solution is that technical or on-line appendices should be a more common feature of WFM studies. Perhaps editors allow more studies with multi-part papers.

In our review of 53 papers, it is our subjective assessment that the greatest deficiencies that authors should address first is that of sensitivity analysis, so that results can be understood within the context of variation in model parameterisation and assumptions. A modest degree of “validation” and some documentation of key coefficients would improve many of the studies we reviewed.

Conclusions
The 53 studies from six years demonstrate the diversity of approaches being used to address whole-farm production, environmental and economic issues and the emergence of a focus on smallholder households in the developing world. Models with a more economic emphasises accounted for constrained resources, while those with a biophysical orientation focussed on dynamics of processes. The further development of approaches to couple dynamic biophysical and static optimisation models would provide opportunities to address issues of dynamics and risk in farming systems under conditions of realistic resource constraints.

The focus on most studies is still policy guidance and research prioritisation, with few studies attempting to influence farm management. More studies are needed to explore effective means to engage with decision makers using WFM s. This is likely to de-emphasise technical issues and place more focus on problem definition, declaration of assumptions and communication of results along with their uncertainty.

The establishment and acceptance of criteria for publications on whole-farm models should strengthen the quality and transparency of studies and encourage the development and application of modelling studies that will lead to a larger number of generalisable insights. A notable deficiency in many studies was lack of a clear objective or audience for the work. Better documentation of coefficients, validation of model output, and sensitivity analysis around prices, seasonal conditions and farm configuration would strengthen many studies.

Acknowledgements
We are grateful to Prof. Ross Kingwell for comments on an early version of the paper. The work was funded by CSIRO and the Centre for Environmental economics and Policy, School of Agricultural and Resource Economics, University of Western Australia.

References
Affhholder F, Jourdain D, Quang DD, Tuong TP and Morize M 2010, ‘Constraints to farmers’ adoption of direct-seeding mulch-based cropping systems: A farm scale modeling approach applied to the


Herrero ME, Gonzalez-Estrada E, Thornton PK, Quiro C, Waithaka MM, Ruiz R and Hoogenboom


Kingwell RS, Pannell DJ and Robinson SD 1993, ‘Tactical responses to seasonal conditions in whole-farm planning in Western Australia’, Agricultural Economics, 8: 211-226.


### Appendix

Table 1 Criteria used to classify papers on whole-farm modelling published in *Agricultural Systems* 2006-11 and percent of papers in category (n=53).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constrained resources?</td>
<td>69%</td>
<td>31%</td>
</tr>
<tr>
<td>Are input levels endogenous?</td>
<td>65%</td>
<td>35%</td>
</tr>
<tr>
<td>Do different activities on the farm interact over time?</td>
<td>51%</td>
<td>49%</td>
</tr>
<tr>
<td>Do different activities on the farm interact across space?</td>
<td>49%</td>
<td>51%</td>
</tr>
<tr>
<td>Are activities spatially separated?</td>
<td>75%</td>
<td>25%</td>
</tr>
<tr>
<td>Is there spatially-specific heterogeneity?</td>
<td>51%</td>
<td>49%</td>
</tr>
<tr>
<td>Are risk attitudes accounted for?</td>
<td>92%</td>
<td>8%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temporal dynamics</th>
<th>Intra-year</th>
<th>Inter-year</th>
<th>Both</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>29%</td>
<td>18%</td>
<td>45%</td>
<td>8%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Based on real or representative farms?</th>
<th>Real</th>
<th>Representative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24%</td>
<td>76%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Primary audience</th>
<th>Government policy</th>
<th>Research prioritisation</th>
<th>Farm management</th>
<th>More than one</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>22%</td>
<td>45%</td>
<td>16%</td>
<td>18%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Objective</th>
<th>Profit/food security</th>
<th>Environment</th>
<th>Both profit and environment</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>57%</td>
<td>16%</td>
<td>22%</td>
<td>1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variation accounted for</th>
<th>Season</th>
<th>Price</th>
<th>Both</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18%</td>
<td>14%</td>
<td>22%</td>
<td>47%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time frame</th>
<th>Short (&lt; =3 years)</th>
<th>Medium (Between 3 and 10 years)</th>
<th>Long (&gt; 10 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>37%</td>
<td>27%</td>
<td>35%</td>
</tr>
</tbody>
</table>
Economic analysis of early ripening system for table grapes

Alexandria Sinnett, William Dalton, Kristen M Pitt and Mark O Downey
Department of Primary Industries, Melbourne Victoria 3000 Australia
mark.downey@dpi.vic.gov.au

Abstract. High temperatures, rain and high winds (at great intensity at times) have led to scientists and producers exploring options that enable greater control over the effects of weather on primary industries. In this study the suitability of an Italian pergola trellising system (the pergola) for table grapes was assessed on a property in Sunraysia. The study was established in 2009 through Palms Vineyard, the Australian Table Grape Association (ATGA) and Horticulture Australia Limited (HAL). The Victorian Department of Primary Industries (DPI) and Regional Development Victoria (RDV) gathered scientific and production information about this technology from the trial site. The scientific study was the subject of a separate report. In this article, we report on a cost and benefit analysis of installing a pergola on a case study farm. The key message from this analysis is that installing a pergola over a table grape property is worth investigating while there is a price premium for the fruit produced.

Keywords: table grapes, new technology, benefit cost analysis.

Introduction
Table grapes make up a significant proportion of agricultural production in Australia. Within the Sunraysia region, table grapes represent 18% of the gross value of agricultural production (ABS 2008).

According to Table Grapes Australia (2010), table grape production has almost doubled in the past 10 years – from 65,000 tonnes in 1998 to about 120,000 tonnes in 2010. Fresh table grapes are now one of Australia’s leading horticultural exports (approximately 45% of grapes produced in Australia are exported). The majority of Australia’s table grape production occurs in the semi-arid Sunraysia region of northwest Victoria.

Weather is a significant factor in growing table grapes; the quality of fruit can be severely downgraded as a result of sun, wind or rain damage. Growers have changed trellis design, and included the use of covers and various canopy structures in order to achieve better management of these elements. Some growers in the late 1990s and early 2000s developed structures that were based on wind net enclosures – such structures resulted in more even bud burst (as a function of increased humidity) and better bunch elongation (as a result of less wind at flowering). However, the use of such structures was isolated in Victoria and did not lead to serious consideration of the role of permanent protection in the table grape industry.

A team of scientists within the Department of Primary Industries Future Farming Systems Research Division (FFSR) investigated the application of the ‘Italian Trellis Pergola’ system under Australian conditions. (This research received funding from Palms Vineyards (Merbein, Vic.), Regional Development Victoria (RDV), Australian Table Grapes Association (ATGA) and Horticulture Australia Limited (HAL)). DPI researchers investigated the temperature, relative humidity, wind speed, soil moisture and plant phenological characteristics with and without an Italian trellis pergola system. This formed the first part of the study (Pitt et al. 2011).

In the second part of the study, which is the focus of this article, the benefits and costs of installing the pergola system on a table grape case study farm were evaluated.

The aim of the economic study was to investigate two different scenarios for a table grape farm in Sunraysia, Victoria. The first involves continuing with the current system. The second scenario involves installing a pergola system on part of the farm, in addition to continuing with current activities. The key research questions were:
- Is there a net benefit from installing a pergola system over part of a table grape property in the Sunraysia region of Victoria?
- What are the implications for risk and returns?

Method
The case study method was used for this project as it enables an in-depth analysis of different decisions a farmer can make. The case study method considers the complex combination of human, production, environmental, financial and risk components of a farm business (Makeham and Malcolm 1993). In-depth examination of a small number of farms can offer greater insight on the impacts of changes in the operating environment or system, compared with analysis or use of broad industry data (Crosthwaite et al. 1997; Sterns et al. 1998).
The usefulness of case studies and the role they play in farm economics has been well established (see Crosthwaite et al. 1997). The learnings from case study research can be used to test theory (either through adding support to current theory or to challenge accepted wisdoms). Further, findings from case study research can be disseminated to other farmers. Results about possible alternative ways of operating can be presented and explained.

Two farms in the Sunraysia region were investigated. The first had trialled the pergola system as part of the FFSR/RDV/ATGA/HAL/Palms Vineyards research project, on one hectare of land for the table grape variety Crimson Seedless. This farm was used to gather information on costs of the trellis, but was not used as the primary case study as it was a much larger operation than a typical table grape property in Sunraysia. The second farm was chosen as it met the case study criteria for this research which included:

- operating with industry best practices;
- maintaining good records;
- representative of current table grape properties (in terms of size, management practices, water use, and a full-time owner operator); and
- supplying the export market.

The primary case study farm had 19 hectares planted to table grapes. For a complete set of details on the farm and the assumptions used refer to the Appendix.

The two scenarios considered for the case study farm were:

- continue with the current system, which included changing variety on 2 acres (0.8 hectares) every four years; and
- continue with the current system (as described above) with the installation of a pergola over 25% of the farm.

The information provided by the analysis that follows can help the case study farmer judge how to run the farm over the next decade.

The steps taken in this research are outlined in Figure 1.

**The measures of performance**

For the purposes of the economic analysis, the farm is ‘purchased’ in year one and ‘sold’ in year 12. The results, the Net Present Value (NPV) and the return to marginal capital, of the investment are based on a 12-year life of the investment. These measures of performance are explained in more detail below.

**The net present value (NPV)** is one criterion used to judge investments on the farm. The NPV is the sum of all the benefits minus all the costs after they have been converted into their equivalent present values by discounting.

The difference between the present value of benefits and costs is called the NPV.

\[
\text{NPV} = \text{PV (benefits)} - \text{PV (costs)}
\]

Decision makers want investments that provide a NPV greater than zero when the NPV is calculated using a cost of capital or discount rate that represents the return foregone from a realistic alternative investment. Net Present Value analysis allows for the fact that when a resource is allocated to one investment, it is no longer available for use in other investments. The process of discounting captures this effect by deducting the amount that the resource could earn in its best alternative use, or, if the capital is borrowed, deducting the interest cost. Therefore the merit of these two different scenarios are compared with the returns the resources invested could earn if alternatively invested on or off the farm. Access to finance is not considered a limitation in the analysis.

**Return to marginal capital** shows the performance of the extra capital that is added to the business if a pergola system was installed over 25% of the property. This figure can be compared with what the extra capital invested could earn in other uses on or off the farm as part of the farmer’s overall investment portfolio. Return to marginal capital is estimated using a partial development budgeting method, where only the extra returns and extra costs resulting from the change to the system and extra capital invested are analysed.

**Risk** associated with each of the different futures for the case study farm over the planning period is incorporated in the analysis by using probability distributions of key variables such as commodity price and water allocations. Information from farmers and researchers was used to develop the probability distributions (see Appendix for more detail).

‘Monte Carlo’ sampling (Kroese et al. 2011) from these probability distributions for 1,000 ‘runs’ of the 12-year farm plan enables random combinations of grape prices, water allocations and temporary tradeable water prices to occur and probability distributions of the NPV output criteria to be estimated. From
this the probability of NPV being above or below critical levels is revealed. These distributions are presented as a probability density function and a cumulative distribution function (CDF). The probability density function shows the range and mean of results. The CDF allows the option that is stochastically dominant to be identified.

That is, plotting CDFs from different scenarios for the same representative farm on the one graph provides a powerful analytical tool for assessing which scenario has the greater business risk and which scenario will make the most efficient use of capital. The scenario that generates a CDF that lies further to the right when plotted on the same axis as an alternative scenario makes more efficient use of that capital. That is, a CDF for one option located to the right of the CDF of another option is said to be a stochastically dominant option. This means that for the same level of risk, the option promises higher return, or, for the same return, lower risk (Hardaker et al. 2004). The first degree stochastically dominant option is preferable (Figure 2) for someone who simply prefers more for no extra risk (i.e. most people).

Risk can be defined in a number of ways. This analysis is primarily concerned with business risk, not financial risk. Business risk refers to the volatility of factors affecting the business such as yields, prices, costs, weather events, disease events, accidents, and so on. Financial risk exists separately to business risk. Financial risk is the risk associated with level of debt and equity of the business, and the debt servicing obligations this entails. The level of gearing (debt to equity) of a business exacerbates business risk. Only business risk is accounted for in the results of this analysis.

**The costs and benefits of an Italian Pergola system**

The following outlines the extra benefits and costs of installing a pergola trellis system on the case study farm.

The extra benefits will result from:

- Price premiums for grapes grown under the pergola system as a result of:
  - Grapes ripening earlier and being sold into markets with low supply levels compared to grapes that are not grown under the pergola; and
  - Improvements in grape quality due to less wind rub and sunburn, resulting in a grape that is more attractive to the consumer compared with those grapes that are grown outside the pergola.

- A lower crop water requirement as grapes that are grown under the pergola system require 15% less water compared to grapes grown outside the pergola.

The extra costs that are included in the analysis are:

- **Capital costs:**
  - Initial capital costs such as steel rail strainers, support posts, extender internal posts, cables and wire, plastic covers and concrete (based on installation over existing vines rather than a greenfield site);
  - Ongoing capital costs, occurring every three years for plastic cover replacements.

- **Variable costs:**
  - Additional variable costs include an increased labour requirement and additional chemical applications.

**Presenting the results**

The results of the analysis are presented as cumulative distribution functions (CDF) and probability density graphs that depict the probability of earning a range of returns for the following outcomes:

- Net Present Value
- Return to marginal capital invested in changing the farm plan
- Cumulative net cash flow

The average (mean) values and standard deviations of the distributions of outcomes are also presented. The discount rate and return to marginal capital are in real terms.

**Results**

The results are presented in two parts:

- the first section presents the analysis based on a table grape property that is operating within the current water trading rules; and
- the second section presents the sensitivity of key variables (price of capital and the price premium).

The key assumptions are presented in Table 1, and case study data in Table 2.

**Results based on current water trading rules**

The results, based on the assumptions in Table 1, suggest that:

- A farm with a pergola system installed over 25% of the property has a 50% chance of generating $1,000,000, in the 12 year period. A farm without a pergola that
has a 50% chance of generating $800,000 over the same period.
• Business risk is less for a farm with a pergola system installed compared with a farm without it.
• The return to marginal capital is expected to be 20% real, when the price premium is set at an extra $20 per box of harvested table grapes (currently a bank term deposit could earn at least three to four% real return to capital).
• The mean annual net cash flows for a farm with a pergola installed are higher compared with a farm that does not have a pergola installed. Annual net cash flow falls every three years because of the capital cost of replacing the plastic covering.
• Greater borrowings are required if a pergola is installed on the property. This is offset by higher cash flows resulting from the expected price premium earned from grapes grown under the pergola (Figure 4).

Sensitivity analysis
The sensitivity analysis shows that:
• At a capital cost of more than $200,000 per hectare to install a pergola system, it results in a net cost to the farmer and is not advisable.
• The farmer on the trial site estimated that the initial capital cost could be as low as $50,000 per hectare. At a capital cost of $50,000 per hectare, the farm system with a pergola is expected to earn approximately $400,000 more real net wealth (over the 12 years) compared with a farm system that does not have a pergola installed.
• If the assumptions listed in Table 1 remain the same, but the price premium is less at say $10 per box (rather than $20 per box), the return to marginal capital is 5% real. At a price premium of $15 per box, the return to marginal capital is 13% real.
• In order for the farm with a pergola to earn a greater net benefit than the farm without a pergola installed, an average or most likely price premium of more than $17 per 10 kilogram box will be required.

Conclusion
The economic merit of investing in a pergola trellis system over part of a table grape property will depend on:
• the initial capital cost of the pergola (and the ongoing capital cost of the replacement plastic);
• the price premium expected to be received;
• the size of the area covered by the pergola; and
• the size of additional costs to manage the pergola (sprays and more labour).

Finally, it is also important to note that this analysis only looks at the numbers; it does not, and cannot include the qualitative factors (such as management) that are crucial in making a venture like this a success. Growers need to manage the timing of installing and removing covers during the season to achieve optimum results. If the covers are left on too long, vines fruitfulness required for the next season will be reduced. Such issues can result in smaller fruit, eroding the price premium expected and therefore eroding the expected benefits of the system. Thus, the expected return depends very much on the grower’s ability to manage increased disease risks and new knowledge about when to open the covers, when to close the covers, when to remove the covers and when to put the covers back on.

References
Pitt KM, Downey MO, Sinnet A and Dalton W 2011, Table grape export enhancement and investment attraction, Final Report prepared for Regional
Development Victoria. Department of Primary Industries Victoria, Melbourne.


Appendix

Water allocations

Given that it is difficult to predict water allocations due to the seasonal nature of resource availability, a number of different estimates for water allocations were used in the model. These allocations were based on historical water allocations for the Murray system. A cumulative distribution function of these historical allocations was developed whereby the probability of different allocations was estimated. These numbers were entered into the software program @Risk™ (http://www.palisade.com/risk/).

For the purposes of this analysis, Low Reliability Water Share (LRWS) has been expressed as a proportion of High Reliability Water Share (HRWS).

Commodity price

Customs collects export and import data by value and volume was obtained via the Australian Bureau of Statistics (2008). In order to calculate price in the model, value was divided by volume. This is only a guide as the calculated price is an average for all grape varieties and across a whole year. The price the grower receives will be different. However, upon examining these data and adjusting it to current dollar value and subtracting charges it was assessed as a reasonable estimate. These data were then used in a triangular distribution. The mean price generated by this distribution was $26 per 10 kilogram box, which was also the average of the prices the case study farmer received.

For the grapes grown under the pergola a premium was added to the price described above. This price premium was based on a triangular distribution (the lowest possible price premium was $0, the most likely price premium was $20, and the highest possible price premium was $30). The mean price premium used was $20 per 10 kg box of table grapes.

Variable and fixed costs

Variable costs and fixed costs are based on the growers estimate and data from Kristic (2005). These data were based on the 2002-03 season, it was inflated (by 3% every year) in order to produce 2010 costs.
• Variable costs: $14,127 per hectare
• Overhead costs: $253,255 (total)

The temporary tradeable water price is another uncertain variable in the model. It is assumed that if allocations are below crop water requirement, then water is automatically purchased from the temporary tradeable market in order to maintain production. Estimating the cost of this water is difficult as the price is determined by a number of external factors. Brennan (2004) and Bjornlund (2005) both argue that the price of temporary trade water is strongly correlated with water allocations. However upon examining data from 2008, the price of water varied from $265 per megalitre to $550 per megalitre even when allocations remained unchanged at 43%. This indicates there are other factors that influence the tradeable price including commodity prices, rainfall and allocations. Qureshi et al. (2010) also take account sunk costs in the form of asset fixity and remaining productivity life of crops. For example, a grower with young vines may be likely to pay more for water than a grower with old vines.

Based on current knowledge it was determined amongst the project team and project working group that an average weighted temporary trade water price (weighted for the volume traded in that year) for the last four years would be appropriate, particularly when considering a long-term climate change scenario.

Initial capital cost of the pergola

The price for capital infrastructure was estimated at $100,000 per hectare. Horticulture Australia Limited (HAL) budgeted for $120,000 per hectare, but actually spent $100,000 per hectare; this was the figure used. Sensitivity analysis has been undertaken to assess the impact different initial capital costs are likely to have on investment return.

It was assumed that the salvage value of the investment at year 12 (when the investment has an expected life of 12 years) would be worth 50% of the initial capital cost if the farm business was sold.
Ongoing capital cost of the pergola
Every three years the plastic covers on the pergola trellis require replacing. This comes at a cost of $20,000 per hectare (a total cost of $95,000 every three years for an area of 4.75 hectares).

Extra variable costs
It was estimated that an extra $10,000 per hectare per year would be required to manage the pergola system – this would cover extra labour and extra chemical sprays. This was estimated from the trial site.

Benefits of the pergola system
The main benefit of the pergola system is a price premium. It is expected that under the pergola system grapes will ripen earlier compared to grapes grown outside the pergola system – early market grapes are assumed to attract a price premium. In addition it was expected that under a pergola system there should be less wind rub and sunburn – which should increase quality and also attract a price premium.

It was assumed that under the pergola a premium variety, such as Crimson Seedless, was grown.

Another benefit of the pergola system is water savings. Under the pergola system, a 15% water saving can be achieved resulting in a crop water requirement of 8.30ML/ha compared to 9.77ML/ha for grapes grown outside the pergola.
## Table 1 Key assumptions

<table>
<thead>
<tr>
<th><strong>Per unit value</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area under pergola trellis</strong></td>
<td>25%</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td></td>
</tr>
<tr>
<td>Initial capital cost of pergola</td>
<td>$100,000 per hectare</td>
</tr>
<tr>
<td>Cost of replacement plastic</td>
<td>$20,000 per hectare</td>
</tr>
<tr>
<td>Additional labour costs</td>
<td>$10,000 per hectare per year</td>
</tr>
<tr>
<td><strong>Benefit</strong></td>
<td></td>
</tr>
<tr>
<td>Average price of grapes outside the pergola</td>
<td>$26 per 10kg box (mean export price)</td>
</tr>
<tr>
<td>Price premium</td>
<td>$20 per 10 kg box (mean price premium)</td>
</tr>
</tbody>
</table>

## Table 2 Case study data

| **Farm size** | 20 hectares (19 hectares planted) |
| **Water share** | 9.144 ML/ha |
| **Crop water requirement** | 9.77 ML/ha |
| **Area redeveloped** | 2 acres (0.8 ha) every four years |
| | Year one 0.8 ha redeveloped and no yield |
| | Year two 0.8ha 50% yield |
| | Year three 0.8ha 100% yield |
| | Year four another 0.8ha redeveloped and no yield on so on |
| **Cost of redevelopment** | 500 vines per hectare |
| | $5.50 per vine |
| | Labour cost of $10,000 |
| **Average yield across varieties** | 1500 ten kilogram boxes per hectare |
| **Purchase price of farm and water (walk in/walk out value)** | $1,100,000 |

## Table 3 Net economic benefit

<table>
<thead>
<tr>
<th><strong>Mean NPV (discount rate is 8%)</strong></th>
<th><strong>Future 1 (no pergola)</strong></th>
<th><strong>Future 2 (pergola installed on 25% of the property)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Future 1 (no pergola)</strong></td>
<td>$809,593</td>
<td></td>
</tr>
<tr>
<td><strong>Future 2 (pergola installed on 25% of the property)</strong></td>
<td>$1,019,744</td>
<td></td>
</tr>
<tr>
<td><strong>Standard deviation</strong></td>
<td>$294,943</td>
<td></td>
</tr>
<tr>
<td><strong>Standard deviation</strong></td>
<td>$292,861</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1 Schematic diagram of methodology used

Data from trial site collected
Data from a case study business collected
Export price statistics collected

Develop probability distributions for key stochastic (uncertain) variables

Discounted net cash flow budget developed

Probability distributions for NPV for two options analysed
Peak debt, cumulative net cash flow for the two options analysed

Figure 2 Hypothetical cumulative distribution function for option one which is stochastically dominant over the base case

Cumulative Net cash flow (NCF)
Figure 3 Cumulative distribution function (CDF) of a farm system without a pergola installed on the property and a CDF of a farm system with a pergola system installed on 25% of the property.

Figure 4 Expected mean annual net cash flows for a farm with a pergola, and expected mean annual net cash flows for a farm without a pergola.
Economic analysis of improved perennial pasture systems

C Lewis1, 3, B Malcolm2, 3, R Farquharson3, B Leury3, R Behrendt4 and S Clark4
1Department of Primary Industries, Ellinbank, Vic, Australia.
2Department of Primary Industries, Parkville, Vic, Australia.
3Melbourne School of Land and Environment, University of Melbourne, Parkville, Vic, Australia.
4Department of Primary Industries, Hamilton, Vic, Australia.
claire.lewis@dpi.vic.gov.au

Abstract. New perennial pasture grazing systems have been developed for livestock production in the high rainfall zone of southern Australia. These systems provide producers in south west Victoria with the opportunity to increase stocking rate per hectare compared to current practice. A partial discounted cash flow budget with a whole farm perspective was used to analyse the economic performance, and risk implications, of a 100 hectare investment in the new perennial pasture systems over time for a representative farm at a range of stocking rates. The effect of seasonal variability was investigated and the impact of establishment failure was examined. Based on the assumptions about pasture performance used in the analysis, the new perennial pasture systems were more profitable than current practice at all stocking rates tested with successful establishment. If establishment was successful, an increase in stocking rate was not required to achieve a positive return on investment as a result of reduced supplementary feeding requirements. Risk and return increased concurrently with increasing stocking rate. Increasing stocking rate up to 30 DSE/ha reduced the time taken for the pasture investment to return to positive net cash flow.

Keywords: representative farm analysis, pasture improvement, EverGraze

Introduction

The national initiative EverGraze® was established to develop and test new livestock grazing systems based on perennials across the high rainfall zone of southern Australia (Friend et al. 2007). One of six proof sites for the national EverGraze project was established at the Department of Primary Industries in Hamilton, Victoria. The pasture systems tested at the site were grazed rotationally and were designed to match different perennial pastures to soils and landscape. Investment in pasture improvement was analysed for 10% (100ha) of a 1000ha representative farm. The main benefit of the EverGraze systems identified in the experimental results increased stocking rates per hectare compared to current common practice. Stocking rate increases derived from changes in feed supply, which also made possible tactical feed-use opportunities for livestock production. Investment in pasture improvement, and subsequently increasing stocking rates, has long been known to increase both the returns and risks to the farm business (Gruen 1959; Pearse 1963; Chisholm 1965; Cacho et al. 1999; Behrendt et al. 2006). Further, intensification of grazing systems increases demands on farmer skills as well as the capacity of the farmer and the business to cope with the increased volatility that accompanies the higher mean income (Malcolm et al. 2005). These later aspects of intensification, when combined with concerns regarding the associated investment costs and returns, and the risk of pasture establishment failure, are often viewed as barriers to adoption of higher stocking rate systems (Scott et al. 2000; Trapnell et al. 2006). The aim in this paper is to report findings about profit and risk from intensification of grazing systems in south west Victoria through investment in novel perennial pasture systems.

Analysing investment in improving pastures

Research questions

- What is the potential profitability associated with investing in the EverGraze pasture systems if the production benefits in the trials were achieved in a commercial farming system?
- What is the relationship between risk and return as a result of intensifying the grazing system through perennial pasture improvement?
- What is the effect of failure of pasture establishment on the potential profitability and risk?

Pasture investment options

In this analysis the EverGraze ‘Best Practice Perennial Ryegrass’ and ‘Triple’ improved pasture systems were investigated for a
representative farm. These two systems were analysed as alternatives compared to continuing current practice of pasture management of the ‘Base Case’ pasture system over time.

Experimental data for 2007, 2008 and 2009 enabled the economic and financial merit and the risk profile of the improved perennial pasture systems under seasonal variability to be tested. Full descriptions of the rainfall pattern for each year can be found in Table 1.

**Representative farm over time**

The representative farm approach to answering farming questions is well documented. Representative farms can be powerful, highly useful tools for analytical purposes, as long as the development of a representative farm is tied closely with the purpose of the specific research question, and typifies the farms and farmers under consideration (Elliott 1928; Becker 1963; Carter 1963; Malcolm 2004). Becker (1963) argues that whilst the exact outcomes from a representative farm will never be duplicated on individual farms, the relative effects of alternatives are demonstrated realistically and reliably. Carter (1963) pointed out that a potential short-coming of representative farm analysis is that they were usually static in nature, encompassing a single time period. Single year analyses of farm systems can represent ‘before’ and ‘after’ situations. However, the interesting part with major implications for management – the process of implementing changes to farm systems – is assumed away. Risk, too, is often overlooked. The limitations on the usefulness of farm analyses of ignoring development processes and the effects of time and risk can be profound. These limitations are avoided in this research by modelling the performance of a representative farm system over time, and through incorporating sequential change such as initial and subsequent capital investment, increases in carrying capacity, and allowing for intermittent good and poor seasons. This approach enables an element of real world dynamism to be introduced. The process of adopting the changed farm system is represented, and the operation of the farm can be changed in response to different circumstances over the whole of the relevant planning period. The information that results from this type of analysis enables decision makers and researchers to form well-informed, sound judgements about the technological change and the results of it for similar farm resources, systems and situations.

The representative farm of this analysis is a typical farm size for the south west region of Victoria, and has an effective grazing area of 1000 ha (Tocker et al. 2009; Tocker and Berrisford 2010; Tocker et al. 2010). All major characteristics of the representative farm were validated by the Hamilton EverGraze Regional Advisory Group consisting of local farmers and industry representatives as a ‘real world’ test of the assumptions used in the model. The farm was located in the high rainfall zone with average annual rainfall exceeding 650mm. Soils across the farm were assumed to have medium level fertility. The topography of the representative farm was assumed equivalent to that of the EverGraze experimental site at the Department of Primary Industries, Hamilton, with equal proportions of hill crest, slope and valley floors. Investments in pasture improvement was analysed for 100ha (10%) of the 1000ha representative farm.

A schematic of the model is shown in Figure 1. Information inputs (grey fill) are used to calculate enterprise feed gaps, gross margins and the partial budget discounted cash flow (dashed lines). Economic, financial and risk measures of each pasture investment option (solid line) are calculated.

**Animal enterprise and management information** The livestock enterprises of the representative farm are summarised in Table 2 and Table 3. The type and composition of each enterprise was designed to reflect current common practice in the 650mm-plus rainfall zone of the south west region of Victoria (Berrisford and Tocker 2009; Tocker 2010; Tocker and Berrisford 2010) Further details of each livestock enterprise are available in Lewis (2011).

Set stocking is still a common practice in the region, with recent data suggesting less than 40% of producers in south western Victoria implement any form of consistent grazing practices (Karunaratne and Barr 2001; Sargeant and Saul 2009).

The representative farm was set stocked at 16.2 dry sheep equivalents (DSE) per hectare consistent with benchmarked average stocking rate for the region ((Berrisford and Tocker 2009; Tocker and Berrisford 2010; Tocker et al. 2009). The DSE measure standardises livestock classes according to their energy requirements, based on the maintenance requirements for metabolisable energy of a mature 50kg Merino wether (Russell 2009).

Livestock feed demand was estimated in megajoules of metabolisable energy per
head per day (MJ ME/head/day) and energy needs were calculated using the ‘ME Required’ program for the midpoint of each month (CSIRO Plant Industry 2006). Changes in animal condition across the year were captured. Maintenance and growth requirements were calculated for all livestock classes, including allowance for the growth required for young stock to meet saleable weight by the date specified. Full details of the ‘ME Required’ inputs for this analysis are available in Lewis (2011). Total pasture demand in terms of kg DM/ha month was calculated from the MJ ME/head/day results. A feed gap was defined as when total pasture demand exceeded total pasture supply (Moore et al. 2009). When the ME required in terms of total pasture supply demanded exceed the ME available from the pasture, supplementary feed was supplied to meet the remaining animal energy requirements. There was no option to destock during the analysis period to counter the effects of a feed gap/shortage. Implicit in this is the notion that destocking and subsequent restocking would incur a capital loss similar to and approximated by the cost of retaining animals and buying extra supplementary feed during the poor seasons.

In the analysis, livestock were agisted off the 100 ha during the initial year of pasture improvement to allow for spraying and pasture establishment. In practice it is likely producers would graze stock intermittently during this period to improve pasture persistence (Sargeant 2009). The timing and length of these grazing periods will depend on seasonal conditions and preferences of management, so grazing benefits from this tactic were not accounted for in this analysis.

For the first year post-successful pasture establishment, the improved pastures systems were initially stocked at half way between the original stocking level on the Base Case pasture system (16.2 DSE/ha), and the new increased stocking level. This followed the approach taken by Scott et al. (2000). After this initial 12 month period, stocking rate was increased to the full production, steady state level and maintained for the remainder of the 12 year investment period for the 100ha.

**Pasture growth, nutritive value and management information** The description and source of the growth and quality information for each pasture system is outlined in Table 4. Further information on botanical composition of the sward and seasonal DM production over the experimental period is in Clark et al. (2012) and Ward et al. (2012). Pasture growth is described as kilograms of dry matter per hectare per month (kg DM/ha month). The nutritive value of pasture is described as metabolizable energy (ME) concentration, and is expressed as megajoules per kg of DM (MJ/kg DM). Metabolizable energy is the amount of energy available in a feed for an animal to use for maintenance, growth or reproduction. The ‘Base Case’ pasture system (Table 4) that was analysed was not a component of the EverGraze experiment. Biophysical modelling using GrassGro (Makki et al. 2001; Moore et al. 1997) was used to construct the expected growth of pasture and metabolisable energy figures for the ‘Base Case’ system over the three years for which EverGraze experimental data was available.

Total pasture availability in dry matter (DM) kg/ha month was calculated for the three pasture systems by combining the new growth in each month plus two thirds of excess pasture carryover from the previous month, as detailed in Moore and Zurcher (2005). A minimum pasture mass of one tonne dry matter per hectare was assumed to be present on all pasture before stock were introduced. This was unavailable to livestock, and was maintained in the analysis for the lifetime of the pasture systems.

For the ‘Base Case’ pasture system, all associated pasture maintenance practices as carried out in the Hamilton district were included in the analysis. This included annual fertiliser application of 14kg P/hectare, and periodic over-sowing via direct drilling of 10% of the farm per annum to maintain stocking rates (Reeve et al. 2000; EverGraze Regional Advisory Group 2009). It was assumed that stock continued to graze the system during all pasture maintenance activities on the ‘Base Case’ system.

Best practice for the district was applied to maintain the soil fertility of the improved EverGraze perennial pasture systems (Cayley and Quigley 2005). The improved perennial pasture systems had 0.9 kg P/DSE applied annually, with the total application per hectare depending on the stocking rate being tested.

The status of the improved pastures was maintained over the 12-year investment period with a renovation investment in year six. The different perennial species in the EverGraze systems were expected to persist to different degrees. For example, perennial ryegrass is sensitive to seasonal conditions.
and soil fertility and its persistence over the medium term can be problematic, whereas well managed summer-active Tall Fescue is expected to persist well (Clark et al. 2012). The perennial ryegrass portions of the improved perennial pastures systems were assumed to be oversown by direct drilling seed. Livestock were removed from the lucerne for 26 weeks to assist with successful renovation. The Tall Fescue was assumed to persist for the 12 year period, without renovation.

The ‘Triple’ system required winter cleaning of the Lucerne portion every three years. Winter cleaning involves spraying the lucerne stand with low rates of selective herbicide to remove annual grasses and reduce the soil weed seed bank (Naji 2006).

**Enterprise costs and prices information**

The variable costs and prices of each enterprise were combined with information about animal enterprise management, pasture growth, nutritive value and management information, to calculate enterprise gross margins for each combination of season and stocking rate tested. A composite animal activity gross margin for each pasture system was calculated according to the proportion of each activity in the farm system. These composite animal activity gross margins were used in the partial budget discounted cash flow analysis.

Farm variable costs from the 2009/2010 south west Victoria Livestock Farm Monitor results were assumed to apply for each enterprise (Table 5) (Tocker and Berrisford 2010) with the exception of the annual pasture maintenance and supplementary feed costs which were calculated in the model.

Supplementary feed costs were calculated independently for each livestock enterprise on each pasture system because of differences in matching pasture supply and demand, and were varied with stocking rate and seasonal conditions. A separate ration was calculated for growing and mature stock for each livestock enterprise. See Table 6 for the price assumptions about each ration component.

Total annual pasture maintenance costs for the ‘Base Case’ pasture system was $4.50 per DSE/year ($73/ha) with single super phosphate. Annual fertiliser application on the improved perennial systems equated to approximately $6.45 per DSE/year using super potash 3:1. Winter cleaning of the lucerne every third year cost $70/hectare for the ‘Triple’ system.

Prices used for the analysis (Table 7) were assumed to be the most likely values expected for the medium term, after consultation from the EverGraze Regional Advisory Group (EverGraze Regional Advisory Group 2009).

**Establishment costs**

Capital costs to establish rotational grazing included fencing, gates and water troughs amounting to approximately $12,000 for the 100 hectare development for each of the improved perennial systems.

Pasture establishment cost was approximately $350 and $380 per hectare for the ‘Best Practice Perennial Ryegrass’ and the ‘Triple’ respectively. These cost estimates included seed, herbicide, insecticide, fuel and fertiliser.

It was assumed existing farm labour and machinery was used to establish the pasture systems. The cost of agistment during the pasture establishment phase was included in the analysis.

When establishment failed, pasture was resown in year two. Lime was not reapplied, and the system was grazed for half of year two at the original stocking rate of 16.2 DSE/ha to align with common practice (G. Saul pers comm.). It was assumed that stock were agisted for 26 weeks during the re-establishment. Extra livestock required to raise stocking rates on the improved EverGraze systems were purchased and included as part of the total extra capital invested.

**Investment analysis**

The investment comparison was between the performances over time of the common practice ‘Base Case’. The measures of performances were annual and cumulative profit, cashflows and risk profiles of the farm system with investment in the alternative improved perennial pasture options as outlined in Lewis (2011).

In 1959 Gruen noted that shortages of finance or labour, combined with the need to remove stock from the grazing system during establishment to protect newly sown pastures, limited the area for pasture improvement that can be considered in any year. These factors remain true. Producers incrementally improve farm pastures. It was assumed in this analysis that 10% of the area of the representative farm, or 100 hectares, was being considered as a first step in pasture improvement for the representative farm. The 100 hectares consisted of equal areas of crests, slopes and flats.
The pasture investment involves adding capital to existing land, stock and other farm capital. A partial development budget was constructed, with a whole farm perspective (Malcolm et al. 2005). This approach includes all the extra benefits of the improved perennial systems, minus all the extra costs. The expected return on extra capital invested over the life of the project was estimated using discounted cash flow analysis (DCF). Nominal cumulative net cash flows are calculated to assess financial implications of the investment. The difference in expected persistence of the pasture species utilised in the EverGraze systems was incorporated in the analysis by running the analysis over 12 years.

Nominal internal rate of return (IRR) and net present value (NPV) at 8% nominal discount rate after tax were estimated for the improved perennial pasture investments over the 12-year period\(^1\). With much of the risk of the investment included in the budgeted numbers, and not the discount rate, this 8% nominal required rate of return per annum is similar to medium-term nominal borrowing rates or earnings in the share market. It is higher than less risky, medium term urban real estate or returns from risk free Commonwealth bonds (Malcolm et al. 2005). The criteria is that if the IRR exceeds the opportunity cost, and if the NPV is positive at the required rate of return, then the investment is more rewarding in economic terms than other alternatives that are available in the economy, and would likely be considered.

As well, cumulative nominal net cash flows (CNNCF) were calculated to identify the financial feasibility of the investment. The CNNCF was calculated after tax of 15% of the approximate annual taxable income with 3% per annum inflation and 8% per annum interest rate. The CNNCF shows the size and timing of peak debt, and time taken to return to positive net cash flow. In practice this information is interpreted in the context of the existing debt to equity state of the farm balance sheet, the debt servicing ability of the investment as 'stand-alone', the sources of additional debt servicing ability from other cash flow and the amount of equity that may be required to be invested.

In practice, information such as the measured potential economic and financial performance results is weighed up by decision-makers in the context of the operation of the whole farm system. This includes the range of goals and practical considerations and constraints that are not accounted for explicitly in the quantitative analysis.

**Risk analysis**

A key concern of producers when considering pasture improvement, particularly when less familiar grazing species are involved, is the possibility of establishment failure and the flow-on financial implications. The economic performance and financial feasibility of each improvement option was calculated for a range of seasonal conditions and for when pasture establishment was successful in year one, and for when establishment failed. The likelihood of pasture failing and the implications for the economic and financial returns from the investment is information for the decision-maker to evaluate.

Mean-standard deviation efficiency analysis, as detailed by Hardaker et al. (2004), was used in this analysis to assess the risk and net income associated with season type when investing in the improved perennial systems compared to the current ‘Base Case’ pasture system. Using results from a run of three actual and diverse seasonal scenarios, and projecting these into the future is one way of incorporating an estimate of the potential risk from seasonal variability. This reveals the effect of variability on the extra annual net cash flows for the improved perennial pastures investment. The expected value, in this case mean total annual gross margins from each pasture system, is plotted against the standard deviation of the annual total gross margins for each alternative. The information provides decision makers with a risk profile of each production system as a 100 hectare investment (Lewis 2011).

**Scenarios investigated**

The assumption in the analysis was that the performance of the pastures in the trials under the diverse seasonal conditions that occurred in 2007, 2008 and 2009 were reasonable representations of the likely range of all seasons that could occur in the future planning period. When the 1963 to 2011 Hamilton DPI rainfall data was considered,

---

\(^1\) The IRR indicates the return on capital invested over the life of each pasture investment, also termed the economic efficiency of the investment. The NPV represents the addition to investor’s wealth above what they would gain if they invested the capital involved in an alternative that earned at the rate of 8% nominal per annum.
total annual rainfall for the 2007, 2008 and 2009 seasons represent the 35th, 45th and 78th percentiles respectively as shown in Table 1. The rainfall total from April to December represented the 41st, 63rd and 69th percentiles. Note that no extreme rainfall scenarios, such as the 2006 year with an annual rainfall total representing the 6th percentile, were included in the analysis.

Firstly the 2007, 2008, 2009 season series was considered for the profitability analysis. For the mean-standard deviation analysis all scenarios outline in Table 8 were used.

The livestock enterprises and enterprise mix on the representative farm was the same for the three pasture systems (Table 2 and Table 3). Increases in stocking rate were on the improved perennial pastures. In practice it is likely that producers would run their most productive livestock on the improved area to maximise the potential of the new pastures, with this likely to be a short term tactical management decision influenced by market and seasonal conditions. Whilst the benefits of tactical management decisions are important, they were not the focus of this research.

A change in the nature of the feed supply can also lead to changes in individual animal performance (Marottie et al. 2002). The impact of this will depend partially on genetic merit, on animal response, and the environmental conditions experienced on the farm. It is difficult to determine the extent to which the livestock run on the EverGraze experiment may have been superior to the other livestock in the region. Given this it was assumed that production quantity and quality per head remained constant across all pasture options and stocking levels.

The stocking rate likely to be sustainable with the EverGraze systems at Hamilton across a range of seasonal conditions was estimated to be approximately 30 DSE/ha. It is well documented that the production levels reported in research experiments are unlikely to be achieved in a commercial environment (Davidson and Martin 1965), rarely exceeding 60-70% of experimental results. Through their own experience, producers involved in the EverGraze Regional Advisory Group indicated that the stocking rates managed by the experiment were achievable in the local commercial grazing environment with improved perennial pasture systems.

For this analysis, it was assumed that the management ability of these producers is well above the ‘typical’ operator for the region. Six stocking rates on the improved perennial pasture systems were tested as shown in Table 9 to account for variation in management ability and other factors that cause commercial farm results to differ from results seen under research conditions. These stocking rates were assumed to be run only on the 100ha of improved perennial pastures, not over the farm as a whole.

**Results**

A positive return on investment was seen for improved pasture systems at all stocking rates for the 100 hectare investment considered in this analysis when establishment was successful (Figure 2). A stocking rate greater than 16.2 DSE/ha was required to earn greater than the nominal opportunity cost of capital of 8% used in this analysis, if establishment failed in year one.

The improved EverGraze ‘Best Practice Perennial Ryegrass’ and ‘Triple’ systems returned a positive NPV at the 16.2 DSE/ha stocking rate of the ‘Base Case’ with successful establishment. The impact of establishment failure was greater at lower stocking rates, reducing potential NPV by up to 75% at 21 DSE/ha compared to 41% to 43% at the higher stocking rates of 30 and 36 DSE/ha, respectively.

Investment in the improved perennial pasture systems earned approximately 10 to 27% nominal return on extra capital invested over the 12-year period with successful establishment for the 100 hectares. This is above the opportunity cost of capital of 8% nominal return. The IRR results indicate a ‘tipping point’ for stocking rate in both systems between 30 and 36 DSE/ha with successful establishment. Increasing stocking rate beyond this point is likely to have a negative impact on the potential return from investment in the perennial pasture systems. Under the establishment failure scenario, the lowest stocking rate of 16.2 DSE/ha failed to return the opportunity cost of capital of 8%. The difference in the rate of return was negligible between the 30 and 36 DSE/ha stocking rates.

The improvement of pasture was able to service the debt incurred, if all capital invested was borrowed, as a ‘stand-alone’ investment if initial pasture establishment was successful. On average, enough extra annual cash flow was generated to meet the annual repayments of a 12-year loan at 8% interest if all funds required for the 100 ha pasture improvement were borrowed and pasture establishment succeeded. If establishment failed in year one, a stocking rate greater than 16.2 DSE/ha was required...
to fully service the debt required to fund the total pasture improvement including re-establishment costs in year two.

The net present value of the investment in new pastures increased with stocking rate in all scenarios (Table 10). The difference in NPV between the extremely high 30 and 36 DSE/ha stocking rates was negligible with added benefit of $13 to $37/ha with successful establishment. This was because the extra benefits of increased stock per hectare in the 36 DSE/ha system was negated by the rapid increase in supplementary feeding requirements per DSE at the higher stocking (Figure 3). The higher supplementary feed costs reduced the net benefits of the additional livestock capital invested. This is compared with the difference in NPV between the 16.2 and 21 DSE/ha of approximately $510 to $625/ha with successful establishment where no supplementary feeding was required at either stocking rate on the perennial systems.

The mean-standard deviation analysis was expanded to include six potential stocking rates. The average results of the two EverGraze systems were used for this analysis. Risk and return increased as the grazing system intensified. The single '2007, 2008, 2009' seasonal series results illustrated in Figure 4 shows that as stocking rate increased and the system intensified, the mean annual NCF increased. Concurrently, the standard deviation of steady state annual NCF increased.

A similar trend was seen when the mean-standard deviation analysis was conducted for the multiple seasonal scenarios, described in Table 8, at the six stocking rates as shown in Table 11. The spread of the mean-standard deviation results at the lowest stocking rate of 16.2 DSE/ha for the EverGraze system showed that investing in the improved pasture system has the potential to increase annual NCF whilst reducing the variability of this NCF when compared to the ‘Base Case’ scenario. This is without the need for extra livestock capital purchases.

As stocking rate was increased on the EverGraze system, the mean annual net cash flow increased concurrently with the volatility of annual net cash flow. For example, approximately 68% of annual net cash flows fell within $4,124 (one standard deviation) of the mean of $48,242 at a stocking rate of 21 DSE/ha, compared to the 30 DSE/ha stocking rate where approximately 68% of annual net cash flows fell within $9,837 of the mean of $57,458.

Discussion
Investment in either of the EverGraze ‘Best Practice Perennial Ryegrass’ or ‘Triple’ perennial pasture systems was profitable at all stocking rates tested with successful establishment for the 100 hectares analysed. The economic indicators of NPV and IRR showed that either system has the potential to return greater than the opportunity cost of capital of 8%, assuming that the production levels tested were achieved in a commercial environment. Returns increased with stocking rate because of greater extra net benefits per hectare, up to 30 DSE/ha for the case study analysed. These results are supported by previous pasture investment research which state that increasing stocking rates on improved pastures increases the profitability of the grazing system (Scott et al. 2000; Trapnell et al. 2006). Increasing stocking rate simultaneously with perennial pasture improvement was a profitable exercise for the two EverGraze systems analysed as 100 ha investments assuming successful establishment.

At the highest stocking rate, the decline in IRR results, and stabilisation of NPV, indicated a ‘tipping point’ in profitability between 30 DSE and 36 DSE/ha, based on the assumptions used for this representative farm analysis when establishment was successful. At this level of stocking, the additional supplementary feed costs negated the increase in extra income per hectare from the additional livestock capital invested. The result, shown in Figure 3, that supplementary feed costs increased at an accelerating rate for successively higher stocking rates is supported by Chisholm (1965) and Warn et al. (2006), both of whom identified similar trends. These results highlight the importance of maximising profitability, and managing risk, rather than maximising production per hectare when considering appropriate stocking rates for newly sown pastures.

Establishment failure had the greatest impact on potential profitability at lower stocking rates. For the scenarios analysed, if stocking rate was not increased beyond the 16.2 DSE/ha stocking rate (same as the ‘Base Case’) and establishment failure occurred in year one, both EverGraze systems failed to return a positive cash flow within the 12-year period analysed, assuming ‘most likely’ prices. These results are of particular importance given the use of perennial species in the EverGraze systems, as it has been previously noted that difficulties establishing
Lucerne was one of the main two barriers to adopting the species in the Glenelg region of western Victoria (Amirtharajah and Kearney 1996). The risk of failure to establish will be affected by the skills and resources of the each manager.

Income (average annual net cash flow) and income risk (standard deviation of net cash flow) increased at a diminishing rate as stocking rate increased on the 100 ha when tested under multiple seasonal scenarios (Table 11). These results agree with previous studies which demonstrate the economic phenomenon of increasing risk and return associated with increasing stocking rates (Chisholm 1965; Hardaker et al. 2004; Behrendt et al. 2006). For a risk-averse producer attempting to maximise utility, rather than profit, an increase in variability of climate will decrease the optimal stocking rate (McArthur and Dillon 1971). When choosing stocking rate, the extent to which higher average annual income is sacrificed to reduce variation in average annual income will ultimately depend on the risk profile of the individual producer (Chisholm 1965). Whilst the higher stocking rates were the most profitable over time and generated the greatest average annual NCF for this analysis, the parallel increase in the riskiness of income highlighted the inherent variability associated with intensifying livestock systems under seasonal variability.

Intensification of the grazing system by increasing stocking rate was not necessary for the perennial pastures to be profitable if establishment was successful under the conditions analysed, and maintaining the ‘Base Case’ stocking rate post pasture improvement reduced income risk. The change in the feed supply curve as a result of perennial pasture investment reduced the supplementary feeding requirements compared to the ‘Base Case’ pasture system. This resulted in the ‘EverGraze’ investments returning greater than the opportunity cost of capital, with the additional annual net cash flow generated able to service the debt of pasture establishment as a stand alone investment over the 100 ha. These results are supported by Moore et al. (2009) who state that management practices that can reduce the impact of feed gaps can greatly improve the profitability of a livestock enterprise by reducing supplementary feeding. Contrary to the previous findings of Trapnell et al. (2006) and current industry recommendations, these results indicated that investment in perennial pastures can be profitable without the need for increased stocking rates when a range of seasons are considered. However, it took 8 to 10 years for NCF to return to positive when the system remained stocked at 16.2 DSE/ha post establishment compared to 6 years when stocking rate was increased to 21 DSE/ha. No additional livestock capital expenditure post establishment was required for the 100 ha perennial pasture investment to be profitable if establishment was successful in year one. However, the time taken to return to positive NCF may limit the attractiveness of low stocking rates based on the representative farm scenarios analysed.

The assumption around renovation of the pasture systems in year six of the analysis was included to account for the phenomenon that sown pastures may not remain in their most productive state over the medium to long-term. The EverGraze reference group believed this assumption was conservative. In their experience, the group believed that the EverGraze systems could persist and maintain stocking levels for at least the 12-year analysis period without the need for renovation with appropriate management. This would increase the profitability of the systems and improve the time taken to return to positive NCF.

Conclusion

This analysis provided information regarding the benefits of changing the pasture base of a grazing systems in south west Victoria. The results suggest that the EverGraze pastures can be more profitable and less risky than the Base Case pasture at the pre-existing stocking rate of 16.2 DSE/ha because the need for supplementary feeding was reduced generally. It is anticipated that once the EverGraze pastures are established, the perennial pasture systems are likely to open up opportunities to further improve economic and financial performance compared to current common practice. More highly productive livestock enterprises can be adopted. For example, tactical management options such as fattening prime lambs prior to sale on summer active perennials such as lucerne.

Interpreting the results of this analysis requires caution. The complexity of higher stocking rate systems and the flexibility to respond to change within such systems are critical determinants of farm management success over the medium term. The potential risk and return reported here by adding new pasture systems and increasing stocking rate on 10% of the whole farm land area and

pasture supply will be different from the situation where a larger proportion of the whole farm system is transformed. So too will the implications for complexity and flexibility be different as intensification proceeds. Whether the financial buffer provided by the higher stocking rates outweighs the difficulties of managing more animals is a question that must be weighed up by the individual producer. Complexity of systems does not usually increase in a linear manner; neither do changes in flexibility in systems. For example, an increase in stocking rate on a small proportion of the farm sums to a marginal increase in stocking rate of the total farm. This has different implications for the whole farm system when compared to the same increase in stocking rate per hectare across most of the farm area, as the total increase in stock on the whole farm carried is much greater.

Transforming farm systems in major ways, such as large increases in total stock carried, involves some costs and benefits that can be measured and some which cannot. Costs associated with whole system complexity and inflexibility are not easily included in budget analyses (e.g., learning and the higher management skills required can be accommodated by a higher owner-operator allowance) but this is only part of the complexity story. The likelihood of major drought effects increase in proportion to total stock carried. Type of stock carried also matters. Major changes have greater implications for the balance sheet, especially gearing and exposure to debt servicing obligations, than minor changes. For each change and scale of change, the expected future balance sheet situation and associated cash flows and returns to extra capital invested, have to be calculated carefully.

The conclusion reached above, that these new perennial pasture systems can be an attractive investment, applies to the situation analysed - as a marginal change to a whole farm system. Further work will investigate the economic, financial and risk implications for a whole farm system when a more substantial proportion of the farm is transformed to utilize the EverGraze perennial pasture systems analysed in this research.

Acknowledgements
This article is based on a previous conference paper presented at the 18th International Farm Management conference New Zealand 2011. This work was supported by the Future Farm Industries CRC and the University of Melbourne. The authors would also like to thank the on-going input from the EverGraze Regional Advisory Group at Hamilton.

References


Cayley J and Quigley PE 2005, Phosphorus for sheep and beef pastures, Department of Primary Industries, Hamilton, Victoria.


CSIRO Plant Industry 2007, GrassGro™: Matching management goals with land capability, CSIRO Plant Industry, Black Mountain, ACT.


Elliott FF 1928, 'The "representative firm" idea applied to research and extension in agricultural...


Karunaratne K and Barr N 2001, *A baseline of adoption of pasture management practices: Glenelg Region*, Department of Natural Resources and Environment, Bendigo, Victoria.


Russell A 2009, *How to use Dry Sheep Equivalents (DSEs) to compare sheep enterprises*, Department of Primary Industries, Orange, New South Wales.


Sargeant K and Saul GR 2009, Practices and attitudes to grazing management of beef and sheep producers in southern Australia – results and recommendations for the EverGraze research and extension strategy, Unpublished manuscript, Department of Primary Industries, Victoria.


Warn L, Webb Ware J, Salmon L, Donnelly J and Alcock D 2006, *Analysis of the profitability of sheep wool and meat enterprises in southern
Appendix

Table 1 Description of the rainfall conditions for each year considered in the analysis

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
<th>Rainfall Percentile (1963-2001)¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>The total annual rainfall for the Hamilton region for 2007 was 800mm, well above the long term average of 683mm. The year was characterised by record rainfalls in January and November, and low October rainfall, with average conditions throughout the rest of the year. These late spring/early summer high rainfall events came at times when pasture growth was severely restricted. Lucerne, in particular, was able to respond after these rainfall events increasing pasture growth and production in summer and autumn (Makki et al. 2001).</td>
<td>Annual total: 78th&lt;br&gt;Apr-Dec: 69th</td>
</tr>
<tr>
<td>2008</td>
<td>In 2008, the total annual rainfall of 628mm was below the long term average of 683mm. Dry conditions were recorded for most of the year with particularly low rainfall recorded in October. This is with the exception of above average rainfall in July and December (Makki et al. 2001).</td>
<td>Annual total: 35th&lt;br&gt;Apr-Dec: 41st</td>
</tr>
<tr>
<td>2009</td>
<td>2009 had an annual total rainfall of 659mm, similar to the long term average of 683mm. The year began with record high temperatures and minimal rain, followed by a wet winter and poor October rains (Makki et al. 2001).</td>
<td>Annual total: 45th&lt;br&gt;Apr-Dec: 63rd</td>
</tr>
</tbody>
</table>

¹Rainfall percentiles calculated on data from the DPI Hamilton weather station from 1963 to 2011 (S. Clark, pers. comm.)

Table 2 Summary of representative farm sheep enterprise (adapted from Lewis 2011)

<table>
<thead>
<tr>
<th>Farm Area Grazed</th>
<th>Lambing Time</th>
<th>Percentage Sheep (%)</th>
<th>Main Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-replacing Merino</td>
<td>September</td>
<td>70</td>
<td>3.4 clean kg/head of 18.4 micron wool</td>
</tr>
<tr>
<td>800 ha equal to 80% of farm area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Merino x Terminal</td>
<td>July</td>
<td>30</td>
<td>41-45 kg live weight trade lambs at six months of age</td>
</tr>
</tbody>
</table>
Table 3 Summary of representative farm cattle enterprise (adapted from Lewis 2011)

<table>
<thead>
<tr>
<th>Farm Area Grazed</th>
<th>Calving Time</th>
<th>Main Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow-calf Angus</td>
<td>200 ha equal to 20% of farm area</td>
<td>April</td>
</tr>
</tbody>
</table>

Table 4 Description and source of data used in the representative farm model for the 'Base Case' and two improved perennial pasture systems

<table>
<thead>
<tr>
<th>Pasture Description</th>
<th>Pasture Growth (kg DM/ha day) and Quality (MJ ME /kg DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Case</td>
<td>Perennial ryegrass/Subterranean clover with capeweed pasture base in the Hamilton region. The simulation model GrassGro was run for the 2007, 2008 and 2009 seasons (Moore et al. 1997; Makki et al. 2001; CSIRO Plant Industry 2007;).</td>
</tr>
<tr>
<td>Triple¹</td>
<td>SARDI 7 Lucerne on the crest, Avalon Perennial Ryegrass on the slope and Quantum Tall Fescue on the valley floor (Makki et al. 2001; Shakya et al. 2012). 2007, 2008 and 2009 EverGraze experimental trial pasture supply fresh growth data (Makki et al. 2001; Shakya et al. 2012). The results reflected the theoretical on-farm potential performance of the pasture technology when managed as recommended including adoption of rotational grazing.</td>
</tr>
<tr>
<td>Best Practice Perennial Ryegrass¹</td>
<td>Fitzroy Perennial Ryegrass on the crest, Avalon Perennial Ryegrass on the slope and Banquet Perennial Ryegrass on the valley floor (Makki et al. 2001; Shakya et al. 2012).</td>
</tr>
</tbody>
</table>

¹All pastures were sown with Leura and Gosse subterranean clover as part of the pasture mix with the main sown species/cultivar.
Table 5 Variable costs ($/DSE) assumptions used in analysis for the sheep and cattle enterprises based on the 2009/2010 South West Farm Monitor results.

<table>
<thead>
<tr>
<th>Variable Cost</th>
<th>Sheep ($/DSE)</th>
<th>Cattle ($/DSE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal health</td>
<td>1.82</td>
<td>1.05, 2.611¹</td>
</tr>
<tr>
<td>Supplementary feed</td>
<td>Calculated²</td>
<td>Calculated</td>
</tr>
<tr>
<td>Pasture maintenance</td>
<td>Calculated</td>
<td>Calculated</td>
</tr>
<tr>
<td>Shearing supplies</td>
<td>0.19</td>
<td>-</td>
</tr>
<tr>
<td>Selling costs</td>
<td>2.45</td>
<td>1.57</td>
</tr>
<tr>
<td>Freight / Cartage</td>
<td>0.47</td>
<td>0.55</td>
</tr>
<tr>
<td>Repairs and maintenance</td>
<td>0.13</td>
<td>0.12</td>
</tr>
<tr>
<td>Contract services</td>
<td>3.94</td>
<td>0.09</td>
</tr>
<tr>
<td>Casual labour</td>
<td>0.02</td>
<td>0.24</td>
</tr>
<tr>
<td>Other</td>
<td>0.41</td>
<td>0.71</td>
</tr>
</tbody>
</table>

¹For ‘animal health’ costs in the cattle enterprise, the improved perennial systems attract an extra cost compared to the ‘Base Case’ pasture of bloat capsules. For this parameter, the first value represents the animal health variable cost used in the model for the ‘Base Case’ pasture followed by the cost including bloat capsules used for the improved perennial pasture systems.

²‘Calculated’ indicates that this cost per DSE varied with changes in stocking rate and/or changes in seasonal conditions, with the value ($/DSE) calculated in the model depending in the individual scenario being analysed.

Table 6 Supplementary feed cost assumptions for barley, lupins and pasture hay. Considered to be the most likely price levels for the medium term.

<table>
<thead>
<tr>
<th>Feed</th>
<th>Units</th>
<th>Cost (AU$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed barley</td>
<td>(AU$/tonne fed)</td>
<td>180</td>
</tr>
<tr>
<td>Lupins</td>
<td>(AU$/tonne fed)</td>
<td>200</td>
</tr>
<tr>
<td>Pasture hay</td>
<td>(AU$/tonne baled on farm)</td>
<td>81</td>
</tr>
</tbody>
</table>
Table 7 Commodity prices assumptions used in analysis for wool and livestock sales. Considered to be the most likely price levels for the medium term.

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Unit</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wool</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 micron fleece</td>
<td>(AU$/kg clean)</td>
<td>12</td>
</tr>
<tr>
<td><strong>Livestock</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trade lambs</td>
<td>(AU$/kg carcass weight)</td>
<td>4.40</td>
</tr>
<tr>
<td>Mature sheep</td>
<td>(AU$/head)</td>
<td>60</td>
</tr>
<tr>
<td>Cast for age ewes</td>
<td>(AU$/head)</td>
<td>55</td>
</tr>
<tr>
<td>Yearling steers</td>
<td>(AU$/kg carcass weight)</td>
<td>2.00</td>
</tr>
<tr>
<td>Yearling heifers</td>
<td>(AU$/kg carcass weight)</td>
<td>1.95</td>
</tr>
<tr>
<td>Mature cows</td>
<td>(AU$/head)</td>
<td>600</td>
</tr>
<tr>
<td>Cast for age cows</td>
<td>(AU$/head)</td>
<td>500</td>
</tr>
</tbody>
</table>

Table 8 Seasonal series used in the analysis. Each seasonal series was assumed to repeat four times across the 12-year analysis period.

<table>
<thead>
<tr>
<th>Seasonal Series</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007, 2008, 2009</td>
<td>This run of seasons was chosen as it is representative of true seasonal variability as seen by the EverGraze trial at Hamilton.</td>
</tr>
<tr>
<td>2009, 2009, 2008</td>
<td>2009 season was considered to be closest to a typical season for the district of the three years in terms of average annual rainfall, with 2008 included to represent poor farming conditions every three years.</td>
</tr>
<tr>
<td>2009, 2009, 2007</td>
<td>2009 season was considered to be closest to a typical season for the district of the three years in terms of average annual rainfall, with 2007 included to represent good conditions every three years.</td>
</tr>
</tbody>
</table>

Table 9 Stocking rates tested on the improved perennial pastures

<table>
<thead>
<tr>
<th>Stocking Rate (DSE/hectare)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.2</td>
<td>Equivalent to 'Base Case' pasture system rate and regional average¹</td>
</tr>
<tr>
<td>21</td>
<td>70% of experimental rate</td>
</tr>
<tr>
<td>24</td>
<td>80% of experimental rate</td>
</tr>
<tr>
<td>27</td>
<td>90% of experimental rate</td>
</tr>
<tr>
<td>30</td>
<td>Equivalent to experimental rate</td>
</tr>
<tr>
<td>36</td>
<td>20% above experimental rate</td>
</tr>
</tbody>
</table>

¹ (Berrisford and Tocker 2009; Tocker and Berrisford 2010; Tocker et al. 2009)
<table>
<thead>
<tr>
<th></th>
<th>EverGraze Triple</th>
<th>EverGraze Perennial Ryegrass</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stocking rate (DSE/ha)</strong></td>
<td>16.2 21 30 36</td>
<td>16.2 21 30 36</td>
</tr>
<tr>
<td><strong>Establishment success</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net present value @ 8% after tax ($)</td>
<td>6 424 61 386 123 811 125 165</td>
<td>15 327 69 943 121 899 125 584</td>
</tr>
<tr>
<td>Nominal peak debt with 8% interest after tax ($)</td>
<td>64 302 64 302 82 794 107 552</td>
<td>59 705 59 705 78 582 103 075</td>
</tr>
<tr>
<td>Year of return to positive cumulative NCF (Year)</td>
<td>10 6 6 7</td>
<td>8 6 6 7</td>
</tr>
<tr>
<td><strong>Establishment failure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net present value @ 8% after tax ($)</td>
<td>-32 110 15 297 70 703 74 213</td>
<td>-23 600 23 822 69 845 74 057</td>
</tr>
<tr>
<td>Nominal peak debt with 8% interest after tax ($)</td>
<td>101 333 103 696 123 696 135 723</td>
<td>95 372 98 846 117 062 132 684</td>
</tr>
<tr>
<td>Year of return to positive cumulative NCF (Year)</td>
<td>&gt;12 10 8 8</td>
<td>&gt;12 9 8 8</td>
</tr>
<tr>
<td><strong>Debt servicing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average annual extra nominal net cash flow after tax ($)</td>
<td>8 970 18 579 21 565 32 324</td>
<td>9 185 18 557 28 291 30 060</td>
</tr>
<tr>
<td>Annuity required for 12-year loan of peak debt @ 8% interest ($)</td>
<td>8 533 8 533 10 986 14 272</td>
<td>7 923 7 923 10 427 13 678</td>
</tr>
<tr>
<td>Establishment success</td>
<td>8 533 8 533 10 986 14 272</td>
<td>7 923 7 923 10 427 13 678</td>
</tr>
<tr>
<td>Establishment failure</td>
<td>13 446 13 760 16 414 18 010</td>
<td>12 655 13 116 15 534 17 607</td>
</tr>
</tbody>
</table>

Results calculated for 100 hectares over a 12-year period at four stocking rates with establishment success and with establishment failure. The seasonal series of 2007, 2008, 2009 was assumed to be repeated four times across the 12-year period. Most likely medium term prices and costs assumed.
Table 11 Multiple seasonal series mean – standard deviation analysis of steady state mean annual net cash flow ($) over the 100 ha investment before tax and inflation. Results are the average of the two EverGraze systems at each stocking rate.

<table>
<thead>
<tr>
<th>System and stocking rate (DSE/ha)</th>
<th>Mean annual NCF of multiple seasonal series ($)</th>
<th>Mean standard deviation of NCF of mult$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Case 16.2</td>
<td>29184</td>
<td>2,301</td>
</tr>
<tr>
<td>EverGraze 16.2</td>
<td>39235</td>
<td>1,419</td>
</tr>
<tr>
<td>EverGraze 21</td>
<td>48242</td>
<td>4,124</td>
</tr>
<tr>
<td>EverGraze 24</td>
<td>52183</td>
<td>6,828</td>
</tr>
<tr>
<td>EverGraze 27</td>
<td>55356</td>
<td>8,490</td>
</tr>
<tr>
<td>EverGraze 30</td>
<td>57458</td>
<td>9,837</td>
</tr>
<tr>
<td>EverGraze 36</td>
<td>59028</td>
<td>10,931</td>
</tr>
</tbody>
</table>

$^a$ See Table 8 for description of seasonal series used.
Figure 1 Stylized depiction of the representative farm model

The representative farm model used in this analysis is described in detail in Lewis (2011).

---

2 The representative farm model used in this analysis is described in detail in Lewis (2011).
Figure 2 IRR (%) results of the improved pasture systems analysis. Results calculated for 100 hectares over a 12 year period at four stocking rates with establishment success and with establishment failure. The seasonal series of 2007, 2008, 2009 was assumed to be repeated four times across the 12 year period. Most likely medium term prices and costs assumed.

Figure 3 Average annual supplementary feed cost per DSE for the EverGraze systems across the 2007, 2008, 2009 seasonal run at the various stocking rates tested.
Figure 4 ‘2007, 2008, 2009’ seasonal series mean – standard deviation analysis of steady state mean annual net cash flow ($) over the 100 ha investment before tax and inflation. Results are the average of the two EverGraze systems at each stocking rate.
Strategies for investment in the Australian macadamia industry: Development and evaluation of an objective investment appraisal software model

GJ Slaughter¹ and S Mulo²

¹ School of Accounting Economics and Finance, University of Southern Queensland, Toowoomba Qld 4350.
² Maroochy Research Facility, Department of Agriculture, Fisheries and Forestry, Nambour, Qld 4560.
Email: geoff.slaughter@usq.edu.au

Abstract. This paper describes the development and application of a dynamic financial appraisal software model, known as the Financial Planner for Macadamia. This whole farm financial model for macadamia farming integrates both the investment and financing decisions of project appraisal into a single software package. This enables the viability of potential investments to be evaluated in terms of net present value and internal rate of return, as well as the most appropriate financing options to ensure sufficient cash flows over the life of a project. Investment scenarios can also be directly compared and sensitivity analyses undertaken to provide further insights into the robustness of potential business scenarios over time. The Financial Planner for Macadamia was developed in response to the limited tools available to assist farmers, investors and financiers to make objective investment decisions in the Australian Macadamia Industry.

Keywords: Investment analysis, cash budget, profile comparison, sensitivity analysis.

Introduction

While macadamia nuts account for less than 3% of the world nut tree trade, Australia’s share of the market is around 45% making it the world’s largest producer (Australian Nut Industry Council 2012). The Australian macadamia industry has approximately 700 growers with more than 6 million trees in production. Australian production is between 35,000 to 40,000 tonnes of nut-in-shell per year and is worth nearly $A100 million at the farm gate (Australian Macadamia Society 2012). In 2007/2008 approximately 70% of Australian production valued at $A90 million was exported (Australian Macadamia Society 2012; Australian Nut Industry Council 2012).

Significant investment in the Australian industry has seen a fivefold increase in plantings since 1990 with demand for production still continuing to exceed supply (Australian Nut Industry Council 2012). However, in spite of strong demand there has been significant price variability for nut-in-shell at the farm gate (mean: $2.65/kg nut-in-shell; standard deviation: 67c) and objective financial data about industry returns has not been readily available (Australian Macadamia Society 2007, 2012).

The Australian Macadamia Society (AMS) the peak industry body in Australia identified the need for objective financial information about the costs and returns of macadamia farming from new macadamia growers and investors entering the macadamia industry. Many growers with existing farms also wanted to benchmark their costs and returns in order to determine which management practices and options would most improve their financial performance. In response to the need for objective financial data, the "On-farm Economic Analysis" (OFEA) project was initiated by the industry in 2003 to begin financial benchmarking of macadamia production in Australia (O'Hare et al. 2008).

Prior to the OFEA project, publicly available financial information for the Australian macadamia industry was limited to three main sources of information. Reilly and Bevan (1995) developed a computer model to assist growers to calculate the percentage return on their operation. Quinlan (2003) published gross margins for 3-, 7- and 15-year-old trees for a 20 hectare orchard in northern New South Wales. O’Hare et al. (2004) also included a gross margin for a 20-hectare 15-year-old farm in south-east Queensland or northern New South Wales. It is clear that these publications only provide information on a limited range of situations and do not allow current and prospective growers to input or benchmark their own financial information. While consultants within the Australian macadamia industry have also developed budgets for growing macadamias, these are not readily available to the wider industry.

Given that most of the financial information was out of date or not available to the industry, an update of financial information with clearly defined benchmarks that would be available to all stakeholders to support their investment decisions was regarded as a high priority. The objective of the resulting on-farm economic analysis project was to develop detailed and current benchmarks of costs, returns and general financial...
performance across the Australian industry to provide an objective basis for future investment in the industry.

**Materials and methods for model development**

The on-farm economic analysis project comprised two distinct stages. Firstly, financial and agronomic data were collected over four years and industry benchmarks established to provide an objective assessment of typical costs and returns for Australian macadamia growers. A key part of the benchmarking was the development of a standard chart of accounts in consultation with industry. The standard chart of accounts provided the basis for the consistent categorisation and measurement of farm financial information. This allowed farmers to directly compare their individual farm performance to industry benchmarks using standard metrics.

During the second stage of the project software was developed to utilise the financial and agronomic data collected in stage one in an integrated and objective way. The resulting *Financial Planner for Macadamia* software is a tool to objectively assess the viability of a wide range of macadamia farm business scenarios and forecast both investment viability and cash flows for periods of up to 30 years.

**Data collection**

Past work by members of the project team with the macadamia industry indicated that the quality and comprehensiveness of records between individual farms varied quite significantly. As such obtaining reliable financial data across the sample would be difficult. Depending on business structure and size, some farms were using cash-based accounting while others used accrual accounting.

Before embarking on the data collection stage, key performance indicators were established and standard classifications developed for financial data to ensure relevance to industry (Brown 1996; Ronan and Cleary 2000; Wilson et al. 2005). The project team held discussions with growers and accountants associated with industry to develop a standard chart of accounts, which was then integrated into existing macadamia farm management software (*MacMan*) previously developed by the project team. Members of the project team were also involved in ongoing extension work with industry best practice groups who widely used *MacMan*. The best practice groups were used to disseminate information about the OFEA project, data collection needs and to promote adoption of the standard chart of accounts.

The sampling and data collection methods were then selected based on their appropriateness and ability to provide an accurate representation of the underlying industry sample, given the nature of the study (Patton 1990; Heiman 2001). The project team had extensive experience in dealing with the macadamia industry and had information demonstrating that the best practice groups formed a representative sample of the industry in terms of farm size, orchard age, geographic location and management structure. As such the sampling frame was compiled from the industry best practice groups. Selection of respondents in the best practice groups was then undertaken through a judgemental sampling process. This was done to ensure respondents had accurate and up-to-date financial and agronomic data which could be readily collected by the project team. This approach is consistent with Malhotra (2010) and Aaker et al. (2010).

As awareness of the project increased along with increased adoption of the standard chart of accounts, data collection was expanded to the broader industry, again using a judgmental sampling process to ensure data availability and accuracy.

Given that the basis of the *Financial Planner for Macadamia* model would be analysis of cash flows, data gathered from accrual based accounting records were converted to a cash based system. This ensured that the cost categories and individual costs being obtained from the standard industry chart of accounts were based on cash flows and thus interpreted as the same items from business to business, allowing data to be benchmarked and direct comparisons to be made.

Data were gathered using a standard questionnaire either emailed or mailed to respondents on a six-monthly basis over the three years of the project. Returned data were checked for accuracy and entered into a purpose built database. Data were also validated by the project team to resolve any issues regarding accuracy in a systematic and timely manner.

By the end of the project, comprehensive financial and agronomic data were collected from 31 growers and 41 farms from 2003 to 2006 representing approximately 5% of the Australian macadamia industry in terms of production.
Design methodology

The Financial Planner for Macadamia was developed utilising the principles of the “Dynamic Systems Development Method” (DSDM), which is part of the larger family of “agile” development methodologies (Abrahamsson et al. 2002). In accordance with the agile paradigm, the project team acknowledged the value of industry representatives as primary drivers of the project’s success (Nerur et al. 2005). The core team comprised a software engineer, an accountant / agricultural economist and a macadamia agronomist. This team worked in collaboration with a steering group comprising four key industry stakeholders. The role of the steering group was to represent the needs of the client industry by reviewing progress, evaluating software functionality and establishing direction and priority for each successive stage of software development. In addition to the steering group, two industry reference groups were formed comprising macadamia industry members from the two major Australian macadamia producing states. These groups of stakeholders were closely and regularly involved with the development process to review functionality of prototypes and to ensure the suitability of the final software product.

By maintaining a strong user-centric focus and a flexible approach to software design, the project team aspired to rapidly deliver functionality that closely met user requirements (Highsmith and Cockburn 2001; Osterwalde 2004).

Instead of pre-determining the scope of functionality of the final product, the DSDM promotes the notion of a set project time and set resources with functionality adjusted within those boundaries (Stapleton 1997). Development phases are iterative and incremental and working results are delivered for client consideration and testing during each of the defined iterations.

Initially the concept and broad design specifications of the Financial Planner for Macadamia software were negotiated with the industry steering group at the commencement of the project. Entity relationship diagrams and spreadsheet based “proof of concept” prototypes were created to assist the steering group to understand the nature and scope of system to be developed.

Following agreement of the concept, software development during the remainder of the three-year project was conducted in iterative phases. Each phase included development, testing and documentation of agreed features and functionality followed by the release of prototypes to industry stakeholders, accompanied by appropriate training. Stakeholders would then use the prototypes for several weeks or more to assess functionality and report any issues as they arose. Specifications and features were then reviewed via facilitated sessions with stakeholders to identify issues and determine further development requirements. Requests for features were prioritised in conjunction with stakeholders and the project steering group prior to implementation. The final model structure and underlying functionality is described below.

Model structure

Users describe specific individual macadamia farm business scenarios by creating orchard “profiles”. Each profile contains a range of farm business information that represents one unique farm business scenario. After creating one or more profiles, users can assess their viability from either an investment or cash budget perspective. They can also compare investment options and undertake sensitivity analyses. Figure 1 shows the structure of the model.

Profiles Each profile includes detailed information about a specific farm business scenario including inflation, depreciation, taxation, initial costs, required rate of return, planting details, nut price estimates, annual costs, periodic capital and finance. Profile templates are available via the Internet and are used as the basis for creating all new profiles within the Financial Planner for Macadamia software. These templates reflect realistic industry scenarios based on data collected during the first stage of the project. Users choose a suitable template to create a new orchard profile, then customise the profile to reflect their specific situation. Profiles can be duplicated and customised to accommodate analysis of a wide range of scenarios. Profiles can also be imported or exported to facilitate sharing.

A relational database management system underpins the model to provide permanent storage for orchard profile data. The database structure is shown in Figure 2.

Price and yield models Production and price are two strong drivers of economic performance. These are also among the most variable and challenging criteria to forecast. The Financial Planner for Macadamia software includes a series of pre-defined yield and price models based on industry benchmarks, which can be used to
forecast future price and production trends. Users can also create their own models to reflect specific circumstances as required.

Price models forecast the price to be paid for nut-in-shell delivered to processors at industry standard moisture content (10%) and sound kernel recovery (33%). Models included in the software reflect a range of potential price scenarios including various rates of annual growth as well as significant positive and negative price adjustment phases due to market forces. Historical nut-in-shell prices are also included to provide actual industry trend data on which to base future price estimates (see Figure 3).

The Financial Planner for Macadamia software also includes models to estimate the yield potential of trees of various ages and planting densities. Pre-defined yield models built into the system are based on historical data collected as part of a national crop forecasting project (Mayer et al. 2006). Users can either select a specific price model themselves or alternatively the software can assign the most appropriate model based on planting density information within the orchard profile. Users can create and customise their own yield models to reflect specific tree performance criteria if required. Custom yield models can support a wide range of atypical or site specific yield scenarios including biennial bearing, yield decline in aging orchards or temporal effects associated with significant changes to management practices through processes such as canopy management, top working and tree removal (see Figure 4).

**Model analyses**

The Financial Planner for Macadamia software comprises four different analyses: investment, cash budgeting, profile comparison and sensitivity. These analyses can be used by investors or their agents to objectively assess the viability of specific farm business scenarios. They are also useful for existing growers who wish to measure the financial impact of proposed changes to their business over time, such as expansion, capitalisation, cost or revenue fluctuation, or physical changes to macadamia plantings through management strategies such as tree removal or canopy management.

The analyses incorporate relevant external factors such as inflation, depreciation, taxation and interest payable. Terms can span anywhere from 3 to 30 years and results are available in tabular and graphical formats.

**Investment analysis**

The investment analysis measures the profitability of specific investment scenarios over time using standard financial indicators such as net present value (NPV) and internal rate of return (IRR). As such, it allows investors to compare the viability of macadamia production with other forms of investment. It also provides a summary of cash flows, periodic capital expenditure and the present values of net cash flows on a yearly basis.

**Cash budget analysis**

The cash budget analysis is underpinned by the cash flow data in the investment analysis as well as specifically tailored budget data. The focus of this analysis is on the estimation of cash on hand at the beginning and end of each year, with detailed estimation and display of annual cash inflows and outflows from all sources. Farm business performance is analysed annually via a series of standard indicators such as profit/loss and income related ratios such as profit to income, expenses to income, debt to income and interest coverage ratio. Various indicators are calculated over the full analysis term including final cash on hand, cumulative principal and interest paid, minimum cash balance and final principal balance.

**Profile comparison analysis**

The profile comparison analysis compares and ranks the profitability of multiple profiles. To use this feature, users must first create two or more profiles, each of which can reflect a different business scenario. By creating individual profiles, users can model complex scenarios involving many dependent criteria. Once created, profiles can easily be cloned and modified to accommodate very specific management changes as required.

Up to ten profiles can be simultaneously compared and ranked according to their net present value or internal rate of return. Charts are also available comparing annual summaries for each of the profiles for a range of criteria including cumulative cash flow, net nut revenue, nut-in-shell price, operating expenses, present value (PV), profit, production and tax payable.

**Sensitivity analysis**

The sensitivity analysis allows users to adjust values for key criteria to measure their impact on profitability over the life of an investment. These criteria include yield, kernel recovery, annual costs, and nut-in-shell price. By adjusting threshold levels for any two of these criteria at a time, users can model the best and worst case outcomes for any given scenario. These

results can then be directly compared with the original or expected scenario.

The investment viability of each scenario is presented using indicators such as NPV and IRR. A range of annual output measures is available for each scenario including cumulative cash flow, net nut revenue, nut-in-shell price, operating expenses, present value, profit, production and tax payable.

In the two following case studies, the Financial Planner for Macadamia is used to demonstrate the additional returns from investing in supplementary irrigation. In the first case study, the software was used to replicate an actual investment scenario on a small macadamia farm to ground truth the concept. In the second case study the software was used to extrapolate the actual small farm data from case study one to a proposed larger-scale investment in supplementary irrigation.

**Case study one: supplementary irrigation versus no irrigation**

Throughout the development of the Financial Planner for Macadamia software, extensive testing has been undertaken to ensure the accuracy and reliability of results. The following case study demonstrates application of the software in evaluating an investment in supplementary irrigation on a small, 6-ha., 1,800-tree farm. The results are then scaled up to model the potential benefits of supplementary irrigation on a larger, 10-ha., 13,000-tree farm.

The aim of the initial analysis was to determine if investment in supplementary irrigation was worthwhile. Data were collected over seven years (2004 to 2010) from a small, 1,800-tree farm. Limited water supply meant only between 0.8 and 1.8 ML/ha. per year could be applied, so irrigation would only be supplemental over the production season. The analysis focuses on two 312-tree blocks, on one of which irrigation was installed (irrigation block) and on the other no irrigation was installed (dry block). Separate agronomic and financial records were kept for each block to allow direct comparison.

The analysis of the dry block versus the irrigated block was performed using the profile comparison analysis. The analysis shows the difference in the net cash flow between the irrigated and dry blocks over a seven-year period. The extra cost involved in both investment in the irrigation ($3,906) and additional running and maintenance are included in the analysis.

The financial and agronomic data were entered into the software to create a separate profile for each block. The price and production models used were based on actual market and production results for the seven-year analysis period. While these results appeared viable, a detailed investment analysis and forecast of net cash flows had not been undertaken prior to investing in the supplementary irrigation, so the Financial Planner for Macadamia provided these analyses.

The dry block control profile did not have any initial investment costs and as such the investment analysis yielded only a PV, whereas a NPV could be calculated for the irrigated block due to the initial investment costs associated with the irrigation infrastructure.

The comparison of yield between the dry block and the irrigated block (two sample one-tailed t-test, assuming equal variances) reveals that the yield of the irrigated block is significantly higher than the dry block at the 1% level (P=0.00). Figure 5 shows that the average yield difference over the seven years between the irrigated and the dry block was equivalent to 1.6 tonnes of nut in shell (NIS) per hectare. Even in the better performing higher rainfall years of the study period (e.g., 2006) the irrigated block had greater improvements in yield compared to the dry block.

Using a required rate of return of 5%, the NPV of supplementary irrigation was $31,947 compared to a Present Value (PV) of $15,529 for the dry block. The incremental NPV of the supplementary irrigation project was therefore $16,418, indicating a significant improvement in returns over the business as usual dry block, due to increased yields. The comparison of net cash flows between the dry block and the irrigated block (two sample one tailed t-test assuming equal variances) reveals that the yield of the irrigated block is significantly higher than the dry block at the 5% level (P=0.04). It is also apparent that the payback period for the investment in supplementary irrigation is less than one year. At the end of the seven-year period, the irrigated block has a cash balance of $41,516 compared to $17,380 for the dry block, a difference of $24,136. Figure 6 shows that the yearly difference in net cash flow was on average $2,890 higher per year with supplementary irrigation.

In case study one, the Financial Planner for Macadamia demonstrated that there were substantial financial benefits associated with
supplementary irrigation. The yield and net cash flows for the irrigated block were significantly higher than the dry block. Using a 5% required rate of return the investment in irrigation yielded a positive incremental NPV of $16,418. The supplementary irrigation system paid for itself in the first year with on-going financial benefits over the remaining six years of the investment analysis, confirming that the investment had been worthwhile.

Based on the results of the small farm in Case Study 1, the data were scaled up to assess the viability of an investment in a dam and supplementary irrigation on a larger, 10-ha., 3,000-tree farm.

Case study two: investment in supplementary irrigation, 3000-tree farm

Assumptions supporting case two study included:
- 20-year forecast based on findings from case study one trial.
- Input data scaled up for a 10-ha., 3000-tree farm.
- Assessment of impact associated with additional infrastructure costs (e.g., using finance to build a 15-Megalitre dam and other irrigation infrastructure).
- Yields from the dry and irrigated blocks in case study one are used as the basis for expected yields in the unirrigated and irrigated scenarios in case study two.
- Dam and irrigation infrastructure are fully financed with a principal and interest loan over 5 years and 6.43% interest per annum, reflecting approximate average market rates.

The business as usual unirrigated scenario has a present value of $141,593 over 20 years, using a 5% required rate of return. The proposed investment in irrigation amounted to $100,000 of which $40,000 was allocated for the construction of a 15-megalitre dam and $60,000 for irrigation infrastructure. These infrastructure costs were based on data from the OFEA project.

The analysis shows that that the extra income from the expected yield increases more than offsets irrigation costs, including the building of the dam and the installation of the irrigation system. The comparison between the business as usual unirrigated scenario and the irrigated scenario (two sample one-tailed t-test assuming equal variances) reveals that the net cash flow of the irrigated block is significantly higher than the business as usual scenario at the 1% level (P=0.00). The NPV of the investment in supplementary irrigation was $506,510 and thus an incremental NPV of $364,917 over the business as usual scenario without irrigation. The average difference in yearly net cash flow per hectare is $31,629 per year over the business as usual scenario. Therefore investment in supplementary irrigation will provide significant financial benefits over the business as usual unirrigated scenario. Figure 7 shows the difference in the net cash flows between each scenario for each year of the 20-year analysis period.

Sensitivity analysis (see Figure 8) reveals that even in a worst case scenario where the yield is 10% lower and costs 10% higher than expected, the investment in irrigation has a net present value of $322,307 using a 5% required rate of return. The incremental NPV over the business as usual unirrigated scenario for the 20-year analysis period is $180,714.

Facilitating adoption by industry

The client base for the Financial Planner for Macadamia software includes the peak industry body (AMS), Grower Liaison staff from the major nut processing companies, industry consultants and leading growers.

A preliminary survey of these stakeholders has revealed some significant impacts from its use.

The Australian Macadamia Society

Through consultation and training, Australian Macadamia Society (AMS) staff have adopted the Financial Planner for Macadamia software for strategic planning.

At the request of the AMS and Horticulture Australia Limited (HAL), a team was formed comprising staff from each of these organisations as well as members of the Financial Planner project team, to evaluate the potential impact of industry’s investment in research and development. The Financial Planner was used to assess the potential impact of specific projects in the research and development (R&D) program in areas such as disease management, canopy management and extension. The Financial Planner was also used to assess the overall impact of the whole macadamia industry research and development program.

Outcomes from these analyses were reported to Industry Reference Groups and the Research and Development Committee and the findings significantly influenced their...
planning processes and support for specific projects.

Quantification of potential industry impact for a range of projects also ensured maximum benefit from R&D investment and satisfied strategic planning requirements for industry and funding bodies. The outcome was optimum use of limited levy funding and matched investment from Horticulture Australia Limited exceeding AU $1M annually.

**Processors**

Four major Australian macadamia processors have adopted use of the *Financial Planner for Macadamia* software to help their suppliers identify key areas where investments can be made to improve production, quality and profitability. Grower Liaison staff in these processing companies are also using the *Financial Planner* to assess potential new investors to assess the viability of a range of investment scenarios in the macadamia industry. Interviews with processors indicated that usage of this nature has directly assisted decision making for more than 50 suppliers or new investors to date.

In some cases processors have published and distributed analysis results via their company journals, newsletters and field days for the benefit of all of their clients. Processors have indicated that information derived from their use of the *Financial Planner* has also informed broader decision making within their companies.

**Consultants**

Macadamia industry consultants are using the *Financial Planner* to assist existing client growers to evaluate farm business performance and further investment to improve their business operations. The survey indicated that some consultants are also using the *Financial Planner* to attract new investors and assist them by providing objective farm profitability information based on actual farm performance data.

**Growers**

The project team has facilitated adoption of the *Financial Planner for Macadamia* by key growers through Best Practice group meetings and training sessions. The team has also directly assisted key growers to create specific profiles to model a range of farm business scenarios using data that relates to their own business.

Several leading growers reported using the *Financial Planner* to assess the viability of potential investment scenarios in their own business operations. These scenarios include changes to capital expenditure or investment, expansion of plantings, estimation of future income for tree valuation and the impact of decline in mature trees. Growers also use the *Financial Planner* to measure the financial impact of a range of management scenarios such as tree removal or replacement, changes to harvesting, sorting and storage practices, employment of staff and replacement of machinery or infrastructure.

The results from many of these analyses have been published by leading growers in industry media and presented at events such as conferences and workshops. As such much of this work has had a significant flow on effect on decision making processes among the wider industry.

Further formal evaluation of the *Financial Planner* is currently underway to more specifically assess the extent and nature of its usage within industry and to facilitate further adoption among each of these industry sectors.

**Conclusion**

The *Financial Planner for Macadamia* software was developed in response to the limited financial analysis tools available to assist farmers, investors and financiers to make objective investment decisions in the Australian Macadamia Industry. Testing of the software has shown it to be a reliable, accurate and relatively straightforward model that can be used by potential investors and existing industry stakeholders.

The user interface allows industry stakeholders to quickly understand and use the software in a range of contexts without the need for complex spreadsheet or accounting skills. The software also enables decision makers to objectively assess the viability of potential management and investment options. The ability to generate reports from all analyses allows a portfolio of information to be created for borrowing and/or investment purposes. Automatic updates for the software are available online, with new profiles and industry data being updated periodically as a part of ongoing project work with the Australian macadamia industry.

The application of the software in the two case studies explored in this article demonstrates that productivity gains can lead to substantial cash benefits over the life of an orchard. Prior to the development of the *Financial Planner for Macadamia*, evaluating the viability of investment in supplementary irrigation was a time consuming process
requiring well developed financial and data analysis skills. Access to objective industry data has also previously been a limiting factor leading to potentially unreliable forecasts.

The case study examples in this article provide only a brief snapshot of two of the software’s potential applications, the profile comparison analysis and the sensitivity analysis. The Financial Planner for Macadamia can also be used to examine other scenarios such as purchasing an established orchard versus establishing a new orchard, tree removal and replacement in existing orchards and many other scenarios that may improve financial performance.

Application of the software by the AMS has provided an objective overview of the returns from investment in Research and Development for the industry overall and informed the strategic direction of the AMS’s research funding initiatives. Consultants, processor representatives and key growers are also routinely using the Financial Planner to inform decision making within their own businesses and on behalf of a wider client base.

In summary the Financial Planner for Macadamia software provides much needed transparency and objectivity in appraising investment opportunities in the macadamia industry as it has been developed in conjunction with the industry, for the industry. Collection of financial and agronomic data to maintain the currency of profiles and refinement of the model is ongoing as is extension and training work to increase industry adoption.

References

Aaker DA, Kumar V, Day DS and Leone RP 2010, Marketing research, 10th edition, Wiley and sons New Jersey, USA.


Brown MG 1996, Keeping score: using the right metrics to drive world-class performance, Quality Resources, New York, USA.


Malhotra NK 2010, Marketing research and applied orientation, 6th edition, Prentice Hall, New Jersey, USA.


O’Hare P, Stephenson R, Quinlan K and Vock N 2004, Macadamia grower’s handbook – a grower’s guide, Department of Primary Industries and Fisheries, Queensland, publication.


Quinlan K 2003, Macadamia gross margins, New South Wales Department of Primary Industries Agnote.


Appendix

Figure 1 Model structure

- Profiles: Each profile contains all the information required to describe a unique business scenario.
- Yield curves: Customizable series of curves projecting cash flows or potential according to a time-series.
- Price models: Customizable series of models projecting expected future price trends relative to a designated starting price.
- Historical prices: Historical data on real prices updated via the internet.
- Analysis module: Analysis of profile data and reporting of results both annually and over the life of an investment.
- Profile comparison: Comparison of performance across multiple profiles.
- Cash budget: Cash flows and annual cash on hand for a single profile.
- Sensitivity analysis: Analysis of relative impact of specific criteria over time for a single profile.
- Investment: Discounted cash flow analysis for a single profile.

Profile templates: Templates for users to create their own profiles, updated with updates available via the internet.
Marginal taxation rates: Updated with the planner with updates available via the internet.
Figure 2 Database structure

Profile
Each profile contains all of the information required to describe a unique business scenario

Plantings
Tree count, spacing, age, yield potential, kernel recovery

Partners
Name and percentage of ownership

Annual costs
Year, orchard stage, fixed costs, variable costs

Periodic expenditure
Year, cash, finance, lease, depreciation, payments

Finance
Year, description, cash in, cash out, finance amount, rate, term

Yield curves
Name, density

Price models
Name, start price

Annual data
Age, yield potential

Annual data
Year, price adjustment
Figure 3 Price model

Figure 4 Yield model
Figure 5 Yield comparison

Case study 1: Nut in Shell - Tonnes per Hectare

Figure 6 Net cash flow comparison

Case Study 1: Net Cash Flows

Figure 7 Net cash flows per hectare

Case Study 2: Net Cash Flows

Figure 8 Sensitivity analysis