Economic value of grazing inter-crops in the high rainfall zone of Southern Australia

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Agronomic management strategies that integrate crop and forage production over summer have the potential to simultaneously increase grain and grazing productivity in the HRZ. Traditionally paddocks are phased from forage to grain production over winter and spring. However, the alternative of inter-cropping forages is expected to reduce 'paddock down time' between crop and pasture, increase stubble feed quality for livestock over summer, and improve soil conditions for grain production. This paper presents a whole-farm biophysical model and farm economic analysis, which were used in combination to determine the productivity and profitability potential of a prime lamb enterprise compared to mixed farming systems that include various forage species grown as an inter-crop with wheat and canola. This analysis showed intercropping was a profitable option for this farm business in south-west Victoria by increasing returns on total capital invested accompanied by a reduction in the variability around such returns. Intercropping with arrowleaf clover or lucerne were the most profitable intercropping options assessed.
Key Words crop modelling, economic risk assessment

Introduction
This paper focusses on arable land in the high rainfall zone (HRZ) of Victoria (annual rainfall > 500mm). This region has experienced significant structural adjustment over the past 25 years, with an increase in cropping and mixed farming systems. Since 1990, the gross value of cropping has increased by 410% in real terms from a low base to $235m, and gross returns from sheep meat has increased by 9% to $502m.

Livestock and cropping enterprises can provide dual income to a farm helping to mitigate against adverse fluctuations in seasonal and market conditions and provide potential benefits to both grazing and cropping enterprises. Agronomic management strategies that integrate crop and forage production over summer have the potential to simultaneously increase grain and grazing productivity in the HRZ. Traditionally paddocks are phased from forage to grain production over winter and spring. However, the alternative of inter-cropping forages, is expected to reduce 'paddock down time' between crop and pasture, increase stubble feed quality for livestock over summer, and improve soil conditions for grain production (less waterlogging, stubble burden, improved nitrogen availability). Furthermore there are also economic benefits from providing high quality feed over summer, potentially enhancing the supply of out of season lamb which could attract premium prices, or conditioning of breeding stock to improve conception rates. Consequently, productivity and profitability are expected to be greater with a well-integrated crop-livestock system at a whole-farm scale. This paper presents the results of a whole-farm biophysical model and farm economic analysis aiming to quantify the productivity and profitability potential of a prime lamb enterprise compared with a mixed farming system, including various forage species which have been grown as an inter-crop with wheat and canola.

Methods
The CAT (Catchment Analysis Tool) model was used to generate the data required to feed into the economic model of this study. CAT simulates biomass accumulation based on extensively used contemporary models (Christy *et al*. 2013) and is readily applicable across all Victorian landscapes (Weeks *et al*. 2008). The biophysical modelling was based on available datasets which encompass the Lamb Directions Case Study 2 farm (Tocker *et al*. 2014), with a total farm area of 950ha, located near Penshurst, in south west Victoria. Local historic climate information, landscape and soil conditions were incorporated, resulting in simulated agricultural productivity relative to that location. The baseline scenario was the Lamb Directions 'Base Farm' where prime lambs were produced from a mix of pasture combinations (740ha of improved pasture, 150ha of lucerne pasture and 60ha of a forage brassica crop). In all scenarios the lucerne and improved pastures were available to stock continuously unless supplementary feeding was required.

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A number of whole farm scenarios were run for 50 years (1960-2009), to enable calculation of the economic advantages or disadvantages of incorporating crops into the farm. Crops were incorporated as either monocultures or intercropped with legumes (Table 1) at a range of adoption rates (Table 2).

Crop adoption for each scenario was the total area sown to wheat and canola each year, which were 5%, 10%, 15%, 20% and 25% of the total farm area. However, the area allocated to cropping on the farm is double this, as crop and pasture phases were rotated in each scenario (Table 2) to maintain the legume component in the intercropped scenario (Zhang 2004). This was balanced by reducing each of the 'Base Farm' pasture components proportionally. The area of 'land changed' for each scenario was split into four equal areas to allow a 4 year crop rotation (Table 1). Four different legumes were considered in the intercropping phase of this study, lucerne, strawberry clover, balansa clover and arrowleaf clover. These include prostrate and tall growing varieties, which may affect grain quality at harvest, and differing growth patterns affecting the supply of feed to livestock. Grazing of the crop rotation paddocks (including crop stubbles) was allowed after crop harvest until the sowing of the following crop, based on feed availability.

Table 1. The area of 'land changed' for each scenario was split into four equal areas to allow a 4 year crop rotation with each crop phase proportionally represented in each year (W=wheat, C=canola, P=Clover and Rye grass pasture, Lg=Intercrop legume (either lucerne, strawberry, balansa, or arrowleaf clover depending on scenario), W/Lg= intercropped wheat, C/Lg=Intercropped canola)

Year	Crop monoculture scenario				Crop and legume intercrop scenarios			
	Paddock1	Paddock2	Paddock3	Paddock4	Paddock1	Paddock2	Paddock3	Paddock4
1	W	C	W	P	W/Lg	Lg	C/Lg	Lg
2	P	W	C	W	Lg	C/Lg	Lg	W/Lg
3	W	P	W	C	C/Lg	Lg	W/Lg	Lg
4	C	W	P	W	Lg	W/Lg	Lg	C/Lg

Table 2. Area of farm allocated to each vegetation type for the 50 year modelled scenarios. 'Pasture' component was a mix of perennial ryegrass and clover, 'Brassica' was a forage brassica sown in spring and grazed in December and January to finish lambs, 'Land changed' was a four paddock crop rotation(see Table 2) with each phase represented in every simulation year.

Scenario	Lucerne	Pasture	Brassica	Land changed
Base Farm (ha)	150	740	60	0
5% cropping (ha)	135	666	54	95
10% cropping (ha)	120	592	48	190
15% cropping (ha)	105	518	42	285
20% cropping (ha)	90	444	36	380
25% cropping (ha)	75	370	30	475

Each scenario was run for a 50 year period, 1960-2009, matching the original case study modelled dates. Stocking rates were adjusted from the case study base farm using the criteria that the amount of supplementary feed used by the farm was the same over the 50 year model run. Lambing percentages relative to the stocking rate were set for each year based on that year's seasonal conditions. Average ewe live weights were 65kg. Lambs were sold at 48kg live weight. Ewes were joined on 2 March, to lamb on the 29 July, and weaned on 1 December. Ewes were shorn on 17 January and weaners on 10 December. Wool cut from the ewes was 4.5 kg/head and 0.9 kg/head for lambs (Tocker *et al*. 2014). Data supplied to the economic modelling for each year included total ewe and lamb numbers, numbers of animals sold, wool sold, grain yields (wheat and canola) and supplementary feed purchased.

The whole farm economic analysis model used the biophysical modelled production outputs, combined with price and cost information to generate annual whole farm budgets, using the method described by Tocker *et al* (2013). Key prices and costs for lamb meat, wheat, canola and supplementary feed price, were represented by probability distributions to reflect the variability in costs and prices paid and received by farmers. These different quantities of inputs used and outputs produced, coupled with different prices and costs modelled over many different combinations (10,000 iterations using @Risk, an add-in software package to Microsoft Excel) enabled a distribution of farm business performance to be calculated. The performance of the base farm system and each alternate farm system scenario was assessed to compare profit and efficiency (economics), debt servicing (finance), additions to wealth (wealth), and business and financial risk (risk analysis).

Results

The results of five development options are presented: a monoculture cropping rotation, and four crop-intercrop rotations incorporating strawberry clover, balansa clover, arrowleaf clover and lucerne with performance of each option being considered relative to the base farm (a grazing enterprise producing prime lambs). Figure 1 shows box and whisker plots for return on total capital (marginal internal rate of return, in real terms) for the base farm (100% pasture), and a 20 % cropped area for each of the five development options. The relative changes resulting from the five development options followed a similar pattern at each level of adoption. The base farm generated an average return on total capital of 5.9%. Planting 20% of the farm into a cereal crop rotation reduced the variability in returns, but also decreased returns slightly, compared to the base farm. All intercropping rotations generated higher returns than the base farm and monoculture cereal crop options. The variability in intercropping returns were also slightly less than for the base farm. Of the intercrop species arrowleaf clover and lucerne gave slightly better returns.

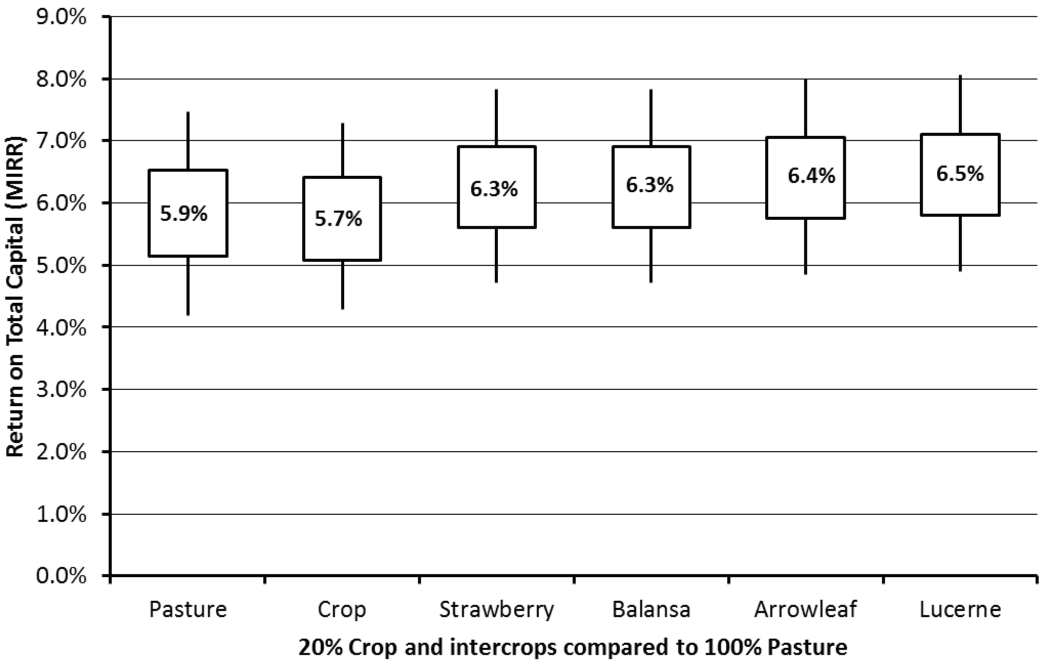

Figure 1. Box and whisker plot (mean, 5,25,75 and 95 percentiles) of return on total capital (marginal internal rate of return, in real terms) for the base farm (100% pasture), 20% of the farm in crop, and 20% intercrop rotations for strawberry clover, balansa clover, arrowleaf clover and lucerne.

A comparison of return relative to risk and planting different proportions of the farm into crop and crop-intercrop rotations for each species is shown in Figure 2. As the area sown in pure crop increased the return on total capital decreased, due to a profitable prime lamb system being substituted for a slightly less profitable cropping system, based on what was considered realistic production for the case study farm. The level of risk, measured as the coefficient of variation in return on total capital also decreased, partly due to the increase in diversification in income streams from crop and sheep, thus reducing the variability around income and costs. For the intercrop options, as the area sown increased, return increased and risk (CV) decreased. Being able to maintain higher sheep numbers than a pure cropping system and also receive cereal crop income enabled for the higher returns, and diversification helped reduce variability. Using the 25% lucerne/cereal intercrop scenario for the farm (for each year this equates to 25% of the area as lucerne and 25 % as lucerne/cereal intercrop in rotation totalling 50% of the farm) gave the highest return on total capital of the options modelled, with approximately 6.8%. Arrowleaf clover and lucerne gave the highest returns relative to level of variability in returns.

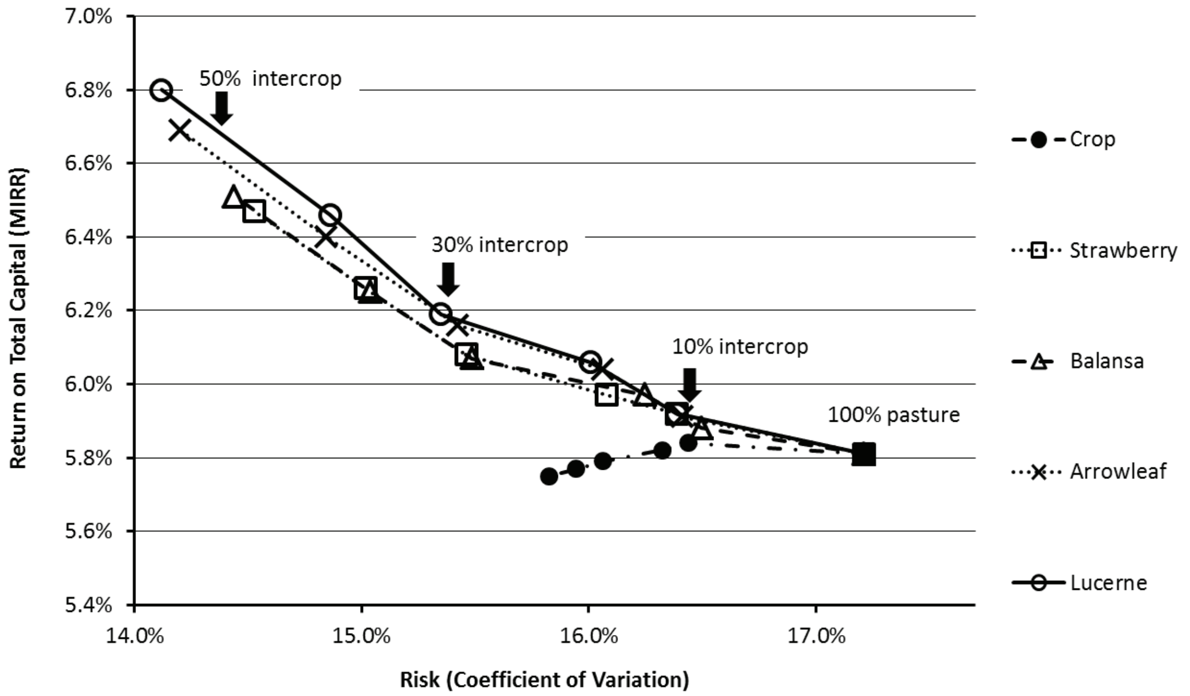

Figure 2. Return on total capital (marginal internal rate of return, in real terms) versus risk (coefficient of variation) for the five development options: cereal crop and each intercrop option at different adoption rates.

Conclusion

This study shows intercropping is a profitable option for the case study farm located in south-west Victoria. The practice increased returns on total capital invested and reduced the variability around such returns. Intercropping with arrowleaf clover or lucerne were the most profitable intercropping options assessed.

In term of risk, measured as the variation in annual economic returns, all intercrop options showed a decrease in risk along with an improved return on capital with increasing adoption. Although this appears to be a 'win-win' solution, these results only represent one location. We expect that the risk and return matrix of results would change in different climates and locations, especially in drier environments.

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