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Impact on farm profit from incorporating perennial pastures in the rotation of crop-livestock enterprises in southern New South Wales

Base model scenarios for lucerne, chicory and perennial grasses

Future Farm Industries CRC Technical Report 5

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This report is based on MIDAS SNSW Model 10 (Version 2t)

Future Farm Industries CRC aims to transform Australian agriculture and rural landscapes by developing and applying Profitable Perennials™ technologies to innovative farming systems and new regional industries.

EverCrop Uniform Rainfall Zone

Impact on farm profit from incorporating perennial pastures in the rotation of crop-livestock enterprises in southern New South Wales (1) Base model scenarios for lucerne, chicory and perennial grasses

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Executive summary

The CRC Future Farm Industries project "EverCrop" is examining the potential expanded role of perennial pastures in cropping systems of the uniform medium rainfall zone of southern New South Wales (NSW) and northern Victoria. Perennials of interest include the widely-used lucerne, and the relatively new species of chicory and new varieties of summer dormant phalaris and cocksfoot.

Whole-farm bioeconomic modelling using the MIDAS (Model of an Integrated Dryland Agricultural System) model was used to estimate the economically-optimal upper limit of such perennials on representative farms of the target region. A MIDAS version (MIDAS SNSW Model 10, version 2t) was set up for the uniform rainfall zone 450-550mm centred around Coolamon, southern NSW with 4 land management units with crop and pasture rotations involving wheat, barley, lupins, canola, field peas, mixed annual pasture (based on subterranean clover) and perennial pasture species adapted to the region (lucerne, chicory, phalaris and cocksfoot). A prime-lamb producing livestock enterprise was assumed. Commodity prices and input costs typical of 2009 were assumed.

This technical report is the first in a series of reports that establishes baseline pasture options which will be used in subsequent model runs. Model runs were conducted for 5 different pasture options in rotation with crops:

(1) Annual pasture (subclover-based), no perennials
(2) Annual pasture plus lucerne
(3) Annual pasture plus lucerne and chicory
(4) Annual pasture plus lucerne and perennial grasses (phalaris, cocksfoot *etc*)
(5) All perennial pasture options (annual pasture + lucerne + chicory + perennial grasses)

The predicted farm profit for a typical 1000 ha property containing 4 soil types is summarised below for various perennial pasture-crop options and compared to a system containing no perennial pasture species. The area of pasture, crop, stocking rates, area of grazed crop and the amount of supplementary feeding required for each option is presented in Table 1.

Table 2 shows the most profitable rotation selected for each of the 4 soil types (LMUs) on the model farm when different perennial pastures are used. Other rotations may be selected in some cases with little change in profit and these rotations should only be considered a guide to possible pasture crop rotations.

The model found that the largest improvement in farm profit, equivalent to a 30% increase, resulted from the introduction of lucerne to the farm rotation. Adding chicory or perennial grasses to a lucerne-crop rotation increased profit by a further 4-5%. A rotation containing all 3 perennials (lucerne, chicory and perennial grasses) was the most profitable with profit being 41% greater than a farm relying on an annual pasture-crop rotation. Only a relatively small area of chicory (24 ha) and perennial grass (66 ha) was required to maximise profitability. The optimum area of crop on farms with perennials in the rotation was estimated to be 57%-60% which is similar to current land allocations to crop on farms in the target region.

Stocking rates increased by up to 40% with the inclusion of perennial pasture species in the rotation. The area of grazed cereal crop increased slightly with perennials as did the amount of supplementary feeding required. Although these increases were only slight compared to the increase in stock numbers, the increase can be attributed to the variation of feed on offer

(FOO) at different stages of the year. This enabled livestock access to changes in feed quality and quantity during different stages of their growth patterns that created better utilisation of the feed base.

Stocking rates predicted by the model are higher than most farmers achieve as the model assumes full utilisation of feed grown and no variation in growing conditions between years. Farmers generally reduce stocking rates to allow a buffer against poor seasons and rarely consume all feed grown. Although predicted stocking rates are higher than present on most farms the relative change in farm profit between the different pasture options is still a reasonable guide to the impact of the different rotations.

The model shows the increased farm profit resulting from including lucerne in the farm rotation and further increases in profitability can be achieved by including relatively small areas of chicory or perennial grasses and without significantly changing the area under crop.

Table 1: Changes in farm profit and key criteria from inclusion of perennial pastures into the pasture crop rotation on 1000 ha farm.

Key statistics	Option 1	Option 2	Option 3	Option 4	Option 5
	Traditional Annual pasture	Annual + lucerne	Annual + lucerne + chicory	Annual+ lucerne + per grass	Annual+ lucerne+ chicory + per grass
Farm profit	$147,000	$191,000	$200,00	$198,000	$207,000
Total area pasture (ha)	300	403	433	440	436
Lucerne	-	281	267	272	246
Chicory	-	-	44	-	24
Perennial grasses	-	-	-	68	66
Annual pastures	300	122	122	100	100
Total area of crop (ha)	700	596	566	560	565
Wheat	250	228	227	232	234
Canola	150	123	113	116	117
Barley	150	123	113	116	117
Pulse	138	122	113	96	97
% Farm under crop	70%	60%	57%	56%	57%
Av stocking rate per grazed ha (DSE)	10	13.5	12.8	14	13.8
Stocking rate whole farm (DSE)	3	5.4	5.5	6.7	5.9
Area grazed crop (ha)	100	106	113	116	117
Supp feed (Tonnes)	127	113	120	139	140

Table 2 Baseline optimal rotations with associated areas for the 5 pasture options*

LMU**	Option 1		Option 2		Option 3		Option 4		Option 5	
	Traditional Annual pasture		Annual +lucerne		Annual +lucerne + chicory		Annual + lucerne + per grass		Annual + lucerne + chicory + per grass	
	Rotation	ha's	Rotation	ha's	Rotation	ha's	Rotation	ha's	Rotation	ha's
1	20PA	100	20PA	100	20PA	100	20PA	100	20PA	100
2	5PWCWB	50	5PCWLB	50	5PWCWLB	50	5HWCWB	50	5HWCWB	50
3	3PWCWB	200	3UWCWLB	132	4UWCWLB	83	3UWCWLB	100	4UWCWLB	85
			WCBL	68	4YWCWLB	117	4HWCWB	100	4YWCWLB	19
									4HWNB	96
4	3PWCWLB	260	4UWCWLB	650	4UWCWLB	650	4UWCWLB	650	4UWCWLB	590
	3PWCWB	390							3YWCWLB	60

* Numeral, Pasture years; PA, Permanent pasture; Y, Chicory; U, Lucerne; H, Perennial summer-dormant grass; W, Wheat; C, Canola; B, Barley; L, Lupins; P, Annual pasture.

** LMU 1, Non-arable Tenosols; LMU 2, Grey Vertosols; LMU 3, Light Red Kandosols and LMU 4, Red Chromosols (see Description in Table 1).

Subsequent model runs will investigate a range of different scenarios including:

1. Explore how rotations change with soil types?
2. Assess the impact of changing lambing times on profit and pasture options.
3. Determine the magnitude of change in livestock to crop prices required before fundamental changes in rotation and enterprise mix occur.
4. What impact do changing input costs (fuel, fertilizer and chemicals) have on the optimum farm enterprise mix?
5. How will different climate scenarios change optimum pasture-crop mix on farms in the future?
6. How do fluctuations in year to year seasonal conditions change profit variability and indebtedness for different pasture-crop enterprises.

Introduction

MIDAS (Model of an Integrated Dryland Agricultural System) is a linear programming (LP) model that represents the biological, physical, technical and managerial relationships of a mixed farm that is representative of production systems within a defined region. The model allocates available resources in order to maximise the objective function of whole-farm profit, subject to resource, environmental and managerial constraints (Bathgate and Pannell, 2002). It is a comparative static framework, which implies the dynamics of changing from one state to another are not captured. Seasons are not explicitly described, however the model 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.

There are a number of implicit assumptions that underlie LP models (Hazell and Norton, 1986). Some of these assumptions define the linearity within activities of the model, which is seen as a major limitation of using LP to represent biological systems that are typically non-linear in nature. However there are a range of model structures that can be employed to increase the flexibility of LP models. For example, non-linear response functions can be estimated using linear piecewise approximation (e.g. Vandeputte and Baker, 1970). A more detailed discussion of this issue can be found in Chapter 2 of Hazell and Norton (1986).

A comprehensive description of MIDAS can be found in Kingwell and Pannell (1987). Modifications of the model have been made over time to refine relationships to better reflect production. Changes to the model are described in Morrison and Bathgate (1990), Bathgate and Pannell (2002) and Bathgate (2005).

Versions of MIDAS have been developed for each of the southern mainland states of Australia. Whilst the general structure of the different versions is similar there are differences in activities and parameter values that reflect the inter-regional variation in climate and production systems. The results in this report are based on The Coolamon model to which additional pasture options of chicory and perennial grasses have been added. The revised model is referred to as SNSW Model 10 (Version 2t).

A major strength of the approach taken in the development of MIDAS is that temporal interactions between enterprises are captured. A number of studies (e.g. Pannell, 1987) have demonstrated the importance of these interactions in the selection of the optimal enterprise mix. Disease break effects in cereals resulting from growing a pulse crop and the influence of crop sequence on herbicide and fertiliser costs are example of such interactions. Additionally, the model is structured such that the interactions between production activities within a year are simultaneously considered in enterprise selection. For example, the selection of the optimal grazing strategy depends on weighing up the availability and quality of pasture for a given period, the effect of grazing pasture on a given part of the farm on the growth rate of pasture on other parts of the farm and hence the future availability of pasture from all pasture paddocks. This needs to be considered simultaneously with the overall influence that grazing strategy has on wool growth, wool quality and sheep liveweight.

Region

Figure 1 shows the study region in southern New South Wales. It is roughly bound by the 450 mm and 550 mm rainfall isohyets and ranges from Grenfell, Cowra and Ariah Park in the north to Holbrook and Brocklesby in the south. The region was defined by rainfall and soil types.

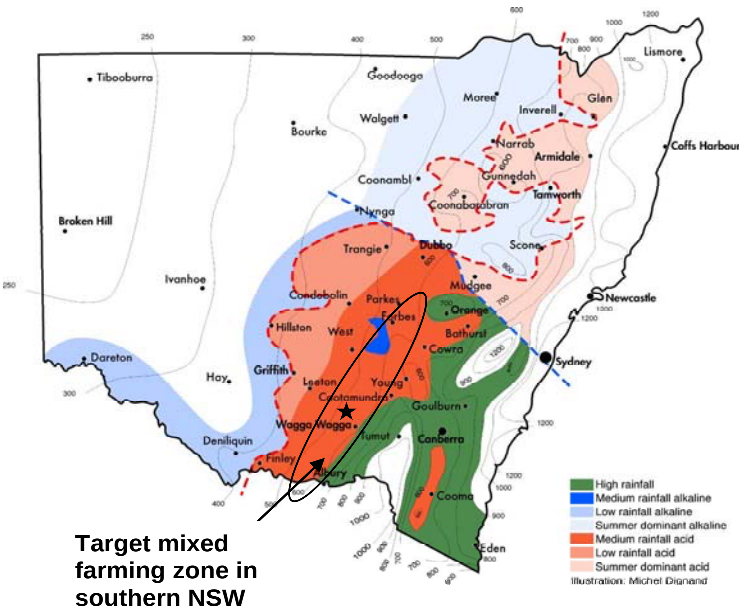

Figure 1: 'Footprint' of the Coolamon version of MIDAS

Rainfall ranges from uniformly distributed in the northern part of the study area to more winter dominant in the southern areas. A significant proportion of rainfall can fall in the warmer months between December and April (Figure 2). Whilst the summer rainfall makes the region suitable for summer active perennial species, the rainfall in all months is quite variable, compared to other agricultural regions in southern Victoria and south-west of Western Australia. This would lead to a less reliable feed supply posing a greater challenge to farmers to match supply and demand for energy for livestock production.

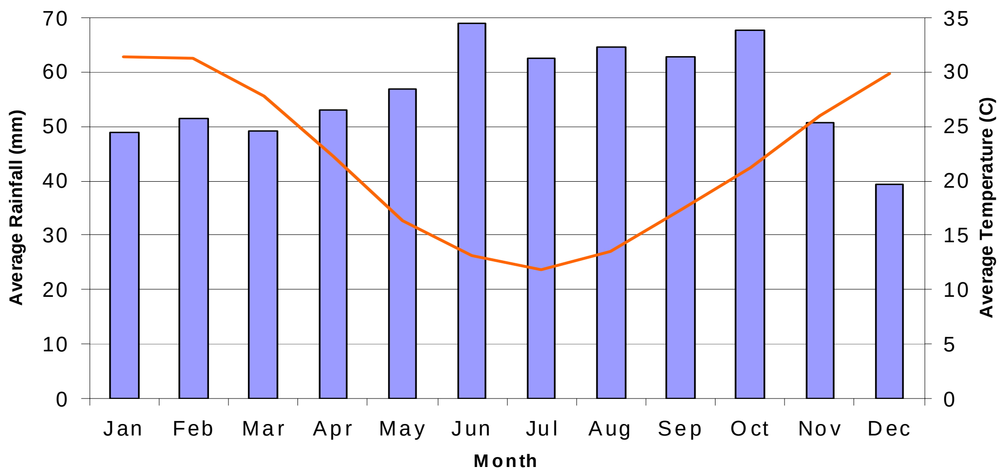

Figure 2: Average maximum daily temperature and monthly average rainfall for Wagga Wagga, NSW.

Low temperatures during late autumn and winter limit the growth rate of pasture over this period. A feed deficit ensues and this occurs at a time when the demand for energy of lambing ewes in high or increasing (depending on the time of lambing).

Farming systems

A typical dryland mixed farm is represented in the model with its crop and pasture sequences, livestock enterprises, stocking rates soil types, labour and capital. In the region typical farm size is 900-2,500 ha and is usually run as a family-owned enterprise with some external labour employed. Most farms produce a mix of grain, wool and meat. Typically 20%-70% of arable land is sown to crop with the balance being pasture. Annual pastures typically consist of subterranean clover (*Trifolium subterraneum*) with volunteer grasses and herbs. Sheep are the dominant livestock enterprise, although cattle are important on some individual farms. Sheep production systems are typically based on the Merino breed.

The dominant crop grown in the region is wheat (*Triticum aestivum*), which in recent times is approximately twice the area of canola (*Brassica napus*) grown. Smaller areas of grain legumes, barley (*Hordeum vulgare*) and oats (*Avena sativa*) are also grown. Crop area is slightly less than half of the total farm area in region

The traditional growing season for crops and pasture is April/May to October. A summer drought follows during which time the quality and quantity of feed available for livestock steadily declines, culminating in the "autumn feed gap", with consequences for livestock liveweight gain, wool growth and quality, and reproductive performance (Rowe *et. al*., 1989). During the autumn feed gap sheep are fed on supplements, such as grain and conserved fodder. In this region the proportion of annual rainfall falling outside the growing season period is greater (about 45%), although the occurrence of this summer rainfall is highly variable. This existence of the autumn feed gap in these farming systems has important implications for the profitability of alternative feed sources (such as perennials), in that the timing of feed supply can be just as important as the amount produced.

Cropping systems are based around wheat, in rotation with canola and several different grain legumes including narrow-leafed lupin (*Lupinus angustifolius*), white lupin (*Lupinus albus*) and field pea (*Pisum sativum*). Perennials in these systems are typically grown as part of a mixture with annual pasture legumes in rotation with crops for 2-7 years. On any given soil type the productivity of crops and pastures is modified as a function of position in the sequence to account for carryover effects such as soil fertility, weed burdens and plant diseases.

Results from "A survey of the use of perennial pastures as part of the pasture crop rotation in the mixed farming zone of southern NSW", Future Farm Industries CRC Technical Report 3 (Dear *et al*. 2010) showed that cover-cropping has been the dominant method of pasture establishment in the past (83%). However the success of this technique in recent years has declined due to more variable rainfall resulting in failed pasture establishment. As a result farmers are re-evaluating the advantages of establishing pastures in the year after the last crop in preference to undersowing.

Model description

The current model is based on the Coolamon model assuming annual average rainfall is around 450 mm and a typical 1000 ha farm has 4 land management units. The season is divided into 10 periods, according to growth rate and quality of pasture. The first 5 periods represent the growing season for annual pasture and the second 5 the summer period during which perennials such as lucerne can exploit summer rainfall or stored soil water. Demand for energy by livestock varies between periods, depending on the change in liveweight the reproductive cycle.

Whilst the standard model assumptions reflect the parameter values of an 'expected average season' the conclusions are never based solely on model runs based on the standard assumptions. Sensitivity analysis is used to examine the influence of parameter values on farm profit. Conclusions of the analysis are reliant on the outcome of the sensitivity analysis.

Model components

The model is comprised of number different components of the farming system. These are:

(i) Crop-pasture rotations
Cropping history (or rotation) is represented by up to 73 different activities for 4 land management units.

(ii) Machinery
Represented by a single activity that describes the availability of machinery to sow crops and pasture during four periods after the break of the season. This constrains the area of crop that can be sown and the reductions in crop yield that occur as a result of delayed sowing.

(iii) Time of sowing penalties
All crops can be sown up to 7 days after a seasonal break without a yield penalty. After 7 days wheat, barley and lupins experience a 20 kg/ha/day yield penalty, oats and triticale 15 kg/ha/day yield penalty, canola 25 kg/ha/day yield penalty and field peas a 5 kg/ha/day yield penalty. Penalties continue to increase in 5 day increments from this point until day 22 after the break, when yield penalties for most crops exceed 1000 kg/ha/day.

(iv) On average, maximum crop yield is achieved when crops are sown within a narrow window after the break of season. Crops sown outside this window have reduced yields. The model describes the relationship between yield reduction and areas of crop sown, based on the availability of machinery.

(v) Grain, wool and livestock selling.
Selling activities in the model link the physical output of the model with the cashflow and objective function

(vi) Pasture production
The season is divided into 10 periods of varying length depending on the growth rate of pasture. For annual pastures there are typically 5 periods of growth and 5 periods of senescence and pasture decline. Species with deeper roots may have an extended growing season to Period 6, while perennial species may grow throughout the year. Pasture is assumed to be undersown to crop in the first year and not available for grazing until December of that year. The pastures are then grazed for up to 4 years before going back into crop. Pasture growth curves for the different species are given in Appendices 2 and 3. All perennial species are assumed to be growing in a mixture with subterranean clover.

(vii) Livestock production

A large number of livestock classes are described. These differ in the demand for energy, time of selling and wool production and quality.

(viii) Supplementary feeding
Alternative sources of supplementary feed are available to ensure adequate supply of energy over the summer/autumn drought.

(ix) Stubble grazing
Crop residues provide an additional source of feed for livestock during the summer drought. The quality and quantity of stubble available for grazing deteriorates with time and with grazing.

(x) Finance
Income and expenditure associated with each activity are described in the cashflow section of the model. Overheads and depreciation are subtracted from the net cashflow to calculate farm profit.

Below is a description of model assumptions and inputs for MIDAS SNSW Model 10 (Version 2t).

Land Management Units (LMU)

Of crucial significance in MIDAS is the concept that the productivity of crops and pastures varies according to soil type (otherwise known as Land Management Unit, LMU) and that for any given farm, with its mix of soil types, there will be an optimum selection of crop-pasture sequence that maximises profit (Pannell, 1987). This concept is important when considering the impact of the introduction of perennials, as it may displace certain crop-pasture sequences from one soil type to another and hence alter enterprise mix and whole-farm profit.

A LMU is defined as a group of soil types on a farm where the same level of inputs returns the same level of production output. It is implied that all soils within an LMU have similar chemical and physical characteristics.

Up to 8 land management units can be accommodated in the current structure and over 80 crop-pasture sequences on each unit. Production parameters associated with each crop sequences include grain yield, grain quality, grain protein (wheat and barley), oil content (canola), and quantity of crop residues and spilt grain and germination rates of pasture.

In the Coolamon model, the representative farm is comprised of 4 LMUs (soil types), corresponding to four common soil types in the district (Table 3). The total area of the 'model farm' incorporating the 4 LMUs is 1000 ha.

Financial assumptions

The baseline financials for the farm assumes an overdraft debt limit of $250,000 annually at 8% interest. The farm also operates with an opening carryover balance of $40,000 with interest on credit of 2%. An opportunity cost of 5.5% annually (based on yield of 10 year treasury bonds) is also included.

The total annual overhead costs attributed to the farm are $75,000 spread evenly across the year (17% bi-monthly). These costs consist of repairs to buildings, fences and water, rates, licences, general insurance, professional fees, telephone, electricity and personal expenditure.

Table 3: Land management units (LMUs) in the Coolamon model, associated soil type descriptions and the wheat yield potential expressed as a percentage of the best soil type.

LMU	Soil Type	Description	Area (ha)	Relative yield potential (%)
1	Non-arable Tenosols	Skeletal soils, shallow or rocky, often steeply sloping, can also include low lying areas not suitable for cultivation.	100	0
2	Grey Vertosols	Sodic grey clays, heavy textured cracking soils, poorly drained, low infiltration rates, subsoil constraints to root growth, can be saline at depth, can have gilgai present, often present on floodplains of inland steams, parent material alluvial or sedimentary	50	60
3	Light Red Kandosols	Acidic gradational soils, lack clear or abrupt B horizon, heavy sandy loams, includes red earths. Assume soil is limed to pH>5.0 ($CaCl_2$) and no subsoil acidity	200	90
4	Red Chromosols	Duplex soils, generally not strongly acidic, acid trend with depth, includes red brown earths and podzolic soils, generally favourable physical properties. Assume soil is limed to pH>5.0 ($CaCl_2$) and no subsoil acidity.	650	100

NB: An acid soil version of LMU 3 is available for use in the model if desired in which the relative productivity of lucerne is reduced. The acid soil version will be used in future scenarios for analysis of whole farm management responses to acid soils.

Labour

Family labour is assumed to be adequate to meet all farm demands during the year except during the busiest periods, when contract labour is employed. This occurs at seeding, harvest and shearing time.

Commodity prices

The model assumes set commodity prices for crop and livestock products. These prices were chosen to reflect prices received at the time of the model runs (October 2009). In subsequent reports we will conduct sensitivity analyses to explore the impact of varying these prices above and below the standard values.

Table 4: Commodity prices used in the base model run

Commodity	Units	Price
Wheat	$/t	220
Barley	$/t	220
Canola	$/t	440
Lupins	$/t	320
Field Peas	$/t	300
1^{st} X Prime lamb (dressed weight)	c/kg	4
Clean wool	c/kg	800

Input costs

Costs of key inputs are reported in Table 5. These were chosen to reflect costs at the time of the model runs (October 2009). In subsequent reports we will conduct sensitivity analyses to explore the impact of varying these costs above and below the standard values.

Crop insurance is included at 2.22% of crop value for cereal crops, 3.8% for canola, 2.72% for lupins and 3.8% for field peas.

Table 5: Costs of selected key inputs used in the baseline model runs

Item	units	Cost
N fertiliser	$/t	520
P fertiliser	$/t	235
Fuel ($0.38/L rebate included)	$/L	1.00
Labour	$/hour	18

Machinery

A medium size machinery plant is assumed for all farm activities. Examples of this equipment include a tractor PTO power 130 (kW) and cropping gear with an average width of 7.3 metres. Farm equipment includes chisel plough, cultivator, air seeder, harrows, spray unit, front end loader, two silos, and truck (with 5 in 1 bin). The total market value of the farm machinery plant is $222,450.

The cost of machinery activities is assigned on a per hectare basis to all enterprises and includes the cost of depreciation (10%), labour, fuel, oil, grease, and repairs and maintenance. Crop establishment logistics and yield penalties are estimated using an hourly rate based on the actual width of the plant, multiplied by its field efficiency, to achieve an effective working width. This width determines the maximum number of hectares that can be established in a day and the costs per hectare of each operation.

Rotations of crops and pastures

A large number of different crop and pasture sequences (or rotations) are possible on each LMU. Each rotation has specific crop yields, pasture growth and inputs levels. Pulse crops reduce the carryover of cereal diseases and fix soil nitrogen, for example. This affects potential cereal yield and optimum nitrogen rate. The number of continuous years of crop affects the ability of pastures to regenerate naturally and thus the number of livestock that can be grazed profitability is affected.

Ten crop and pasture options are included in the Model. These are:

- Crops: Wheat, Barley, Canola, Lupins and Field peas
- Pastures: Annual pastures (mixed sward), lucerne, chicory, summer-dormant perennial grasses (cocksfoot and phalaris) and grazing wheats

Crop and pasture production achieved and the inputs applied assume a good level of management. Management skill in the medium to high level of farm management (3rd decile) is assumed by data levels provided.

Crop yield varies with LMU (see Table 3) and position in the rotational sequence, in order to account for the impact of soil fertility, soil water, pest, disease and weed carryover from previous seasons (Table 6).

A factorial combination of cropping phases involving wheat, canola, lupins and barley with different lengths of pasture phases for each species model were included in the model (Table 7).

In the baseline model runs it was assumed that perennials were established by under-sowing in the preceding crop year.

Gross margins for each crop on each LMU are given in Appendix 1. These are based on standard gross margins produced by Industry & Investment NSW 2009.

Table 6: Example yields of crops on LMU 4. See Table 1 for scaling factors for crop yields on the other three LMUs.

Crop	Yield (t/ha)
1st & 2nd Wheat after canola	3.8
1st Wheat after pasture	4.3
1st & 2nd Wheat after cereal	3.7
2nd & 3rd Wheat after legume	3.8
1st Canola after pasture	1.8
1st Canola after wheat	2.1
2nd Canola after wheat	1.8
Barley as last crop in rotation	3.7
Lupins after canola, wheat	2.1
Lupins after wheat, wheat	1.9
Field peas following cereals	1.4

Table 7: Descriptions of crop sequences in combination with 3-5 years pasture phase for lucerne, chicory, summer-dormant perennial pastures (phalaris and cocksfoot) and mixed annual pasture.

Crop sequences	Code
Canola, wheat, lupins, wheat, barley	CWLWB*
Canola, wheat, canola, wheat	CWCW
Canola, wheat, wheat, barley	CWWB
Canola, wheat, canola, barley	CWCB
Canola, wheat, lupins, barley	CWLB
Wheat, canola, wheat, canola	WCWC
Wheat, canola, wheat, barley	WCWB
Wheat, wheat, lupin, wheat	WWLW

*First wheat crop in the sequence is hard wheat; second and third crops are soft wheat

Pasture growth

An annual pasture is a mixed sward of grasses, herbs and legumes. (The model defines the annual cycle of growth of pastures into 10 periods (Table 6 and Figure 3). The quality and quantity of feed is the average of the sward for each period. Periods 1 to 5 represent the growing season. Each period varies in length according to growth rate and pasture quality (digestibility) Pasture is assumed to germinate in Period 1.

Germination is dependent on soil class and crop-pasture sequence. Growth rate in subsequent periods is a function of feed on offer (FOO, kg DM/ha), and is approximated by linear segments. Feed on offer is a function of FOO at the beginning of the period, the amount of pasture grazed by livestock during the period and the rate of physical deterioration and trampling by livestock.

Table 8: Pasture periods (days) being used in the model and associated maximum pasture growth rates (kg/ha/day) in year 2 for mixed annual pasture, summer-dormant perennial grasses, chicory and lucerne on LMU 4.

Period	Start date	Length	Average pasture growth rates (kg/ha/day) in year 2			
		days	Mixed Annual	Perennial grass	Chicory	Lucerne
1	6 May	28	9	14	14	16
2	3 June	56	14	17	11	14
3	29 July	35	17	18	16	18
4	2 Sept	42	31	36	41	32
5	14 Oct	21	32	41	50	47
6	4 Nov	28	14	22	37	25
7	2 Dec	42		2	14	8
8	13 Jan	42		-	7	6
9	24 Feb	41		1	7	7
10	6 Apr	30		5	12	15

Note: The model uses the average growth rate for years 1-5 when calculating dry matter production for each pasture type.

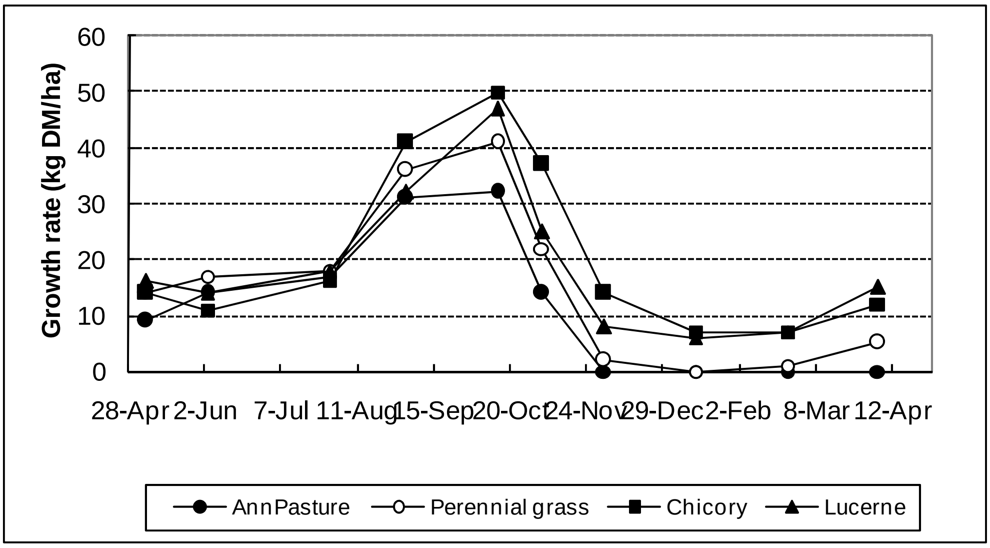

Figure 3: Pasture growth pattern in year 2 for mixed annual pasture, summer-dormant perennial grasses, chicory and lucerne on LMU 4

Pasture quality and quantity decline rapidly after senescence (Periods 6–10). Conservation constraints prevent over grazing of pastures and crop residues. Further detail on the representation of pasture production can be found in O'Connell et al. (2000). Digestible dry matter for each pasture in each period is given in Table 9.

The grazing management strategy for lucerne and chicory was assumed to be 6 weeks rest followed by 2 weeks grazing. After 6 weeks sheep are turned onto the deferred stand for a period of weeks. This is because perennials require specific management to ensure that they persist over a number of years. Overgrazing by sheep can lead to reduced plant density and lower production. Therefore the grazing strategy, and hence growth rates, are determined exogenously to the model. Grazing management of annuals and perennial grasses is based on the idea that they are grazed when they provide feed allowing for a residual for groundcover.

The growth of pastures are assumed to be at their maximum on LMU 4 (100%) these rates are then revised relative to LMU 4 by assigning percentage points for decreased growth as indicated in Tables 10a, b and c.

Table 9: Digestible dry matter (%) by period for each pasture type

Period	Mixed Annual	Perennial grass	Chicory	Lucerne
1	76	76	76	76
2	75	75	76	75
3	75	75	75	75
4	76	76	79	76
5	73	73	83	73
6	69	69	81	68
7	64	64	65	67
8	57	57	65	67
9	53	53	65	67
10	53	53	70	67

Table 10a: Growth of lucerne on each LMU relative to LMU 4

Period	LMU1	LMU2	LMU3	LMU4
P1	40%	50%	100%	100%
P2	40%	50%	100%	100%
P3	40%	50%	95%	100%
P4	40%	50%	90%	100%
P5	40%	50%	90%	100%
P6	40%	50%	85%	100%
P7	40%	50%	85%	100%
P8	40%	50%	85%	100%
P9	40%	50%	85%	100%
P10	40%	50%	85%	100%

Table 10b: Growth of chicory on each LMU relative to LMU 4

Period	LMU1	LMU2	LMU3	LMU4
P1	40%	50%	100%	100%
P2	40%	50%	100%	100%
P3	40%	50%	95%	100%
P4	40%	50%	90%	100%
P5	40%	50%	90%	100%
P6	40%	50%	85%	100%
P7	40%	50%	85%	100%
P8	40%	50%	85%	100%
P9	40%	50%	85%	100%
P10	40%	50%	85%	100%

Table 10c: Growth of perennial grasses on each LMU relative to LMU 4

Period	LMU1	LMU2	LMU3	LMU4
P1	95%	100%	100%	100%
P2	95%	100%	100%	100%
P3	90%	90%	100%	100%
P4	75%	80%	100%	100%
P5	75%	80%	100%	100%
P6	0%	80%	100%	100%
P7				
P8				
P9				
P10				

Annual dry matter production for each pasture is expressed in kilograms per hectare (kg/ha) per year in Tables 11a, b and c. The growth is derived from weekly pasture growth rates (Appendix 2) for each pasture over the lifespan of that pasture. Pasture growth rates assume long term average seasonal conditions occur during the period modelled.

Table 11a: Lucerne annual dry matter production (kg/ha) under different land management units

Growing year	LMU1	LMU2	LMU3	LMU4
1st year	1,070	1,084	2,674	2,674
2nd year	2,475	2,682	6,188	6,188
3rd year	2,475	2,682	6,188	6,188
4th year	2,131	2,281	5,327	5,327
5th year	1,758	1,874	4,396	4,396

NB: See appendix for weekly growth rate

Table 11b: Chicory annual dry matter production (kg/ha) under different land management units

Growing year	LMU1	LMU2	LMU3	LMU4
1st year	1,364	1,084	3,409	3,409
2nd year	2,780	2,682	6,951	6,951
3rd year	2,173	2,682	5,432	5,432
4th year	1,504	2,281	3,759	3,759
5th year	787	1,874	1,967	1,967

Table 11c: Perennial grasses annual dry matter production (kg/ha) under different land management units

Growing year	LMU1	LMU2	LMU3	LMU4
1st year	966	1,208	2,415	2,415
2nd year	2,080	2,682	5,201	5,201
3rd year	2,080	2,682	5,201	5,201
4th year	1,872	2,281	4,681	4,681
5th year	1,664	1,874	4,161	4,161

Grazing wheat

In a subset of runs all second wheat crops in the rotational sequence are grazed during period 2 and 3 providing 1000 kg/ha of grazing (based on Gummer, Virgona and Angus data) with a digestibility of 78%. This activity attracts an additional cost of 46 kg N/ha after grazing. A nil grain yield penalty due to grazing is assumed. Stocks are removed from crops by mid August to allow grain yield recovery.

Stubbles

Crop residues can be a source of high quality feed for livestock after harvest. Sheep preferentially graze the high quality components of the stubble so the quality of stubble declines as it is grazed. Conservation constraints limit the total amount of dry matter available for grazing. Table 12 provides stubble quantity data for all crops across the grazing periods defined in the model to estimate grazing potential. Table 13 provides an example of the process for assessing cereal stubble quality after harvest for use in livestock calculations and similar data is provided for all other crops in the model but is omitted from this report due to the complexity in presenting the data.

Feed supply and demand and livestock production

Feed is characterised by its energy in megajoules per kilogram of feed and the dry matter equivalent of intake capacity of livestock "used". The extent to which livestock may consume feed from a given source depends on its quality and availability. Feed of low digestibility reduces intake, therefore "using" a greater share of intake capacity of the livestock. Intake may also be reduced when accessibility of pasture is low and livestock need to cover greater distances to graze a given quantity of dry matter.

Table 12: Stubble quantity calculations

Period	Length of period	Cumulative days	Cereals	Canola	Lupins	Field peas
Percentage decline in quantity						
P7	42	11	4%	4%	4%	4%
P8	42	42	15%	15%	15%	15%
P9	41	84	28%	28%	28%	28%
P10	30	119	38%	38%	38%	38%
P1	28	148	45%	45%	45%	45%
Actual quantity remaining from each initial 1000 kg						
P7	42	11	1,000	1,000	1,000	1,000
P8	42	42	846	846	846	846
P9	41	84	717	717	717	717
P10	30	119	622	622	622	622
P1	28	148	554	554	554	554

Table 13: Cereal stubble quality calculations (digestible dry matter, %)

	Length of period	Grain	Blade	Sheath	Cocky-chaff	Stem
Cereal stubble quality at harvest		80%	58%	45%	42%	24%
Quality deterioration factor (%/day)		0.05%	0.30%	0.30%	0.30%	0.30%
P7	42	79%	56%	44%	41%	23%
P8	42	78%	51%	39%	37%	21%
P9	41	76%	43%	34%	31%	18%
P10	30	75%	37%	29%	27%	15%
P1	28	74%	32%	25%	23%	13%

Supplementary feeding

Grain supplements can be stored on farm and can be fed to livestock from Period 6 through to Period 3 (following season). This ensures that the supply of energy to sheep, particularly pregnant ewes, is adequate to optimise liveweight over the summer and autumn period. At this point sufficient pasture becomes available to maintain or increase liveweight.

Sources of feed include lupins, wheat, barley and oats. Lupins are broadcast in grazed paddocks with a super spreader. Grain for Grain for feeding may be grown on-farm or purchased. Hay may also be purchased. Feeding may be grown on-farm or purchased. Hay may also be purchased.

It is assumed that seasonal labour is used to feed grain to sheep during Periods 1 to 3. This is because the cropping program is the priority during this period and therefore it will be the focus of the family labour. The implication of this is that supplementary feeding incurs an addition cost during this period.

Livestock systems

Merino and merino-cross livestock options are described in the model. Ewes may be bred to replace those culled or merino-cross ewes may be purchased for prime lamb production. There are 46 classes of sheep to describe differences in age, times of sale and gender. Wethers can be sold as store lambs, spring lamb, carryover lambs or held to be sold as shippers or for wool production. Ewe lambs can be sold or kept and mated to a merino ram or terminal sire. Ewes are culled after 5 or 6 years. Death rates, annual wool growth and hauteur are a function of the liveweight of each sheep class. Liveweight of ewes also affects lambing rates. Live weights of animals are a function of the availability and quality of feed. Production relationships were taken from CSIRO bluebook. Liveweight patterns and associated production are determined exogenously to the model. This approach was adopted because an endogenous specification of livestock energy requirements and production levels would be computationally difficult in an LP framework. Sheep production activities can be combined in different combinations over the ten periods. The possible combinations imply up to 32 alternative liveweight patterns for each livestock class, other than lambs.

Production parameters associated with livestock include wool cut, wool fibre diameter, hauteur and liveweight. Input costs include fertiliser, chemicals for weed, pest and disease control, machinery costs, seasonal labour, crop insurance, seed costs, selling costs and transport, ownership costs of capital assets and sheep husbandry.

Parameters used to calculate liveweight patterns assumed for these runs are summarised in (Table 14).

Table 14: GrassGro model parameters used to derive the standard liveweight patterns assumed. The parameters are for an example class of livestock.

Parameter	Value
Age (years)	3
Wool production (kg/hd clean)	2.75
Fibre diameter (micron)	64.1
Percent vegetable matter in wool	0.7
Percent mid-breaks	73
Percent ewes barren	9
Percent single bearing	71
Percent twin bearing	19
Average conception	1.1
Lamb survival (singles)	91
Lamb survival (twins)	68
Lambing percentage	92
Annual liveweight range (kg)	42 to 52
Age of youngest animal at weaning (wks)	8
Wool growth of lambs before weaning (kg)	0.5

Three types of livestock system were available for selection by the model. They ranged from predominantly wool to meat-based production. In the wool-dominant system, ewes are replaced by lambs from within the flock and castrated male lambs (wethers) can be sold as lambs to other graziers or as live sheep exports (18 months or older). A mixed wool-meat enterprise also uses a self-replacing merino flock, but uses surplus ewes (cast for age or surplus ewe hoggets) for crossbred lamb production. A draft of merino wether lambs can be sold as merino prime lambs. Remaining wethers can be sold as lambs to other graziers or for live export (18 months or older). In predominantly meat production systems the emphasis is on merino ewes producing crossbred carryover lambs for meat. Replacement ewes are bought in.

Lambing is at the end of May. Lambs are sold at 40 kg by the end of period 6 (beginning of September) as suckers. Carryover lambs (46 kg) are sold on 2 December.

Variable costs for sheep production are documented in Table 15.

Table 15: Variable costs for sheep production (Contract cost are included)

Item	Unit cost ($)
Shearing*	4.20
Crutching	0.85
Vac (Glanvac 3)	0.25
Drench(1:1 Ivom:Other) × 2	0.70
Backline/Dip	1.65
Jetting	0.56
Mulesing, marking and ring	1.35
Ear tags	0.30
Fuel (Not feeding out)	0.20
Repairs and Maintenance	0.10

* Assuming some family labour to reduce the contract cost

Results and Discussion

The model found that the largest increase in farm profit resulted from the introduction of lucerne to the farm rotation. Profit was increased by around $44,000 when lucerne was added to the farming system (option 1 to option 2) and constituted approximately 28% of the farm land use (Table 16). The profit can be attributed to the increase in livestock numbers with breeding ewes increasing by 65% resulting in a net increase in annual livestock returns of approximately $109,000 (increase in value of wool and lambs sold – see Appendix 3).

Adding chicory or perennial grasses to a lucerne-crop rotation increased profit further but the increase was relatively small ($9,000 and $7,000 options 3 and 4). A rotation containing all 3 perennials (lucerne, chicory and perennial grasses) was the most profitable (increase of $16,000 from option 2) resulting from a further 20% increase in breeding ewe numbers (Table 16).

Only a relatively small area of chicory (24 ha) and perennial grass (66 ha) was required to maximise profitability whilst maintaining the lucerne area around 250 hectares. Results indicated the optimal area of chicory is between 20 and 50 ha, depending on the presence (and production) of other pasture species. The value of chicory is therefore around $200 per hectare.

The optimum area of crop on farms with perennials in the rotation was estimated to be 57-60% which is similar to current land allocations of crop on farms in the target region. In a system with only annual pastures (option 1) the optimum area of cropping is approximately 70% of the farm area

Stocking rates increased by up to 40% with the inclusion of perennial pasture species in the rotation. The area of grazed cereal crop increased slightly with perennials as did the amount of supplementary feeding required (10% increase)

Table 16: Baseline MIDAS Results for 1000 ha farm

Key statistics	Option 1	Option 2	Option 3	Option 4	Option 5
	Traditional Annual pasture	Annual +lucerne	Annual +lucerne + chicory	Annual + lucerne + per grass	Annual + lucerne + chicory + per grass
Farm profit	$147,000	$191,000	$200,00	$198,000	$207,000
Total area pasture	300	403	433	440	436
Area lucerne	-	281	267	272	246
Area chicory	-	-	44	-	24
Area per grass	-	-	-	68	66
Area Ann Pasture	300	122	122	100	100
Total area of crop	700	596	566	560	565
Area Wheat	250	228	227	232	234
Area Canola	150	123	113	116	117
Area Barley	150	123	113	116	117
Area Pulse	138	122	113	96	97
% Farm under crop	70%	60%	57%	56%	57%
Av stocking rate per grazed Ha (DSE)	10	13.5	12.8	14	13.8
Stocking rate whole farm (DSE)	3	5.4	5.5	6.7	5.9
Total ewes on farm	1816	2781	3037	3345	3302
Area grazed crop	100	106	113	116	117
Supp feed (Tonnes)	127	113	120	139	140

Optimal pasture-crop rotations are shown in Table 17 for each of the 4 soil types (LMUs) on the model farm when different perennial pastures are used. Other rotations (Table 18) may be selected in some cases with little change in profit suggesting that there are a number of valid rotations. Of interest though is the length of rotations. In most cases on LMU 2 the rotation selects 4-5 years of pasture and 4-5 years of crop, an overall rotation of 8-10 years As the yield potential of soils increases (LMU 3 and 4) the pasture phase varies between 3-4 years whilst the cropping phase is 5 years in many options.

Table 17: Baseline optimal rotations and the land area allocated to each rotation*

LMU	**Option 1**		**Option 2**		**Option 3**		**Option 4**		**Option 5**	
	Traditional Annual pasture		Annual +lucerne		Annual +lucerne + chicory		Annual + lucerne + per grass		Annual + lucerne + chicory + per grass	
	Rotation	ha’s	Rotation	ha’s	Rotation	ha’s	Rotation	ha’s	Rotation	ha’s
1	20PA	100	20PA	100	20PA	100	20PA	100	20PA	100
2	5PWCWB	50	5PWCWLB	50	5PWCWLB	50	5HWCWB	50	5HWCWB	50
3	3PWCWB	200	3UWCWLB	132	4UWCWLB	83	3UWCWLB	100	4UWCWLB	85
			WCBL	68	4YWCWLB	117	4HWCWB	100	4YWCWLB	19
									4HWCWB	96
4	3PWCWLB	260	4UWCWLB	650	4UWCWLB	650	4UWCWLB	650	4UWCWLB	590
	3PWCWB	390							3YWCWLB	60

* Numeral, Pasture years; PA, Permanent pasture; Y, Chicory; U, Lucerne; H, Perennial summer-dormant grass; W, Wheat; C, Canola; B, Barley; L, Lupins; P, Annual pasture.

Table 18: Alternative near profitable rotations

LMU	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Option 5**
	Traditional Annual pasture	Annual +lucerne	Annual +lucerne + chicory	Annual + lucerne + per grass	Annual + lucerne + chicory + per grass
1	20PA	20PA	20PA	20PA	20PA
2	4PWWLB	5PWCWB	5UWWLB	4HWWB	4YWWB
	4PWCWLB	4PWCWLB	5UWWB	5PWCWLB	5PWCWLB
	5PWCWLB	3PWCWLB	4YWCWLB	5PWCWB	5PWCWB
				4PWWB	
3	3YWCWLB	4UWCWLB	4UWCWLB	4PWCWLB	3YWCWLB
	3PWCWLB	5PWCWB	3YWCWLB	5HWCWLB	4HWCWLB
		4PWCWLB	3PWCWLB	3HWCWB	4HWCWB
				3PWCWLB	
4	3UWCWLB	3PWCWLB	5UWCWLB	3UWCWLB	4YWCWLB
	3YWCWLB	5UWCWLB	3UWCWLB	3YWCWLB	3PWCWLB
	WCWBF		4YWCWLB		3UWCWLB
			3YWCWLB		

Results also show that lucerne is nearly always in rotations on LMU 4. As new pasture species are introduced they are usually selected to be grown on LMU 2 and 3 where lucerne is less productive. However in option 5 where all perennial options are available the area of lucerne decreases by 10% and chicory is introduced to LMU 4 (60ha). Chicory is not selected in LMU 2 or 3 as its growth is penalised considerably.

The optimal chicory rotation for the standard assumptions is 4 years of chicory followed by wheat, canola, wheat, lupins and barley (4YWNLB). However a number of other rotations that include 3 years of chicory are equally profitable (within the confidence limits of the data) It is apparent the length of the chicory phase is perhaps less critical to farm profit. The results show that the longer phases tend to be more profitable particularly when they include canola.

Lupins are also prevalent in many of the optimal rotations. This suggests that at current high prices >$320 tonne and average annual yields around 2 tonnes per hectare lupins are an important crop in the rotation. The modelling is based on crop yields expected under long term average climatic conditions. However under climatic conditions experienced in the past 10 years the risks associated with declining yields has seen the area of lupins decrease in the area. Target yields for lupins for inclusion in rotations in southern NSW will be explored further in future sensitivity analyses.

The base model runs presented in this report assume soils have been limed to reduce the affects of soil acidity. If surface or subsoil acidity is present, different rotations to those presented are likely to be more profitable with more acid tolerant pastures and crops selected.

Subsequent model runs will investigate a range of different scenarios including:

1. Explore how rotations change with soil types?
2. Assess the impact of changing lambing times on profit and pasture options.
3. Determine the magnitude of change in livestock to crop prices required before fundamental changes in rotation and enterprise mix occur.
4. What impact do changing input costs (fuel, fertilizer and chemicals) have on the optimum farm enterprise mix?
5. How will different climate scenarios change optimum pasture-crop mix on farms in the future?
6. How do fluctuations in year to year seasonal conditions change profit variability and indebtedness for different pasture-crop enterprises.

Conclusions

Results indicated that the introduction of perennial pasture species to farms in the study region has the potential to substantially increase farm profit. Lucerne is the most profitable perennial for the region and has the most impact on increasing profits if not already used in pasture crop rotations; however the profit is highest when chicory, perennial grass and lucerne are all present in the system. This results mainly from the increase in livestock numbers that are able to be supported by this perennial pasture system. Whole farm stocking rates have doubled on farms incorporating perennial pastures whilst supplementary feeding has only increased by 10% in grain rations (tonnes). This indicates the improved ability of perennial pastures to meet livestock feed requirements compared to annual pastures.
A greater area of perennial grasses (68 ha) is selected when in rotation with lucerne than chicory (44 ha) and lucerne. However as all three pasture options are combined on farm the area of perennial grass remains relatively constant and chicory begins to substitute for lucerne.

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Appendix 1: Crop gross margins for each LMU

1a. GROSS MARGINS - Costs for Gross Margin Calculations on LMU 2

COSTS	**Wheat**	**Wheat**	**Wheat**	**Canola**	**Canola**	**Barley**	**Lupins**	**Field Peas**
	after cereal	***after canola***	***after Luc***	***after cereal***	***after Luc***			
Fertiliser Costs								
DAP	16.05	27.29	35.31	0.00	38.52	28.89	0.00	0.00
Extra Sul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gypsum	0.00	0.00	0.00	0.00	14.25	0.00	0.00	0.00
Starter 15	0.00	0.00	0.00	38.70	0.00	0.00	0.00	0.00
Urea	45.72	53.34	22.86	32.39	0.00	38.10	0.00	0.00
Superphosphate	0.00	0.00	0.00	0.00	0.00	0.00	18.33	18.33
Total Fertiliser Costs	**61.77**	**80.63**	**58.17**	**71.09**	**52.77**	**66.99**	**18.33**	**18.33**
Chemical Costs								
Herbicides	69.03	69.03	95.41	63.03	103.82	72.31	53.52	87.69
Insecticides	0.00	0.00	0.00	11.80	8.63	0.00	16.94	23.60
Fungicides							7.35	
Total Chemical Costs	**69.03**	**69.03**	**95.41**	**74.83**	**112.45**	**72.31**	**77.81**	**111.29**
Other								
Seed	3.30	3.30	3.30	14.13	14.13	4.98	13.80	8.01
Machinery for cultivation and seeding	28.01	35.75	35.75	28.01	44.77	28.01	15.46	32.22
Crop Insurance	8.47	8.47	8.47	16.99	17.48	10.02	13.46	9.05
Casual Labour	10.43	10.43	14.58	10.43	18.72	10.43	5.03	13.32
Contract harvesting (& swathing)	33	33	33	75	75	33	50	50
TOTAL COSTS	**214.01**	**240.60**	**248.67**	**290.48**	**335.32**	**225.75**	**193.90**	**242.22**

1b. GROSS MARGINS - Income for Gross Margin Calculations on LMU 2

	Wheat	Wheat	Wheat	Canola	Canola	Barley	Lupins	Field Peas
INCOME	***after cereal***	***after canola***	***after Luc***	***after cereal***	***after Luc***			
Gross Price ($/t)	220	220	220	440	440	220	160	300
Deductions ($/t)								
Farm to Bin	5.00	5.00	5.00	5.00	5.00	5.00	0.00	5.00
Receival	19.90	19.90	19.90	9.80	9.80	9.00	0.00	9.00
Storage	0.00	0.00	0.00	5.48	5.48	10.16	0.00	5.48
Outloading	0.00	0.00	0.00	4.10	4.10	4.10	0.00	4.10
Freight	23.90	23.90	23.90	23.90	23.90	23.90	0.00	23.90
Port	13.20	13.20	13.20	9.80	9.80	9.00	0.00	9.00
Research Levy	1.60	1.60	1.60	3.88	3.88	1.61	0.00	2.47
Farm gate price ($/t)	156	156	156	378	378	157	160.00	241.05
Total Yield (t/ha)	2.28	3.42	2.58	1.26	1.08	2.22	1.26	0.89
TOTAL INCOME	**356.58**	**534.88**	**403.50**	**476.33**	**408.29**	**349.05**	**201.60**	**214.05**

1c. GROSS MARGINS - Gross Margin Calculations for LMU 2

	Wheat	Wheat	Wheat	Canola	Canola	Barley	Lupins	Field Peas
	after cereal	***after canola***	***after Luc***	***after cereal***	***after Luc***			
Yield (t/ha)	2.28	3.42	2.58	1.26	1.08	2.22	1.26	0.89
Total Income ($/ha)	357	535	404	476	408	349	202	214
Total Costs of ($/ha)	214	241	249	290	335	226	194	242
Gross Margin ($/ha)	**143**	**294**	**155**	**186**	**73**	**123**	**8**	**-28**

2a. GROSS MARGINS - Costs for Gross Margin Calculations on LMU 3

COSTS	Wheat	Wheat	Wheat	Canola	Canola	Barley	Lupins	Field Peas
	after cereal	*after canola*	*after Luc*	*after cereal*	*after Luc*			
Fertiliser Costs								
DAP	24.08	40.93	52.97	0.00	57.78	43.34	0.00	0.00
Extra Sul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gypsum	0.00	0.00	0.00	0.00	21.38	0.00	0.00	0.00
Starter 15	0.00	0.00	0.00	58.05	0.00	0.00	0.00	0.00
Urea	68.58	80.01	34.29	48.58	0.00	57.15	0.00	0.00
Superphosphate	0.00	0.00	0.00	0.00	0.00	0.00	27.50	27.50
Total Fertiliser Costs	**92.66**	**120.94**	**87.26**	**106.63**	**79.16**	**100.49**	**27.50**	**27.50**
Chemical Costs								
Herbicides	69.03	69.03	95.41	63.03	103.82	72.31	53.52	87.69
Insecticides	0.00	0.00	0.00	11.80	8.63	0.00	16.94	23.60
Fungicides							7.35	
Total Chemical Costs	**69.03**	**69.03**	**95.41**	**74.83**	**112.45**	**72.31**	**77.81**	**111.29**
Other								
Seed	3.30	3.30	3.30	14.13	14.13	4.98	13.80	8.01
Machinery for cultivation and seeding	28.01	35.75	35.75	28.01	44.77	28.01	15.46	32.22
Crop Insurance	8.47	8.47	8.47	16.99	17.48	10.02	13.46	9.05
Casual Labour	10.43	10.43	14.58	10.43	18.72	10.43	5.03	13.32
Contract harvesting (& swathing)	33	33	33	75	75	33	50	50
TOTAL COSTS	**244.90**	**280.92**	**277.75**	**326.02**	**361.71**	**259.25**	**203.06**	**251.39**

2b. GROSS MARGINS - Income for Gross Margin Calculations on LMU 3

	Wheat	Wheat	Wheat	Canola	Canola	Barley	Lupins	Field Peas
INCOME	***after cereal***	***after canola***	***after Luc***	***after cereal***	***after Luc***			
Gross Price ($/t)	220	220	220	440	440	220	160	300
Deductions ($/t)								
Farm to Bin	5.00	5.00	5.00	5.00	5.00	5.00	0.00	5.00
Receival	19.90	19.90	19.90	9.80	9.80	9.00	0.00	9.00
Storage	0.00	0.00	0.00	5.48	5.48	10.16	0.00	5.48
Outloading	0.00	0.00	0.00	4.10	4.10	4.10	0.00	4.10
Freight	23.90	23.90	23.90	23.90	23.90	23.90	0.00	23.90
Port	13.20	13.20	13.20	9.80	9.80	9.00	0.00	9.00
Research Levy	1.60	1.60	1.60	3.88	3.88	1.61	0.00	2.47
Farm gate price ($/t)	156	156	156	378	378	157	160.00	241.05
Total Yield (t/ha)	3.42	3.80	3.87	1.89	1.62	3.33	1.89	1.33
TOTAL INCOME	**534.88**	**594.31**	**605.25**	**714.50**	**612.43**	**523.57**	**302.40**	**321.08**

2c. GROSS MARGINS - Gross Margin Calculations for LMU 3

	Wheat	Wheat	Wheat	Canola	Canola	Barley	Lupins	Field Peas
	after cereal	***after canola***	***after Luc***	***after cereal***	***after Luc***			
Yield (t/ha)	3.42	3.80	3.87	1.89	1.62	3.33	1.89	1.33
Total Income ($/ha)	535	594	605	715	612	524	302	321
Total Costs of ($/ha)	245	281	278	326	362	259	203	251
Gross Margin ($/ha)	**290**	**313**	**328**	**388**	**251**	**264**	**99**	**70**

3a. GROSS MARGINS - Costs for Gross Margin Calculations on LMU 4

COSTS	Wheat	Wheat	Wheat	Canola	Canola	Barley	Lupins	Field Peas
	after cereal	*after canola*	*after Luc*	*after cereal*	*after Luc*			
Fertiliser Costs								
DAP	26.75	45.48	58.85	0.00	64.20	48.15	0.00	0.00
Extra Sul	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gypsum	0.00	0.00	0.00	0.00	23.75	0.00	0.00	0.00
Starter 15	0.00	0.00	0.00	64.50	0.00	0.00	0.00	0.00
Urea	76.20	88.90	38.10	53.98	0.00	63.50	0.00	0.00
Superphosphate	0.00	0.00	0.00	0.00	0.00	0.00	30.55	30.55
Total Fertiliser Costs	**102.95**	**134.38**	**96.95**	**118.48**	**87.95**	**111.65**	**30.55**	**30.55**
Chemical Costs								
Herbicides	69.03	69.03	95.41	63.03	103.82	72.31	53.52	87.69
Insecticides	0.00	0.00	0.00	11.80	8.63	0.00	16.94	23.60
Fungicides							7.35	
Total Chemical Costs	**69.03**	**69.03**	**95.41**	**74.83**	**112.45**	**72.31**	**77.81**	**111.29**
Other								
Seed	3.30	3.30	3.30	14.13	14.13	4.98	13.80	8.01
Machinery for cultivation and seeding	28.01	35.75	35.75	28.01	44.77	28.01	15.46	32.22
Crop Insurance	8.47	8.47	8.47	16.99	17.48	10.02	13.46	9.05
Casual Labour	10.43	10.43	14.58	10.43	18.72	10.43	5.03	13.32
Contract harvesting (& swathing)	33	33	33	75	75	33	50	50
TOTAL COSTS	**255.19**	**294.35**	**287.45**	**337.87**	**370.50**	**270.41**	**206.12**	**254.44**

3b. GROSS MARGINS - Income for Gross Margin Calculations on LMU 4

INCOME	Wheat *after cereal*	Wheat *after canola*	Wheat *after Luc*	Canola *after cereal*	Canola *after Luc*	Barley	Lupins	Field Peas
Gross Price ($/t)	220	220	220	440	440	220	160	300
Deductions ($/t)								
Farm to Bin	5.00	5.00	5.00	5.00	5.00	5.00	0.00	5.00
Receival	19.90	19.90	19.90	9.80	9.80	9.00	0.00	9.00
Storage	0.00	0.00	0.00	5.48	5.48	10.16	0.00	5.48
Outloading	0.00	0.00	0.00	4.10	4.10	4.10	0.00	4.10
Freight	23.90	23.90	23.90	23.90	23.90	23.90	0.00	23.90
Port	13.20	13.20	13.20	9.80	9.80	9.00	0.00	9.00
Research Levy	1.60	1.60	1.60	3.88	3.88	1.61	0.00	2.47
Farm gate price ($/t)	156	156	156	378	378	157	160.00	241.05
Total Yield (t/ha)	3.80	3.80	4.3	2.10	1.80	3.70	2.1	1.48
TOTAL INCOME	**594.31**	**594.31**	**672.50**	**793.89**	**680.48**	**581.74**	**336.00**	**356.75**

3c. GROSS MARGINS - Gross Margin Calculations for LMU 4

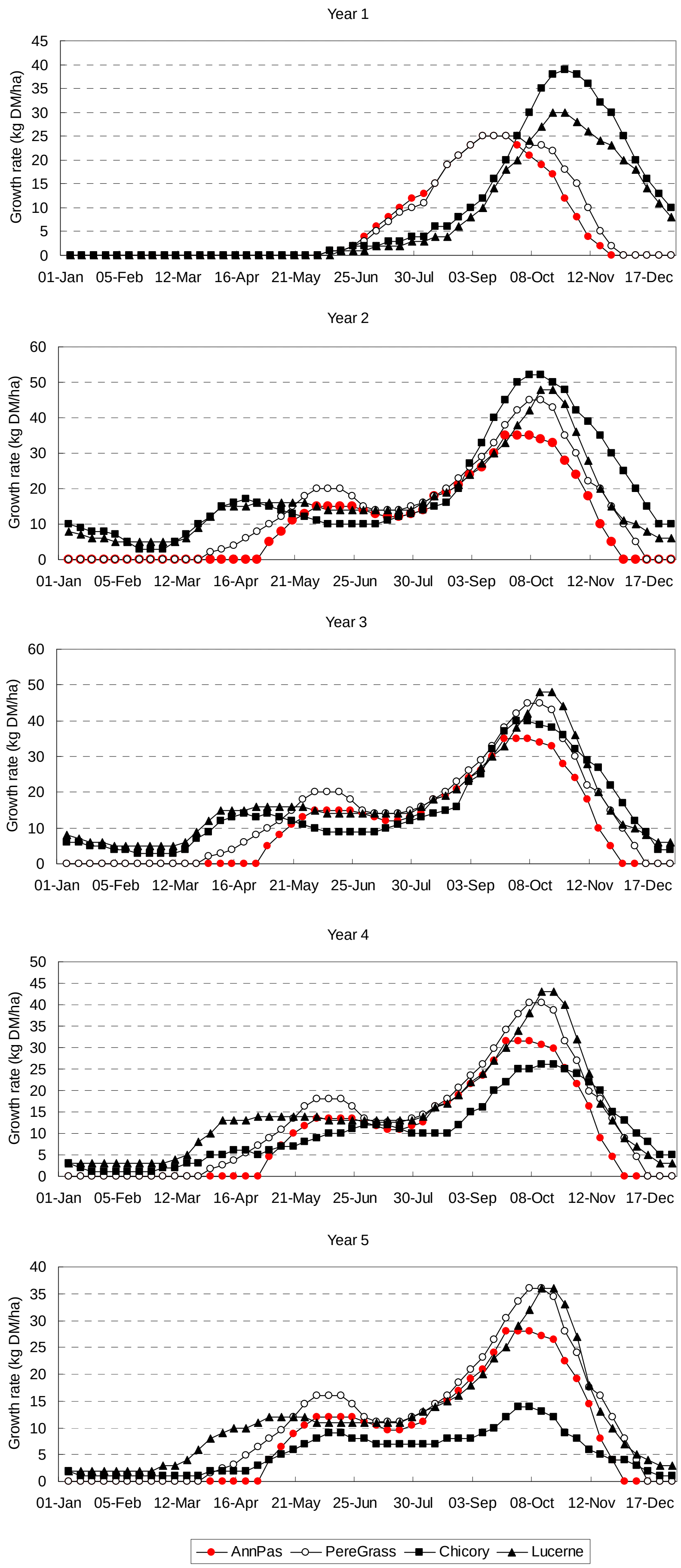
	Wheat *after cereal*	Wheat *after canola*	Wheat *after Luc*	Canola *after cereal*	Canola *after Luc*	Barley	Lupins	Field Peas
Yield (t/ha)	3.80	3.80	4.30	2.10	1.80	3.70	2.10	1.48
Total Income ($/ha)	594	594	673	794	680	582	336	357
Total Costs of ($/ha)	255	294	287	338	371	270	206	254
Gross Margin ($/ha)	**339**	**300**	**385**	**456**	**310**	**311**	**130**	**102**

Appendix 2: Weekly pasture growth for each type of pasture (kg/ha/day)

Week		**Year1**				**Year2**				**Year3**				**Year4**				**Year5**			
		AnnPas	PereGrass	Chicory	Lucerne	AnnPas	PereGrass	Chicory	Lucerne	AnnPas	PereGrass	Chicory	Lucerne	AnnPas	PereGrass	Chicory	Lucerne	AnnPas	PereGrass	Chicory	Lucerne
1	07-Jan	0	0	0	0	0	0	14	8	0	0	8	8	0	0	6	5	0	0	2	4
2	14-Jan	0	0	0	0	0	0	7	7	0	0	5	7	0	0	1	4	0	0	1	3
3	21-Jan	0	0	0	0	0	0	7	6	0	0	5	6	0	0	1	3	0	0	1	2
4	28-Jan	0	0	0	0	0	0	7	6	0	0	5	6	0	0	1	3	0	0	1	2
5	04-Feb	0	0	0	0	0	0	7	5	0	0	5	5	0	0	1	3	0	0	1	2
6	11-Feb	0	0	0	0	0	0	7	5	0	0	5	5	0	0	1	3	0	0	1	2
7	18-Feb	0	0	0	0	0	0	7	5	0	0	5	5	0	0	1	3	0	0	1	2
8	25-Feb	0	0	0	0	0	0	7	5	0	0	5	5	0	0	3	4	0	0	1	3
9	04-Mar	0	0	0	0	0	0	7	5	0	0	5	5	0	0	3	4	0	0	1	3
10	11-Mar	0	0	0	0	0	0	7	5	0	0	5	5	0	0	3	4	0	0	1	3
11	18-Mar	0	0	0	0	0	0	7	6	0	0	5	6	0	0	3	5	0	0	1	4
12	25-Mar	0	0	0	0	0	0	7	9	0	0	5	9	0	0	3	7	0	0	1	5
13	01-Apr	0	0	0	0	0	2	7	12	0	2	5	12	0	2	3	9	0	2	1	7
14	08-Apr	0	0	0	0	0	3	16	15	0	3	13	15	0	3	5	13	0	2	2	10
15	15-Apr	0	0	0	0	0	4	16	15	0	4	13	15	0	4	5	13	0	3	2	10
16	22-Apr	0	0	0	0	0	6	16	15	0	6	13	15	0	5	5	13	0	5	2	10
17	29-Apr	0	0	0	0	0	8	16	16	0	8	13	16	0	7	5	14	0	6	2	10
18	06-May	0	0	0	0	5	10	14	16	5	10	13	16	5	9	7	14	4	8	6	12
19	13-May	0	0	0	0	8	12	14	16	8	12	13	16	7	11	7	14	6	10	6	12
20	20-May	0	0	0	0	11	15	14	16	11	15	13	16	10	14	7	14	9	12	6	12
21	27-May	0	0	0	0	13	18	14	16	13	18	13	16	12	16	7	14	10	14	6	12
22	03-Jun	0	0	2	1	15	20	11	15	15	20	10	15	14	18	11	14	12	16	8	12
23	10-Jun	1	1	2	1	15	20	11	14	15	20	10	14	14	18	11	13	12	16	8	11
24	17-Jun	1	1	2	1	15	20	11	14	15	20	10	14	14	18	11	13	12	16	8	11
25	24-Jun	2	2	2	1	15	18	11	14	15	18	10	14	14	16	11	13	12	14	8	11
26	01-Jul	4	3	2	1	14	15	11	14	14	15	10	14	13	14	11	13	11	12	8	11
27	08-Jul	6	5	2	1	13	14	11	14	13	14	10	14	12	13	11	13	10	11	8	11
28	15-Jul	8	7	2	1	12	14	11	14	12	14	10	14	11	13	11	13	10	11	8	11
29	22-Jul	10	9	2	1	12	14	11	14	12	14	10	14	11	13	11	13	10	11	8	11
30	29-Jul	12	10	6	3	13	15	16	14	13	15	14	14	12	14	11	13	10	12	8	11

Week		Year1				Year2				Year3				Year4				Year5			
		AnnPas	PereGrass	Chicory	Lucerne	AnnPas	PereGrass	Chicory	Lucerne	AnnPas	PereGrass	Chicory	Lucerne	AnnPas	PereGrass	Chicory	Lucerne	AnnPas	PereGrass	Chicory	Lucerne
31	05-Aug	13	11	6	4	14	16	16	16	14	16	14	16	13	14	11	14	11	13	8	13
32	12-Aug	15	15	6	4	18	18	16	18	18	18	14	18	16	16	11	16	14	14	8	14
33	19-Aug	19	19	6	4	19	20	16	19	19	20	14	19	17	18	11	17	15	16	8	15
34	26-Aug	21	21	6	5	21	23	16	21	21	23	14	21	19	21	11	19	17	18	8	17
35	02-Sep	23	23	18	11	24	26	41	24	24	26	33	24	22	23	21	22	19	21	11	18
36	09-Sep	25	25	18	13	26	29	41	27	26	29	33	27	23	26	21	24	21	23	11	20
37	16-Sep	25	25	18	14	30	33	41	30	30	33	33	30	27	30	21	27	24	26	11	23
38	23-Sep	25	25	18	15	35	38	41	33	35	38	33	33	32	34	21	30	28	30	11	25
39	30-Sep	23	25	18	18	35	42	41	38	35	42	33	38	32	38	21	34	28	34	11	29
40	07-Oct	21	23	18	20	35	45	41	42	35	45	33	42	32	41	21	38	28	36	11	32
41	14-Oct	19	23	37	30	34	45	50	48	34	45	38	48	31	41	26	43	27	36	11	36
42	21-Oct	17	22	37	30	33	43	50	48	33	43	38	48	30	39	26	43	26	34	11	36
43	28-Oct	12	18	37	27	28	35	50	44	28	35	38	44	25	32	26	40	22	28	11	33
44	04-Nov	8	15	35	30	24	30	37	36	24	30	28	36	22	27	20	31	19	24	6	24
45	11-Nov	4	10	35	31	18	22	37	28	18	22	28	28	16	20	20	24	14	18	6	19
46	18-Nov	2	5	35	22	10	20	37	20	10	20	28	20	9	18	20	17	8	16	6	14
47	25-Nov	0	2	35	17	5	15	37	15	5	15	28	15	5	14	20	13	4	12	6	10
48	02-Dec	0	0	11	13	0	10	14	11	0	10	8	11	0	9	6	6	0	8	2	5
49	09-Dec	0	0	11	12	0	5	14	10	0	5	8	10	0	5	6	6	0	4	2	5
50	16-Dec	0	0	11	10	0	0	14	8	0	0	8	8	0	0	6	5	0	0	2	4
51	23-Dec	0	0	11	7	0	0	14	6	0	0	8	6	0	0	6	3	0	0	2	3
52	30-Dec	0	0	11	7	0	0	14	6	0	0	8	6	0	0	6	3	0	0	2	3
		2212	2415	3,193	2,568	3990	5201	7,000	6,188	3990	5201	5,507	6,188	3591	4681	3,793	5,304	3192	4161	2,022	4,374

Appendix 3 Weekly pasture growth curve for each type of pasture



Appendix 3: Additional output from baseline MIDAS analysis (1000 ha)

Cropping	**Option 1**	**Option 2**	**Option 3**	**Option 4**	**Option 5**
Quantity of wheat grown (tonnes)	88	804	801	817	823
Quantity of barley grown (tonnes)	523	430	399	407	410
Quantity of canola grown (tonnes)	285	240	227	232	234
Value of wheat sold	$134,900	$124,700	$124,500	$127,200	$128,000
Value of barley sold	$67,130	$55,540	$51,746	$52,584	$52,952
Value of canola sold	$107,700	$91,045	$86,067	$87,895	$88,491
Amount of fed wheat (tonnes)	48	44	44	45	45
Amount of fed barley (tonnes)	79	65	60	61	62
Amount of fed lupin (tonnes)	0	4	16	33	33
Quantity of lupins sold	279	230	203	158	161
Total of fed grain (tonnes)	127	113	120	139	140
Total value of all (sold & kept) grain produced ($)	$408,000	$345,000	$326,000	$332,800	$335,000
Total fertiliser cost	$75,328	$67,627	$65,957	$66,840	$67,226
Total herbicide, insecticide and fungicide cost ($)	$55,205	$49,826	$47,927	$47,767	$48,020
Livestock					
Number of ewes	1816	2781	3037	3345	3302
Number of wethers	0	690	433	523	447
Number of hoggets	436	830	831	926	898
Number of lambs	1750	2630	2828	3166	3075
Number of rams	27	42	46	50	50
Total quantity of wool sold (kg's)	7356	14527	14725	16146	15914
Total value of all wool sold	$60,053	$118,100	$118,200	$130,900	$127,700
Total value of cross-bred prime lambs sold	$0	$51,025	$101,600	$60,448	$110,500
Total value of all sheep sold	$77,318	$128,200	$152,600	$155,200	$166,100
Total cost of sheep husbandry	$34,294	$59,995	$62,838	$69,106	$68,108
Farm Overheads					
Total depreciation cost	$24,984	$24,827	$24,639	$25,161	$25,156
Opportunity cost of capital	$27,144	$33,296	$33,162	$34,652	$34,203
Total machinery costs	$21,883	$19,548	$19,132	$19,282	$19,412
Total miscellaneous cost	$23,934	$22,255	$21,400	$21,300	$21,359