FUTURE FARM INDUSTRIES CRC

EverCrop Uniform Rainfall Zone

Assessing the impact of soil type change on whole farm performance indicators for the uniform medium rainfall zone of southern New South Wales

Geoff Casburn, Richard Hayes, Guangdi Li, Andrew Bathgate, Michael Robertson

CSIRO

NSW Government Department of Primary Industries

TECHNICAL REPORT 12

An Australian Government Initiative

CRC Australia

Published by: Future Farm Industries CRC

The University of Western Australia

M 081

35 Stirling Highway

Crawley WA 6009

ISBN: 978-0-9871562-8-0

ISSN: 1837-686

Future Farm Industries CRC Technical Report 12

Sub-series: Economic Analysis

Citation: Geoff Casburn, Richard Hayes, Guangdi Li, Andrew Bathgate, Michael Robertson (2014), *EverCrop Uniform Rainfall Zone – Assessing the impact of soil type change on whole farm performance indicators for the uniform medium rainfall zone of southern New South Wales.*

Future Farm Industries CRC

Technical Report **12**, First Edition June 2014. This report is based on MIDAS SNSW Model 10 (Version 2t). Future Farm Industries CRC, Perth, Western Australia. Electronic copies of this publication can be downloaded from Future Farm Industries website
http://www.futurefarmonline.com.au/publications/Technical_Reports

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.

Assessing the impact of soil type change on whole farm performance indicators for the uniform medium rainfall zone of southern New South Wales

Future Farm Industries CRC Technical Bulletin

Geoff Casburn[1,2], Richard Hayes[1,2], Guangdi Li[1,2], Andrew Bathgate[3], Michael Robertson[4]

1 NSW Department of Primary Industries, Wagga Wagga Agricultural Institute, NSW 2650

[2] Future Farm Industries CRC

[3] Farming Systems Analysis Service, 41 Trebor Road, Albany, WA 6330

[4] CSIRO Ecosystem Sciences and Sustainable Agriculture Flagship, Private Mail Bag 5, PO Wembley, WA 6913

ABSTRACT

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. The MIDAS (Model of an Integrated Dryland Agricultural System) Future Farm Industries CRC Technical Report 5: "Impact on farm profit from incorporating perennial pastures in the rotation of crop-livestock enterprises in southern New South Wales" (Bathgate *et al*. 2010) is the 'base' model describing scenarios for the incorporation of lucerne, chicory and phalaris into mixed farming systems, and is the base upon which the current report builds.

Whilst the standard model assumptions reflect the parameter values of an 'expected average', the conclusions are never based solely on model runs as per the standard assumptions. A series of sensitivity analyses were conducted to examine the influence of variation in parameter values on farm profit. Results of a sensitivity analysis of input costs and commodity prices using the same base model are reported in Technical Report 11 (Robertson *et al*. 2014).

The base run assumes a set mix of soil types on the representative farm that is typical of the study region. These soils vary in their capability to support crop and pasture production. However, farms in the study region vary in the make-up of soil types, thus influencing the potential capability of the farm to adopt perennial pastures. This technical report presents sensitivity analyses looking at the impact of differing soil types on the results of the 'base' run. It seeks to answer the following questions: How does soil type impact on *a*) whole farm profit; *b*) the use of annual pasture and the perennial pastures, including lucerne, chicory and phalaris; and *c*) the mix of crops and pastures.

The base model assumed crop yield potential on Grey Vertosols and Light Red Kandosols to be 10% and 40% less, respectively, than on Red Chromosols. The current analysis compared farms that were comprised of a single soil type rather than a mix of three soil types as assumed in the base run. The results showed that a farm comprised of Red Chromosols was 28% more profitable than one comprised of Light Red Kandosols, and 5 times more profitable than one comprised of Grey Vertosols and 10% more than the base farm, which included all three soil types.

Annual pasture was the least profitable pasture option on each soil type including the base farm. For the base farm, along with Light Red Kandosols and Red Chromosols, the annual only pasture option achieved approximately 24-29% less profit than pasture option 5 - all pastures. Annual pasture on the Grey Vertosol made a loss of $6,137 compared to a profit of $40,342 with the inclusion of chicory and phalaris.

Each of the perennial species played a key role in the different soil types to increase profit. They achieved this by more closely matching the year round nutritional requirements of livestock, reducing the amount of supplementary feed, increasing the carrying capacity of ewes per pasture hectare while in some cases providing increased crop yield in the first year following the pasture phase. They also lowered the proportion of the farm sown to crop. In general, the profit was lower when the area of crop exceeded 70% of total farm area.

For all soil types the main cropping rotation included 3-4 years of pasture followed by wheat, canola, wheat, lupin and barley. Grazing wheat played an important role in the system often making up 12-14% of the total farm area. The 3-4 year pasture phase supports producer reasoning behind sowing pasture under a cover crop in the first year of the pasture phase. Findings from a previous study (McCormick *et al*. 2012) suggest the net income generated from the crop combined with the livestock production from the short pasture phase is likely to be greater than the net income solely from livestock production with a straight sown pasture, assuming pasture performance is at least 50% of that produced by a straight sown pasture.

CONTENTS

1 INTRODUCTION

Whole-farm bio-economic modelling using the MIDAS (Model of an Integrated Dryland Agricultural System) model was used to estimate the economically-optimal area of a range of perennial pastures on representative farms of the target region. The current model (SNSW Model 10 -Version 2t) is based on the 'Coolamon' version of MIDAS.

The base model targeted the region bound by the 450 mm and 550 mm rainfall isohyets and ranges from approximately Grenfell, Cowra and Ariah Park in the north to Holbrook and Brocklesby in the south of south-west New South Wales. In practice the results of this study are likely to be applicable beyond the immediate study region described above, into northern Victoria in the south and the Central West of NSW, as shown in Figure 1.

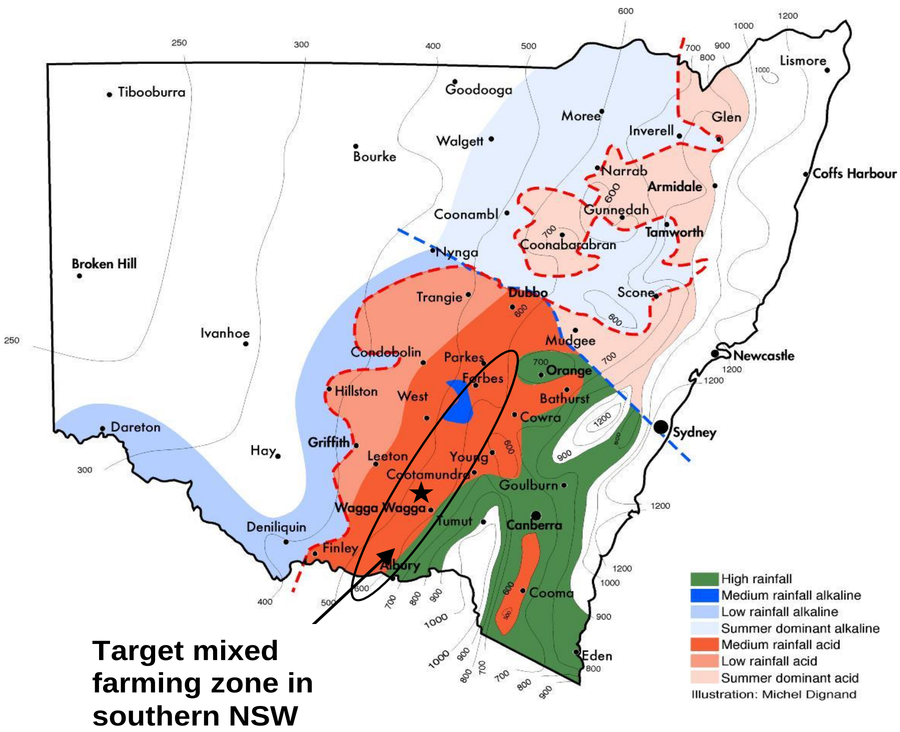

Figure 1: 'The target study region upon which the Coolamon version of MIDAS is based (From Bathgate et al. 2010).

2 IMPACTS OF SOIL TYPE CHANGES

The 'base' model comprised 4 soil types or land management units (LMUs) typical of farms in the district (Table 1). The total area of the base farm is 1000 ha. The productivity of crops and pasture were varied according to soil types.

LMU 1 is not included in the current sensitivity analysis as it is non-arable. In the three remaining LMUs, grain yield is varied according to crop and pasture rotations as well soil type characteristics (Table 1).

Table 1 Land management units and associated crop yield as a % of Red Chromosols (LMU 4) (From Bathgate et al. 2010).

LMU	Soil type	Baseline area (ha)	Crop yield reduction
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%

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

To assess the impact of the different soil types on profitability and enterprise makeup, the base farm was modelled with the 1000 ha farm solely comprised of a single soil type: grey vertosol, light red kandosol, and red chromosol..

Each farm was modelled with five different pasture options available for selection in the profit-maximising list of activities. The model had the ability to select one, multiple and all the species available within each pasture option. These were:

1. Annual pasture only

2. Annual pasture + lucerne
3. Annual pasture + lucerne+ chicory
4. Annual pasture + lucerne+ phalaris
5. All pasture options

In the base model, annual cycle of growth of pastures was grouped into 10 periods as listed in Table 2. The quality and quantity of feed is the average of the sward for each period. Each period varies in length according to growth rate and pasture quality (digestibility). Annual pasture seedlings are assumed to germinate in Period 1. Similar to grain yield, pasture growth rates were constrained in differing growth periods for LMU 2 and 3 in relation to LMU 4 (Appendix 1).

Table 2 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 phalaris, chicory and lucerne on Red Chromosols.

Period	Start date	Length	Average pasture growth rates (kg/ha/day) in year 2			
		Days	Mixed Annual	Phalaris	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.

A notable constraint in the model is phalaris and annual pasture only grow for 8 and 6 of the 10 growth periods, respectively, whereas lucerne and chicory grow in all 10 periods. Local field data, such as Hayes *et al*. (2010), would generally support this assumption.

The model optimised selection of crop-pasture areas and livestock numbers to maximise profit for each LMU (Appendices 2, 3, 4 and 5). The results were then compared to the base model to help assess the differences.

3 Results and Discussion

3.1 Whole farm profit from different soil types

Soil type had a large impact on annual whole farm profit. The farm dominated by the red chromosol soil type was 28% more profitable than that dominated by the light red kandosol, 5.5 times more profitable than the farm comprised of the grey vertosol, and 10% more profitable than the baseline farm which incorporated all three soil types (Table 3).

The pasture option containing all species available (option 5) was the most profitable pasture system for the grey vertosol farm and the light red kandosol farm which is consistent with which pasture option is selected for these soil types in the case of the base farm. Pasture option 5 was equally as profitable as pasture option 3 (annual, lucerne and chicory) for the red chromosol farm.

On the grey vertosol farm, the model selected only chicory (217 ha) and phalaris (211 ha) and not annual or lucerne pastures. The grey vertosol farm had the largest area sown to pasture (43% of the farm) compared to the light red kandosol farm (34%) and the red chromosol farm (35%).

There were significant differences in profit between the farms depending upon which pasture options were made available to be selected in the profit-maximising mix. Where annual pasture was only available profit was least on all four farm types, generating approximately 24-29% less profit than the situation where all pasture species were available for selection.

On the grey vertosol farm, where annual pasture or annual pasture + lucerne were available, the farm made a loss of $6,137 compared to a profit of $40,342 with the inclusion of chicory and phalaris. With the absolute profit considerably lower on the grey vertosol farm, this emphasises the importance of alternative perennial species for lower yielding soils that are less suitable to lucerne and annual pastures.

Table 3 The optimal farm mix based on the most profitable system for each model farm

Soil type	Baseline	Grey Vertosol	Light Red Kandosol	Red Chromosol
Most profitable pasture option	**All species**	**All species**	**All species**	**AP+lucerne + chicory**
Profit	**$206,867**	**$40,342**	**$177,778**	**$227,607**
Total pasture area (ha)	**436**	**428**	**344**	**351**
Annual pasture area	100	-	41	25
Lucerne area	246	-	60	272
Chicory area	24	217	161	53
Phalaris area	66	211	82	-
Total Crop area (ha)	**564**	**572**	**656**	**649**
Wheat area	234	250	274	260
Barley area	117	125	137	130
Canola area	117	125	137	130
Legume area	97	72	107	128
% Farm under crop	**56%**	**57%**	**66%**	**65%**
SR per grazed ha	13.8	10	15.2	14.2
SR per farm ha	6	4.4	5.2	5.0
Total ewes	3302	2654	2352	3007
Crop grazed (ha)	117	125	137	130
Supplementary feed (t)	140	158	118	135

** See Bathgate et al. (2010).*

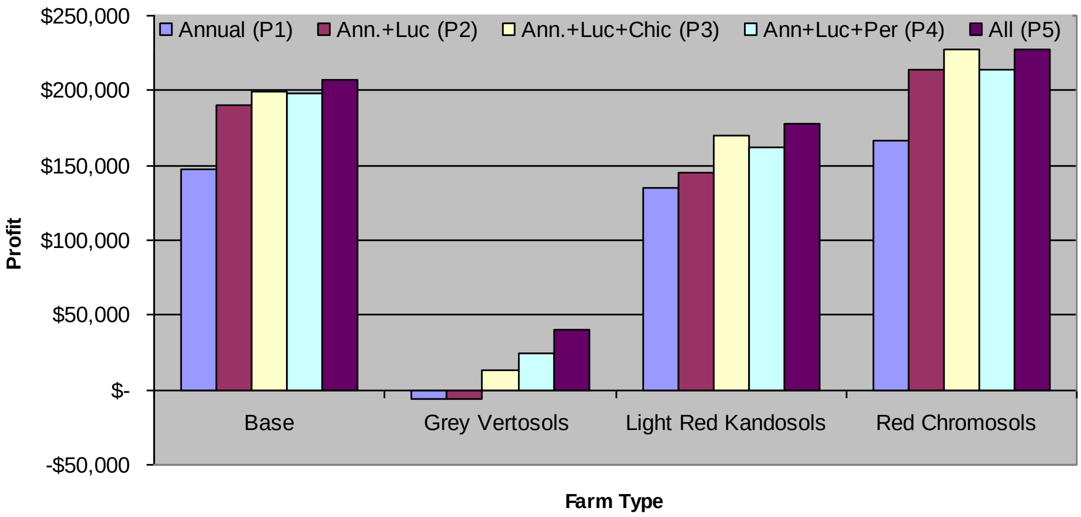

Figure 2 Impact of available pasture options on whole farm profit on four different farms, made up of the base mix of four soil types, and three farms comprised solely of grey vertosol, light red kandosol and red chromosol soils.

3.2 Pasture area under different soil types

Only on the light red kandosol farm did the model select all pasture species. Chicory had the largest area with 161 ha followed by phalaris with 82 ha and lucerne and annual pasture with 60 and 41 ha, respectively (Table 3). Annual pasture was selected because it occurred in crop-pasture rotations that maximised profit on this farm type.

On the red chromosol farm, lucerne was the favoured species with 272 ha followed by chicory (53 ha) and annual pasture (25 ha; Table 4).

On the light red kandosol and red chromosol farm, approximately 65% of the area was cropped which is approximately 10% greater than on the base farm and the grey vertosol farm. The base farm included 100 ha of non-arable land (non-arable tenosols) which explains the lower area sown to crop. The lower crop yields on grey vertosols explains why the model selected a greater pasture area when all species were available for selection. However, when chicory and phalaris were not available the model selected more crop, because the performance of lucerne and annual pasture was lower relative to crop.

The model selected similar areas of crop for the light red kandosol and red chromosol farms. This was because even though crop yields on light red kandosols is 10% less this was balanced by 5-15% less production from chicory and lucerne during key growth periods (see Appendix 1).

The smallest component of pasture on each of the model farms was pasture option 1 - annual pasture (Figure 3), with the light red kandosol farm having only 100 ha. This area increased to 370 ha with the addition of lucerne and phalaris (option 4). This increase in pasture area corresponded with a 20% increase in profit compared to annual pastures only (pasture option 1) (Figure 2).

Table 4. Individual pasture area where pasture options available vary, on each model farm.

Area in ha	AP	AP+lucerne	AP+lucerne +chicory	AP+lucerne +phalaris	All pastures
			Base farm		
Total pasture	**300**	**404**	**434**	**440**	**436**
Annual pasture	300	122	122	100	100
Lucerne	0	281	267	272	246
Chicory	0	-	44	-	24
Phalaris	-	-	-	68	66
			Grey vertosol farm		
Total pasture	**264**	**264**	**335**	**350**	**428**
Annual pasture	264	264	129	-	-
Lucerne	-	-	-	-	-
Chicory	-	-	205	-	217
Phalaris	-	-	-	350	211
			Light red kandosol farm		
Total pasture	**116**	**270**	**286**	**366**	**344**
Annual pasture	116	194	90	-	41
Lucerne	-	76	42	125	60
Chicory	-	-	154	-	161
Phalaris	-	-	-	241	82
			Red chromosol farm		
Total pasture	**286**	**364**	**351**	**364**	**351**
Annual pasture	286	36	25	36	25
Lucerne	0	327	272	327	272
Chicory	-	-	53	-	53
Phalaris	-	-	-	-	-

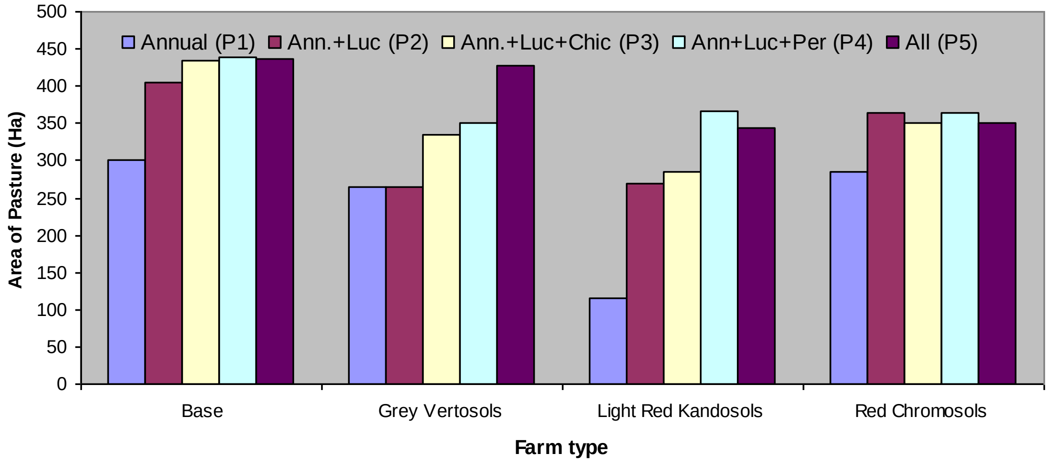

Figure 3 Difference in total pasture area for different model farms varying in soil types as a function of different pasture option availability.

On the farm with the most arable soil type (the red chromosol farm) there was little difference in total pasture area for the four different available perennial pasture options (Fig. 3). However, this can be misleading, as the model did not select all species available within each option. Lucerne was the main species selected with at least 5 times the area of any other pasture species, along with small areas of chicory and annual species, but no phalaris. This highlights the importance of lucerne in this region compared to other perennial species, although as previously stated alternative species such as lucerne and phalaris can add significant additional economic benefit.

Lucerne was not selected on the grey vertosol farm irrespective of available pasture option. This is likely to be a reflection of the constraints imposed within the model which assumed lucerne to be unsuitable to the water-logging prone soils, despite more recent research suggesting lucerne can be relatively productive on these soil types particularly where gypsum is applied to improve surface drainage (Dear et al. 2010b). Instead the model selected similar amounts of phalaris and chicory in pasture option 5(all species) and selected annual pasture when phalaris was not available. The growth of chicory and lucerne were constrained by 50% on the grey vertosol soil compared to the red chromosol (the most fertile soil type) whereas phalaris was only constrained by approximately 10% (Appendix 1).

On the light red kandosol farm, the model selected annual pasture for all available pasture options except in pasture option 4 where the model selected 241 ha of phalaris (Table 4). In pasture option 2, there was 2.5 times more annual pasture grown compared to lucerne and almost double the pasture area compared to option 1 (annual only). Annual pasture was selected because it occurred in crop-pasture rotations that maximised profit on this farm type.

The growth of lucerne on the light red kandosol soil was constrained in the model by 13% with no constraint applied to phalaris. This may explain why the model selected almost double the area sown to phalaris compared to lucerne in pasture option 4. With pasture option 5, all species were selected with 161 ha of chicory, 82 ha of phalaris, 60 ha of lucerne and 41 ha of annual pasture.

The model did not select phalaris in the most fertile soil type, the red chromosol. This is an indication that the model assumes lucerne to out-perform phalaris in soils suited to both species; again an assumption supported by some recent field data (Hayes *et al*. 2010).

3.3 Livestock under different pasture types

The farm comprising of the most fertile land management unit (red chromosol) ran the greatest number of livestock, with approximately 3000 ewes for each of the pasture options 2 to 5 (Table 5). Not only did perennial pastures run more livestock on a whole farm basis, they also supported higher stock densities, with greater than 8 ewes per hectare of pasture, combined with lower supplementary feeding rates. For pasture option 1 - annual pasture, the model ran 1784 ewes, which is 60% of the capacity achievable with the perennial pasture species.

The annual pasture on the light red kandosol farm carried the lowest number of ewes (991), equating to 8.5 ewes per ha of pasture. This high density is due mainly to the benefits of stubble from a large cropping area combined with high supplementary feeding rates. However this option made $42500 less profit compared to the situation when pasture option 5 was made available (Figure 2).

For the light red kandosol farm, the availability of lucerne (option 2) resulted in the total ewe numbers increasing as the area of pasture increased (Table 4). However, this resulted in a large decrease (almost 50%) in the number of ewes per ha of pasture while the level of supplementary feeding remained high (94kg per ewe). With the inclusion of chicory and phalaris pastures the total ewe numbers and the ewes per ha of pasture increased further combined with a halving of supplementary feeding levels. This resulted in an increase in profit totalling $35000.

Survey results (Dear *et al*. 2010a) indicated that in lower rainfall regions of the mixed cropping zone a greater proportion of the farm area was sown to crop in contrast to higher rainfall regions where a greater area was sown to pasture. While topography plays a role in this difference, anecdotal evidence suggests that this trend is also related to livestock carrying capacities. Results of the survey indicated that farms with 45% of crop carried 2.4 ewes/ha while 60% of crop had 1.8 ewes/ha over the whole farm.

In the higher rainfall areas of the region, the pasture growing season is longer, supporting higher stocking rates, resulting in profitability of livestock enterprises approaching profitability of cropping. Conversely, the pasture growth period is shorter in lower rainfall regions resulting in correspondingly lower stocking rates compared to crop yields, resulting in cropping being more favourable.

Table 5. Individual pasture area where pasture options available vary, on each model farm.

	AP	AP+lucerne	AP+lucerne +chicory	AP+lucerne +phalaris	All pastures
			Base farm		
Total ewes	1816	2781	3037	3345	3302
Ewes/ha of pasture	6.05	6.88	7.00	7.60	7.57
Suppl. feed (t)/ewe	0.070	0.041	0.040	0.042	0.042
Grazing crop (ha)	**100**	**106**	**113**	**116**	**117**
			Grey vertosol farm		
Total ewes	1139	1139	1442	2598	2654
Ewes/ha of pasture	4.31	4.31	4.30	7.42	6.20
DSE/ewe	1.65	1.65	1.65	1.62	1.61
Suppl. feed (t)/ewe	0.074	0.074	0.053	0.063	0.060
Grazing crop (ha)	**132**	**132**	**133**	**87**	**125**
			Light red kandosol farm		
Total ewes	991	1336	2010	2167	2352
Ewes/ha of pasture	8.54	4.95	7.03	5.92	6.84
Suppl. feed (t)/ewe	0.096	0.094	0.061	0.057	0.050
Grazing crop (ha)	58	135	143	143	137
			Red chromosol farm		
Total ewes	1784	3026	3007	3026	3007
Ewes/ha of pasture	6.24	8.31	8.57	8.31	8.57
Suppl. feed (t)/ewe	0.077	0.044	0.045	0.044	0.045
Grazing crop (ha)	143	127	130	127	130

3.4 Crop areas under different soil types

For all model farms, the greatest area sown to crop was where pasture option 1 was available (Figure 4). The light red kandosol farm had the greatest area of crop with 884 ha and 116 ha of annual pasture. This returned $43,000 (23%) less profit where there was 656 ha of crop and 344 ha of pasture for pasture option 5.

Farm profit appears to be lower when crop area is equal to or greater than 70% (700 ha) of total farm area. The exception to this trend is pasture option 3 on the light red kandosol farm, as it achieved 5% more profit with 714 ha of crop compared to pasture option 4 with 634 ha of crop. One reason for this anomaly is the superior productivity and growth habit of chicory, which allowed for 18% more ewes per ha of pasture compared to phalaris (Table 5). The growth of phalaris is constrained in the model with minimal or no growth in periods 8, 9 and 10 (Table 2).

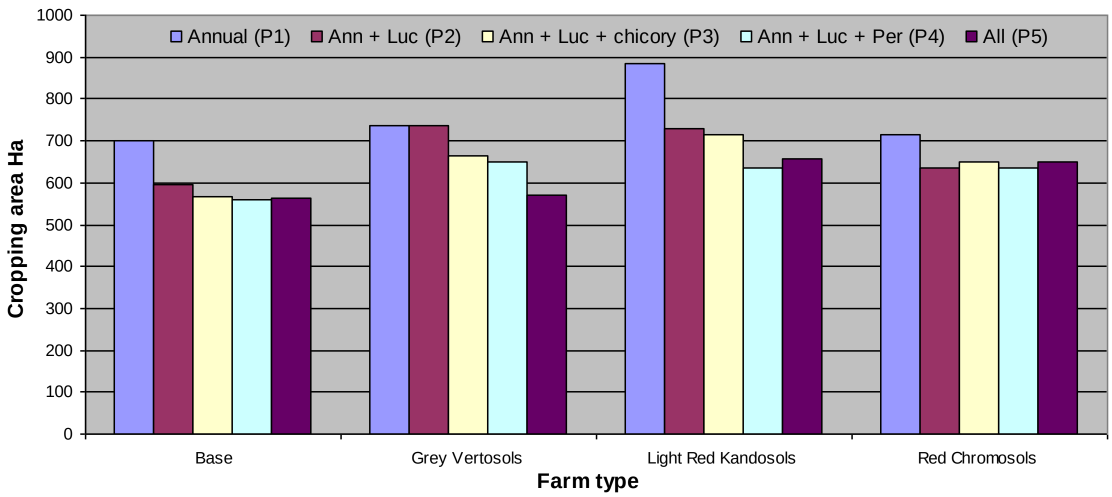

Figure 4 Area sown to crop for the different available pasture options and model farms

On the grey vertosol farm the model selected a greater area of crop with available pasture options 1, 2 and 3. This result was most likely due to the model having greater restraints on pasture growth compared to crop yields for annual pasture, lucerne and chicory (Appendix 3 and Table 2). This result is supported by lower stocking rates per hectare grazed and higher supplementary feeding levels (Table 5). Low pasture growth rates are likely to make cropping more favourable.

As a trend, the area sown to barley, canola and lupins was greatest with pasture option 1, while there was little difference between the pasture options 2 to 5. For pasture option 1, the greatest difference was in the light red kandosol farm with 25% more crops than the other options (Table 6). It is interesting that with the inclusion of lucerne pasture (option 2), the total area of barley, canola and lupins was reduced by 179 ha, while the total cropping area was reduced by only 154 ha. The reason behind this is a 20ha increase in the area sown to wheat which may be a result of increased yield potential due to lucerne providing nitrogen in the 1st year after pasture (Table 4). On the red chromosol farm the area sown to lupins was around 12% of total farm area even though this soil type had the greatest area sown to lucerne with 27 to 32% of total farm area.

On the grey vertosol farm, the inclusion of chicory (pasture option 3) led to the total cropping area being reduced by approximately 70 ha (Table 4). While this does not translate into an increase in stocking rate per hectare of pasture, it resulted in a reduction of approximately 30% in the level of supplementary feeding per hectare of pasture, which corresponds with chicory's year round growth habit (Table 5). With the inclusion of pasture option 4 – phalaris, there was an increase of 30 ha each for both barley and canola and a reduction of 50ha in lupins.

On the light red kandosols farm with pasture option 4, there was a reduction of 75 ha in the area sown to lupins with a similar increase in the area sown to lucerne. In pasture option 5 – all pastures, there was an increase of 45 ha in the area sown to lupins which was partly balanced by a reduction of 65 ha in the area sown to lucerne.

For pasture options 2-5 on the red chromosol farm there was little difference in the area sown to wheat, barley, canola or lupins. It is interesting that the proportion of area sown to wheat for Red Chromosols and the base farm equals the proportion of area sown to canola and barley combined.

For nearly all land management units and pasture options, the area sown to grazing crop ranged from 12 -14% of total farm area. However, on the grey vertosol farms with pasture option 4 and the light red kandosol farm with pasture option 1 there was considerably less grazing crop with 9% and 6% respectively. This low level of grazing crop is a result of large areas of crop-only rotations of 594 and 300 ha, respectively (Table 7), and therefore the reduced need for additional feed for livestock from grazing crops.

Table 6 Individual crop areas (ha) for each available pasture option and model farm.

	AP	AP+lucerne	AP+lucerne	AP+lucerne	All pastures
			Base farm		
Crop	700	596	566	560	564
Wheat	250	228	227	232	234
Barley	150	123	113	116	117
Canola	150	123	113	116	117
Lupin	138	122	113	96	97
% Farm under crop	**70%**	**60%**	**57%**	**56%**	**56%**
			Grey vertosol farm		
Crop	736	736	665	650	572
Wheat	283	283	266	250	250
Barley	151	151	133	163	125
Canola	151	151	133	163	125
Lupin	134	134	125	75	72
% Farm under crop	**74%**	**74%**	**67%**	**65%**	**57%**
			Light red kandosol farm		
Crop	884	730	714	634	656
Wheat	264	284	286	286	274
Barley	207	149	143	143	137
Canola	207	149	143	143	137
Lupin	199	136	137	62	107
% Farm under crop	88%	73%	71%	63%	66%
			Red chromosol farm		
Crop	714	636	649	636	649
Wheat	286	255	260	255	260
Barley	143	127	130	127	130
Canola	143	127	130	127	130
Lupin	125	125	128	125	128
% Farm under crop	71%	64%	65%	64%	65%

3.5 Cropping rotations

Pasture and crop rotations for the different pasture options and land management units are described in Table 7

Virtually all rotations that include crop and pasture consist of wheat, canola, wheat, lupin, and barley. The inclusion of a second year of wheat in the rotation (grazing wheat) supports the argument that grazing wheat is an important feed source in mixed farming systems as well as producing valuable grain.

The pasture phase is mainly either three or four years for all crop rotations. This is a significant finding as many pastures in the region are sown under a cover crop in the first year of the pasture phase (Dear *et al*. 2010a). Generally the use of a cover crop in a three to four year pasture phase has been shown to be more profitable when compared to straight sowing. The net income generated from the cover crop combined with the livestock production from the short pasture phase, is likely to be greater than the net income solely from livestock production with a straight sown pasture. This assumes pasture performance is at least 50% of that produced by a straight sown pasture (McCormick *et al*. 2012).

The model selected large areas of crop only rotations in the grey vertosol and light red kandosol farms consisting of wheat, canola, barley and lupin. It is likely that the model selected lupins as the last crop in the rotation to provide nitrogen for the following wheat crop as well as a disease break.

Low pasture production on the grey vertosol resulted in the model selecting large areas of crop only rotations for all the available pasture options except option 5. In the case of the light red kandosol farm and available pasture option 1, the model selected a crop only rotation consisting of 594 ha which is 60% of total farm area. The shorter crop sequence perhaps also reflects the need for increased intensity of legume crops (1 in 4 as opposed to 1 in 5) in the absence of N_2-fixing legume pastures (Table 4).

It is interesting that the most fertile land management unit (red chromosol) did not have a crop only rotation. This indicates the valuable contribution that livestock production makes to farm profitability in fertile soils suitable for good pasture growth.

In the grey vertosol and light red kandosol farms with available pasture option 4, the model selected a novel cropping rotation consisting of four and five years of phalaris followed by wheat, canola, wheat, barley that excluded lupins.

Table 7 Crop and pasture rotation for the different land management units with pasture options 1-5.

	Annual pasture		Annual +lucerne		Annual+Lucerne +chicory		Annual+Lucerne + phalaris		All pasture	
					Base farm					
LMU	Rotation	Area	Rotation	Area	Rotation	Area	Rotation	Area	Rotation	Area
1	20PA	100	20PA	100	20PA	100	20PA	100	20PA	100
2	5PWNB	50	5PWNLB	50	5PWNLB	50	5HWNB	50	5HWNB	50
3	3PWNB	200	3UWNLB	132	4UWNLB	83	3UWNLB	100	4UWNLB	85
			WCBL	68	4YWNLB	117	4HWNB	100	4YWNLB	19
									4HWNB	96
4	3PWNLB	260	4UWNLB	650	4UWNLB	650	4UWNLB	650	4UWNLB	590
	3PWNB	390							3YWNLB	60
					Grey vertosol farm					
	3PWNLB	925	3PWNLB	925	4YWNLB	548	5HWNB	700	4YWNLB	578
	WCBL	75	WCBL	75	WCBL	452	WCBL	300	5HWNB	422
					Light red kandosol farm					
	3PWNLB	406	3UWNLB	267	3UWNLB	148	3UWNLB	437	3UWNLB	209
	WCBL	594	3PWNLB	679	3YWNLB	538	4HWNB	563	4HWNB	191
			WCBL	54	3PWNLB	314			4YWNLB	342
									3YWNLB	116
									3PWNLB	142
					Red chromosol farm					
	3PWNLB	1000	4UWNLB	873	4UWNLB	726	4UWNLB	873	4UWNLB	726
			3PWNLB	127	3YWNLB	186	3PWNLB	127	3YWNLB	186
					3PWNCB	88			3PWNCB	88

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.

4 Conclusion

A farm dominated by red chromosol soil was estimated to be almost 30% more profitable than a similar farm dominated by light red kandosol soil, and more than 5 times more profitable than a farm dominated by grey vertosol soil. This reflects the higher growth potential of both crops and pastures on the red kandosol; a soil largely unaffected by the acidity and lower nutrition of the light red kandosol, or by the sodicity, salinity and heavy texture of the grey vertosol. It also reflects a higher stocking rate to utilise the increased pasture biomass. The model predicted whole farm profitability to be greatest where all pasture options were available, particularly on the constrained soils, and generally least where annual pasture was the only option available. The optimal area of the farm under pasture increased on the highly constrained soil type to approximately 45% compared to 35% on the better soil types, illustrating an emphasis away from crops and towards pastures with increased soil constraints.

This study can be viewed at two levels. First, it attempts to quantify differences in whole farm profitability of different soil types. This may be of value when making decisions about buying or leasing new land. However, on land that is already owned or leased, there is relatively little that can be done to alter soil type. In that instance, this study presents options for how profitability might be optimised in a mixed livestock/crop production enterprise. It highlights the increased relative importance of pastures compared to crops in highly constrained soils, as well as the importance of having viable alternative perennial pasture species other than lucerne. Whilst perennial pastures were shown to increase profitability across all soil types compared to only annual pastures, the relative importance of chicory and phalaris increased on the grey vertosol where lucerne was not selected due to its poorer adaptation, particularly to waterlogging. The current sensitivity analysis indicates the results obtained in the baseline analysis would change as assumptions about soil type mix change, with increased importance placed upon alternative perennial species for profit optimisation.

References

Bathgate A, Reynolds M, Robertson M, Dear B, Li G, Casburn G and Hayes R (2010). 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.. Future Farm Industries CRC, Perth, Technical Report 5

Dear BS, Peoples MB, Hayes RC, Swan AD, Chan KY, Oates AA, Morris SG, Orchard BA (2010b) Effect of gypsum on establishment, persistence and productivity of lucerne and annual pasture legumes on two grey Vertosols in southern New South Wales. Crop and Pasture Science 61, 435-449

Dear BS, Casburn GR, Li GD, Walker J, Bowden P, Hayes RC, (2010a). A survey of the use of perennial pastures as part of the pasture-crop rotation in the mixed farming zone of southern New South Wales. Future Farm Industries CRC Perth, Technical Report 3

Hayes, RC, Dear, BS, Li, GD, Virgona, JM, Conyers, MK, Hackney, BF and Tidd, J (2010). Perennial pastures for recharge control in temperate drought-prone environments. Part 1: productivity, persistence and herbage quality of key species. New Zealand Journal of Agricultural Research 53 (4): 283 - 302.

McCormick J, Hayes R, Li G, Nordblom T, Casburn G, Hutchings T, Moore AD, Zurcher E, Peoples M, Swan T (2012). To under-sow or not? A decision support tool to determine the most profitable method of pasture establishment. In 'Proceedings of 16th Australian Agronomy Conference, Capturing Opportunities and Overcoming Obstacles in Australian Agronomy'. Armidale, NSW. (Ed. I Yunusa). (Australian Society of Agronomy).

Robertson M, Bathgate A, Reynolds M, Hayes R, McCormick J, Li G, Casburn G, (2013). Assessing the impact of input costs on enterprise mix on crop-livestock farms in southern New South Wales. Future Farm Industries CRC Perth, Technical Report 11

APPENDIX 1 - PASTURE GROWTH RATES

Period	LMU1	LMU2	LMU3	LMU4
Growth of lucerne on each LMU relative to Red Chromosols				
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%
Growth of chicory on each LMU relative to Red Chromosols				
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%
Growth of phalaris on each LMU relative to Red Chromosols				
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				

APPENDIX 2 - BASELINE MIDAS RESULTS FOR 1000 HA FARM

Key statistics	Option 1	Option 2	Option 3	Option 4	Option 5
	AP	AP+lucerne	AP+lucerne +chicory	AP+lucerne +per grass	All pastures
Total pasture area	300	404	434	440	436
Annual pasture area	300	122	122	100	100
Lucerne area	0	281	267	272	246
Chicory area	0	-	44	-	24
Phalaris area	-	-	-	68	66
Wheat area	250	228	227	232	234
Barley area	150	123	113	116	117
Canola area	150	123	113	116	117
Legume area	138	122	113	96	97
SR per grazed ha	10.0	13.5	12.8	14.0	13.8
SR per farm ha	3.0	5.4	5.5	6.2	6.0
Crop grazed (ha)	100	106	113	116	117
Supplementary feed (t)	127	113	120	139	140

APPENDIX 3 - MIDAS RESULTS FOR 1000 HA FARM WITH GREY VERTOSOLS

Key statistics	Option 1	Option 2	Option 3	Option 4	Option 5
	AP	**AP+lucerne**	**AP+lucerne +chicory**	**AP+lucerne +per grass**	**All pastures**
Total pasture area	264	264	335	350	428
Annual pasture area	264	264	129	-	-
ucerne area	-	-	-	-	-
Chicory area	-	-	205	-	217
Phalaris area	-	-	-	350	211
Wheat area	283	283	266	250	250
Barley area	151	151	133	163	125
Canola area	151	151	133	163	125
egume area	134	134	125	75	72
SR per grazed ha	7.1	7.1	7.1	12	10
SR per farm ha	1.9	1.9	2.4	4.3	4.4
Crop grazed (ha)	132	132	133	87	125
Supplementary feed (t)	84	84	77	164	158

Appendix 4 - MIDAS Results for 1000 ha farm with Light Red Kandosols

Key statistics	Option 1	Option 2	Option 3	Option 4	Option 5
	AP	AP+lucerne	AP+lucerne +chicory	AP+lucerne +per grass	All pastures
Total pasture area	116	270	286	366	344
Annual pasture area	116	194	90	0	41
Lucerne area	-	76	42	125	60
Chicory area	-	-	154	-	161
Phalaris area	-	-	-	241	82
Wheat area	264	284	286	286	274
Barley area	207	149	143	143	137
Canola area	207	149	143	143	137
Legume area	199	136	137	62	107
SR per grazed ha	14.1	14.5	14.9	17.5	15.2
SR per farm ha	1.6	3.9	4.3	6.4	5.2
Crop grazed (ha)	58	135	143	143	137
Supplementary feed (t)	95	126	123	123	118

Appendix 5 - MIDAS Results for 1000 ha farm with Red Chromosols

Key statistics	Option 1	Option 2	Option 3	Option 4	Option 5
	AP	AP+lucerne	AP+lucerne +chicory	AP+lucerne +per grass	All pastures
Total pasture area	286	364	351	364	351
Annual pasture area	286	36	25	36	25
Lucerne area	0	327	272	327	272
Chicory area	-	-	53	-	53
Phalaris area	-	-	-	-	-
Wheat area	286	255	260	255	260
Barley area	143	127	130	127	130
Canola area	143	127	130	127	130
Legume area	125	125	128	125	128
SR per grazed ha	10.3	13.7	14.2	13.7	14.2
SR per farm ha	2.9	5.0	5.0	5.0	5.0
Crop grazed (ha)	143	127	130	127	130
Supplementary feed (t)	137	134	135	134	135