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Economics of soil management in pasture systems for sheep enterprises in the Central West Catchment of NSW

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Abstract

In this research Grassgro® was used to compare the optimum sheep stocking rates for gross margins against the optimum stocking rates for best practice soil management for five regions in the Central West of NSW.

Five best practice management scenarios were used to evaluate the impacts of changes to pasture and soil characteristics. Results show that maintaining legumes in pastures up to the 30 per cent level would have had the greatest impact on the enterprise gross margins relative to other management changes. The next largest benefit would have been to increase soil fertility by 10 per cent as it would increase the gross margin by $17/ha at Trangie and $87/ha at Mudgee.

The optimal stocking rates according to the gross margins were 12 hd/ha for Bathurst, 8 hd/ha for Mudgee, 5 hd/ha for Dubbo and Peak Hill, and 4 hd/ha for Trangie. Minimum total herbage mass estimates indicate that there would have been insufficient ground cover for Peak Hill and Trangie at these stocking rates to minimise soil erosion. Stocking rates in these two regions would therefore need to decrease to 4 and 3 hd/ha respectively which is a reduction of 1 hd/ha in each region.

Key words: stocking rates, soil quality, soil loss, ground cover and pasture value.

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1. Introduction

The aim of this study was to identify the optimal stocking rates for best practice management of pastures and soils for five locations in the Central West Catchment of NSW. The study regions include tablelands, slopes and plains geographic areas within the catchment. One of four sheep enterprises: fine, medium and strong wool, or first cross lamb production was analysed for five regions: Bathurst, Mudgee, Dubbo, Trangie and Peak Hill. The enterprises were selected to represent the dominant sheep stocking practice of each region.

Warn, Webb Ware, Salmon, Donnelly and Alcock (2005) and Warn, Geenty and McEachern (2006) have used Grassgro® to model optimal stocking rates on pastures. In this research the aim was to identify the optimum stocking rates through gross margins analysis and then to assess changes in gross margins resulting from varying pasture and soil management factors. Simpson, Richardson, Salmon, Graham, Mckay and Riley (2007) provide a detailed discussion of soil factors affecting pasture production.

The locations in the far west and north of the catchment could not be adequately modelled due to the limited capacity of the Grassgro® program (2007) to represent C4 grass species in the region. The Grassgro® program is also limited in that it does not include alternate feeds such as crop stubble or standing cereal crops as feed alternatives for grazing animals. There is a significant late summer feed gap within the catchment, which is typically filled with cereal crop stubble, which could not be adequately modelled.

The Grassgro® program uses historical rainfall, temperature and evaporation conditions for the selected period 1980 to 2006 to model growth of pastures over time. The 2007 version of the program does not enable two groups of livestock to be run together in the same paddock and the range of pasture species available is predominantly C3's. No native grasses or native legumes are included in the program, which limits its application within the catchment. Initial soil conditions and pasture mixes were selected within the program for each paddock in each region. The selection of pasture types follows the best practice recommendations of Ayres and Clements (2007). Modelled pasture production is grazed by the selected animal enterprise, which in turn impacts on subsequent pasture growth and seeding events.

The income sources are derived from the sale of animals or wool. Variable costs are incurred from purchasing replacement animals, supplementary feed, animal husbandry, and pasture establishment and maintenance. The Grassgro® option for pasture costs is a fixed establishment rate with variation in the pasture life and maintence cost. Soil fertility is managed by selecting the appropriate soil fertility percentage at the start of the analysis and then the Grassgro program applies a constant cost for fertiliser in each subsequent year, which is reflected in the gross margin.

The gross margin is total income minus the total of the variable costs. Fixed costs such as fencing, sheep yards, council rates and depreciation are not accounted for in this gross margin analysis.

Stocking rates were selected to provide a range in values that would show the effects of under and overgrazing in the gross margins for each region. Optimal stocking rates were selected according to the gross margin and risk profile (CDF data not shown). A rotation system of five paddocks was selected to simulate a controlled grazing system. In three regions the paddock size was set to 30 hectares, but in the two western regions (Peak Hill and Trangie) it was set to 40 hectares to accommodate the lower levels of pasture production per hectare. The enterprise type, stocking rate, optimal stocking rate, paddock size and pasture mix data are presented for each region in Table 1.

Table 1 shows that the optimal stock rates were 12 hd/ha for Bathurst, 6 hd/ha for Mudgee, 5 hd/ha for Dubbo, 5 hd/ha for Peak Hill, and 4 hd/ha for Trangie.

Table 1: Summary of major model variables by region

Region	Enterprise	Stock Rate	Optimal Rate	Paddock ha's	Pasture mix
Bathurst Tablelands	Sheep Merino Ewes	10 - 14	12	30 x 5	An Rye Grass, Phalaris, Lucerne
Mudgee Slopes	Sheep Merino Ewes	6 - 10	8	30 x 5	Per Rye Grass, Phalaris, Lucerne, Sub clover
Dubbo Slopes	Sheep First Cross Ewes	3 - 7	5	30 x 5	Per Rye Grass, Phalaris, Lucerne
Peak Hill Plains	Sheep Merino Ewes	3 - 7	5	40 x 5	An Rye Grass, Phalaris, Lucerne
Trangie Plains	Sheep Merino Ewes	2 - 6	4	40 x 5	An Rye Grass, An Grass, Phalaris, Medic

The above table presents information across regions; however, the analysis is only valid for within region comparisons. That is we can only compare the optimum stocking rates for gross margin with the corresponding optima for best practice management within each region. It is not valid to compare the gross margins for Trangie and Bathurst for example.

2. Pasture production

The levels of pasture production, herbage mass and drainage for each stocking rate and region are presented in Table 2. The minimum pasture cover for each area was set to 400 kgs/ha before supplementary feed options would be triggered. Supplementary grain and straw were made available to the sheep in periods where feed availability declined to 400 kgs or below. There is no option in Grassgro® to specify different straw prices at different times of the year to represent stubble demand in January and February. The cost of straw was therefore constant across the year. Given that the feed gap and therefore hay demand was mostly high in late summer then this issue was not significant when summer hay prices were used.

Pasture production varies with the mix of pasture, grazing pressure and environmental conditions. The levels of pasture production increased with increasing rainfall and soil fertility. The highest levels of pasture were produced at Bathurst with 7.9 tonnes per hectare and the lowest was 3.7 tonnes per hectare at Peak Hill.

Table 2: Pasture production, herbage mass and drainage by stocking rate and region

Bathurst	Stocking rate		10 hd/ha	11 hd/ha	12 hd/ha	13 hd/ha	14 hd/ha
Annual Pasture production	kg/ha	7990	7988	7972	7950	7941
Minimum total herbage	kg/ha	1921	1733	1553	1390	1235
Drainage	mm	52	53	54	55	56
Mudgee	Stocking rate	6 hd/ha	7 hd/ha	8 hd/ha	9 hd/ha	10 hd/ha
Annual Pasture production	kg/ha	6162	6073	5969	5953	5881
Minimum total herbage	kg/ha	1722	1489	1275	1111	976
Drainage	mm	86	90	94	98	103
Dubbo	Stocking rate	3 hd/ha	4 hd/ha	5 hd/ha	6 hd/ha	7 hd/ha
Annual pasture production	kg/ha	6062	5994	5963	5944	5853
Minimum total herbage	kg/ha	2265	1919	1613	1361	1121
Drainage	mm	35	36	37	38	40
Peak Hill	Stocking rate	3 hd/ha	4 hd/ha	5 hd/ha	6 hd/ha	7 hd/ha
Annual pasture production	kg/ha	3933	3867	3791	3711	3692
Minimum total herbage	kg/ha	1185	946	743	583	481
Drainage	mm	12	13	14	15	15
Trangie	Stocking rate	2 hd/ha	3 hd/ha	4 hd/ha	5 hd/ha	6 hd/ha
Annual Pasture production	kg/ha	4544	4408	4301	4198	4108
Minimum total herbage	kg/ha	1138	922	761	606	481
Drainage	mm	61	63	65	65	66

3. Minimum total herbage

The minimum levels of herbage masses are reported in Table 2 for each region. The minimum total herbage mass was 1.2 to 1.9 tonnes per hectare at Bathurst for 10 to 14 head per hectare. Bathurst, Mudgee and Dubbo were the only regions with a minimum total herbage mass above 800 kilograms per hectare for the optimal stocking rates selected by maximising the gross margin. The minimum herbage mass to prevent soil erosion on relatively flat landscapes was 800 kgs (Rosewell 1993). The Peak Hill and Trangie regions were not able to sustain the minimal ground cover requirement of 800 kgs and the available quantity fell to 481 kgs/ha with the highest stocking rates. The reduction in minimal total herbage, as stocking rates increased, limited feed availability but also reduced the capacity of the soils to hold water, which reduced productivity. Paddocks should carry no more than 4 hd/ha at Peak Hill and 3 hd/ha at Trangie to comply with this recommendation.

4. Drainage

The levels of drainage for a range of stocking rates are also shown in Table 2. The level of drainage was affected by soil depth, fertility, which was a proxy variable for organic matter in the model, rainfall and water infiltration, which was a function of soil bulk density. For most regions the increase in drainage, due to increased stocking rates, was in the 5 to 6 mm range from the lowest to highest stocking rates; however, the water loss at Mudgee was 27 mm when stocking rates increased from 6 to 10 hd/ha. Lucerne was set to 25 per cent of the pastures in the Mudgee region and a higher percentage of legumes within the crop at that location may have assisted with increasing water utilisation. Deep-rooted perennial pastures may also assist.

5. Income

Incomes, selected expenses and gross margins for each region are shown in Table 3. Incomes from wool and livestock sales increased with higher stocking rates. Wool income was driven by wool yield and fibre diameter, which varies with each season and stocking rate. It was expected that as stocking rates increased then micron and yield would decrease. Fibre diameter and yield were found to be positively correlated implying that wool yield did increased with micron. Wool price increased with higher yields and decreased with higher micron counts and this caused much of the variation in wool incomes.

6. Expenses

Costs increase as the stocking rate increases with the exception of pasture costs. Some costs such as shearing increase in fixed proportion to the increase in the stocking rate; however, other costs increase at an increasing rates such as feed costs (maintenance supplement). Indeed the largest variable costs to the farm systems were the maintence supplements, which caused the higher stocking rates to reduce the gross margins very quickly.

7. Gross margins

The optimum gross margin at Bathurst was $173 per ha. Mudgee produced it highest gross margin at $157 per ha. The western regions of Peak Hill and Trangie produced their highest gross margins at $75/ha and $59/ha respectively. The first cross ewe production system at Dubbo produced an optimum gross margin at $60/ha.

Table 3: Income, expenses and gross margins by stocking rate and region

Bathurst	Stocking rate	10/ha	11/ha	12/ha	13/ha	14/ha
Net wool income - main flock	$/ha	174	190	206	221	237
Net wool income - young stock	$/ha	43	46	50	52	55
Total income A	$/ha	468	505	543	575	610
Animal husbandry	$/ha	49	54	58	62	67
Shearing costs	$/ha	96	105	115	124	133
Rams purchased	$/ha	40	44	48	52	56
Sale costs	$/ha	46	50	54	58	62
Maintenance supplement	$/ha	31	37	49	63	78
Total expenses* B	$/ha	309	336	370	404	441
Gross margin A-B	**$/ha**	**159**	**168**	**173**	**171**	**168**

Mudgee	Stocking rate	6/ha	7/ha	8/ha	9/ha	10/ha
Net wool income - main flock	$/ha	94	109	122	134	145
Net wool income - young stock	$/ha	55	62	68	74	78
Total income* A	$/ha	390	444	495	539	577
Animal husbandry	$/ha	18	21	24	26	29
Shearing costs	$/ha	42	49	55	62	69
Replacements purchased	$/ha	82	96	109	123	136
Rams purchased	$/ha	19	22	26	29	32
Sale costs	$/ha	32	37	41	46	50
Maintenance supplement	$/ha	16	26	41	58	79
Total expenses* B	$/ha	251	293	338	386	437
Gross margin A-B	**$/ha**	**139**	**152**	**157**	**153**	**140**

Dubbo	Stocking rate	3/ha	4/ha	5/ha	6/ha	7/ha
Net wool income - main flock	$/ha	28	37	46	54	61
Sale income - young stock	$/ha	125	159	190	219	246
Total income A	$/ha	191	246	297	344	388
Animal husbandry	$/ha	11	14	17	20	22
Shearing costs	$/ha	12	16	20	24	28
Sale costs	$/ha	19	25	30	36	40
Maintenance supplement	$/ha	7	18	36	58	91
Total expenses * B	$/ha	148	190	237	289	352
Gross margin A-B	**$/ha**	**42**	**56**	**60**	**55**	**36**

Peak Hill	Stocking rate	3/ha	4/ha	5/ha	6/ha	7/ha
Net wool income - main flock	$/ha	51	66	80	91	102
Sale income - young stock	$/ha	101	131	158	181	203
Sale income - cast-for-age	$/ha	38	50	61	72	82
Total income A	$/ha	190	246	299	344	386
Animal husbandry	$/ha	9	12	15	18	20
Shearing costs	$/ha	12	16	20	24	28
Replacements purchased	$/ha	25	33	42	50	58
Sale costs	$/ha	17	22	27	32	37
Maintenance supplement	$/ha	25	49	78	114	149
Total expenses* B	$/ha	127	172	224	281	338
Gross margin A-B	**$/ha**	**63**	**74**	**75**	**63**	**48**

Trangie	Stocking rate	2/ha	3/ha	4/ha	5/ha	6/ha
Net wool income	$/ha	35	50	65	76	88
Sale income - young stock	$/ha	68	99	127	149	172
Sale income - cast-for-age	$/ha	26	38	50	60	71
Total income A	$/ha	128	186	241	285	330
Animal husbandry	$/ha	6	9	12	15	17
Shearing costs	$/ha	8	12	16	20	24
Rams purchased	$/ha	3	5	6	8	10
Sale costs	$/ha	11	16	22	27	31
Maintenance supplement	$/ha	17	35	57	86	119
Total expenses* B	$/ha	98	138	182	233	287
Gross margin A-B	**$/ha**	**30**	**48**	**59**	**52**	**44**

* Some income and variable costs may not be included in this table.

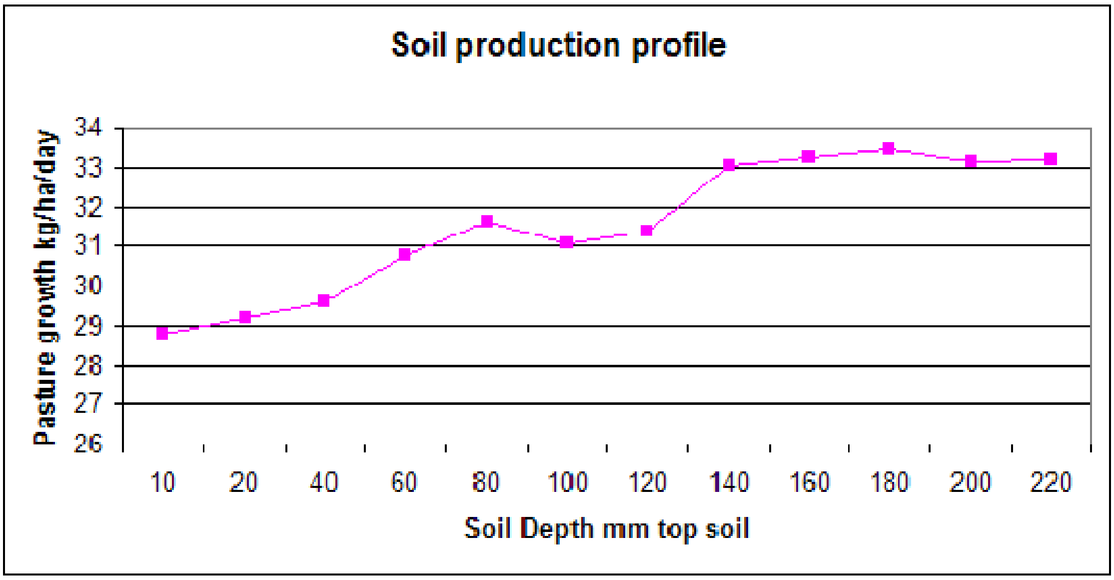
The gross margins tables show the stocking rates that would be selected to maximise gross margins for each region. The optimal stocking rates shown in the gross margins tables were 12 hd/ha for Bathurst, Mudgee 8 hd/ha, Dubbo and Peak Hill 5 hd/ha and Trangie 4 hd/ha. To minimise soil loss the stocking rates for Peak Hill and Trangie would need to decrease by 1 hd/ha to 4 and 3 hd/ha respectively. The next sections show the potential loss of soil for different levels of ground cover within each region.

8. Ground cover

The level of ground cover varies throughout the year and the Grassgro® model shows the minimum total herbage mass rather than ground cover, which depends on several factors such as pasture height, leaf canopy, ground contact and leaf litter. In this analysis ground cover levels ranging from 30 to 100 per cent for each region were used to model soil losses with the Soiloss program (Rosewell, 1993).

Figure 1 shows that pasture growth varied by only 4 kilograms per day for soil depths of 10 mm to 220 mm; however, pasture growth was sensitive to soil fertility, water-holding capacity and in some cases soil bulk density, which may reflect the loss of production that might be caused from water and wind erosion.

Figure 1: Pasture growth with varying topsoil depths



9. Soil loss

The Soiloss program (Rosewell 1993) uses soil type, slope, rainfall, crop type, tillage implement and practice, and ground cover levels to model soil loss in tonnes per hectare. Rainfall for a zone is selected and the rainfall history simulates rain of different intensities over a number of years.

Soil loss estimates for varying ground cover in each region are shown in Table 4. Higher levels of soil loss were produced in regions with steeper slopes such as Bathurst and Mudgee, which would lose 0.82 and 0.03 tonnes per hectare respectively with 100 per cent ground cover. Larger soil losses occur with lower levels of ground cover. In the Bathurst region up to 39 tonnes per hectare could be lost with only 30 per cent ground cover. The Soiloss model was not particularly sensitive for the relatively flat western regions of the catchment; however, Trangie farms could lose up to 2.5 tonnes per hectare with only 30 per cent ground cover. This figure may be higher with wind erosion (Leys 2002). The soil loss results show the importance of maintaining sufficient ground cover levels, which mean the stocking rates should not exceed the levels indicated. Grassgro® was not sensitive for most regions to changes in topsoil depth and therefore could not be used to estimate the value of lost soil directly. Indirectly the loss can be measured through reduced water holding capacity, increased drainage and higher soil bulk densities.

Table 4: Soil loss estimates for varying ground cover in each region

Bathurst							
Ground cover	%	30	50	70	80	90	100
Soil loss estimate	t/ha	39	18	6.8	3.4	1.5	0.82

Mudgee							
Ground cover	%	30	50	70	80	90	100
Soil loss estimate	t/ha	14	6.7	2.4	1.2	0.53	0.3

Dubbo							
Ground cover	%	30	50	70	80	90	100
Soil loss estimate	t/ha	12	5.6	2	1	0.45	0.25

Peak Hill							
Ground cover	%	30	50	70	80	90	100
Soil loss estimate	t/ha	7.6	3.6	1.3	0.67	0.29	0.16

Trangie							
Ground cover	%	30	50	70	80	90	100
Soil loss estimate	t/ha	2.5	1.2	0.44	0.22	0.1	0.05

10. Management scenarios

A base case and five management scenarios were modelled with Grassgro® to show how a particular change to the farm system in each region would impact on the gross margin. Five management changes were reported, although up to seven types of changes were examined. The management options included the base system with the optimum stocking rate and changes included an increase in soil fertility, a reduction in field capacity of soil, a reduction in topsoil depth, an increase in soil bulk density, a reduction in the legume content of the pasture, and a replacement of phalaris with cocksfoot.

The changes to the system were made one at a time to enable a comparison with the base case. In practice some of the changes may occur simultaneously, but the results from two or more changes should not be added together as the relationships between the variables may not be additive.

The type of management scenario presented for each region was dependent on the sensitivity of the variable changed in the model. Some changes were not sensitive to the changes and therefore not reported. Topsoil depth was not sensitive in many regions to a five-centimetre change in depth. In some cases an increase in bulk density increased the gross margin, which is counter intuitive. This was a limitation of the Grassgro model rather than a function of the soil types.

The following sections describe each of the management changes in more detail. The income, feed costs and gross margins for the base system and the five reported management scenarios are shown for each region in Table 5.

11. Base system

The base system for each management scenario was the optimal stocking rate selected from the gross margins shown for each region in Table 3. The stocking rates ranged from 12 head per hectare at Bathurst to 4 head per hectare at Trangie. The pasture mix and paddock size for each region was reported in Table 1.

12. Soil fertility

Soil fertility reflects the underlying ability of the soil to take up, produce and release nutrients to plants throughout the year. The Grassgro® model does not enable the user to specifically manipulate organic matter, nutrient levels or the location of nutrients in a soil profile. Hence the fertility increase is a total measure of the underlying soil fertility rather than a specific change. In most regions the base fertility level was set to 70 per cent, but in others it was set to 65 per cent to reflect the lower levels of topsoil organic matter. In each case the fertility levels were raised by 10 per cent to test the benefit of increased organic mater and nutrient flows which could be achieved by accumulating nitrogen and activating more soil biota over time (Carman and Murphy 2007).

The improvement in soil fertility was more beneficial to producers at Mudgee who could potentially increase their gross margin by $87 per ha, relative to producers located at Peak Hill ($32/ha), Bathurst ($30/ha), Dubbo ($23/ha) and Trangie ($17/ha).

13. Field capacity

Field capacity is the maximum amount of water that a soil profile can hold before it becomes saturated. Soils in good condition have more organic matter and therefore can hold more water (Carman and Murphy 2007). The field capacity of most soils was set to 30 per cent. The change in this variable was to reduce the field capacity by 10 per cent down from 30 to 20 per cent. The reduction in field capacity had the largest impact on the Bathurst system with a $32/ha reduction. The reduction led to a $4/ha decrease for the Mudgee system. The enterprises in other locations were reduced by $12 to $14 per ha.

14. Topsoil depth

The Grassgro® model was not responsive to changes in soil depth and in some cases a reduction in topsoil depth produced an increase in the gross margin. At Trangie, for instance, the gross margin increased by $4/ha with a decrease in soil depth. Alternative parameters were changed to test for sensitivity. A constraint on rooting depth resulted in an $8/ha reduction in the gross margin for slope locations. The wilting point was decreased from 15 to 10 per cent for sheep at Bathurst and this resulted in a $3/ha reduction in the gross margin. Hence the effect of a reduction in soil depth can modelled indirectly; however, the model requires further developed in this respect.

15. Bulk density

A change in the bulk density of soil from 1.4 to 1.6 Mg/M3 was modelled for sheep at Dubbo, Peak Hill, Mudgee and Trangie. The purpose of this example was to show the effects of compaction on soils from overstocking following Greenwood et al. (1998). The reduction in gross margin was $3/ha for sheep at Dubbo and $14/ha at Trangie with losses of $4/ha for Peak Hill and Mudgee.

16. Legume content

The importance of maintaining legumes in the pasture mix was evaluated with a 10 per cent reduction in the legume content of the pastures. Without careful management the legume content of pasture can decline rapidly. Legumes produce nitrogen and create deep root channels that enable greater water penetration and promote aeration of soils. In the base situation most pastures contained legumes at 30 per cent while others only contained 20 per cent due a fourth pasture species being added to the mix (Ayres and Clements 2007). The legume content change caused a $149/ha reduction in the gross margin at Mudgee and $100/ha at Bathurst. The gross margin fell by $8/ha for the reduction of medic for the Trangie region.

17. Phalaris and cocksfoot

Phalaris can be replaced with cocksfoot on land with subsoil constraints to sustain pasture productivity and maintain stocking rates (Ayres and Clements 2007). This species change affected those enterprises with a higher summer and autumn feed demand. The enterprise at Mudgee was reduced by $24/ha, and Peak Hill and Trangie fell by $17/ha each. The Dubbo region gross margin was reduced by $3/ha. The enterprise at Bathurst increased its gross margin by $8/ha with a change to cocksfoot. These results imply that a change in pasture species may also require a change in management to fit lambing and finishing periods in better with feed availability.

The results for each of the above five scenarios are reported in Table 5 for each region.

Table 5: Income, feed costs and gross margins for the base system and five management scenarios by region

Bathurst	Total Income $/ha	Feed Supplement $/ha	Gross margin $/ha	GM Difference $/ha
Base system	*543*	*58*	*173*	
Scenarios:				
1. Increase soil fertility to 80 %	569	36	203	30
2. Reduce field capacity by 10 %	527	68	141	-32
3. Reduce wilting point by 5 %	542	51	170	-3
4. Reduce legume content to 10 %	484	100	73	-100
5. Replace phalaris with cocksfoot	552	49	181	8

Mudgee	Total Income $/ha	Feed Supplement $/ha	Gross Margin $/ha	GM Difference $/ha
Base system	*450*	*104*	*44*	
Scenarios:				
1. Increase soil fertility 65 to 75 %	509	61	131	87
2. Reduce field capacity by 10 %	448	107	40	-4
3. Increase bulk density 1.4-1.6 Mg/M3	447	109	36	-8
4. Reduce legume content to 20 %	454	255	-105	-149
5. Replace phalaris with cocksfoot	434	113	20	-24

Dubbo	Total Income $/ha	Feed Supplement $/ha	Gross Margin $/ha	GM Difference $/ha
Base system	*297*	*36*	*60*	
Scenarios				
1. Increase soil fertility 65 to 75 %	310	19	83	23
2. Reduce field capacity by 10 %	291	42	48	-12
3. Increase bulk density 1.4-1.6 Mg/M3	296	37	57	-3
4. Reduce legume content to 20 %	278	78	0	-60
5. Replace phalaris with cocksfoot	295	36	57	-3

Peak Hill	Total Income $/ha	Feed Supplement $/ha	Gross Margin $/ha	GM Difference $/ha
Base system	*299*	*78*	*75*	
Scenarios:				
1. Increase soil fertility 65 to 75 %	314	56	107	32
2. Reduce field capacity by 10 %	292	86	61	-14
3. Increase bulk density 1.4-1.6 Mg/M3	298	81	71	-4
4. Reduce legume content to 20%	297	94	57	-18
5. Replace phalaris with cocksfoot	286	83	58	-17

Trangie	Total Income $/ha	Feed Supplement $/ha	Gross Margin $/ha	GM Difference $/ha
Base system	*241*	*57*	*59*	
Scenarios:				
1. Increase soil fertility 65 to 75 %	250	46	76	17
2. Reduce field capacity by 10 %	233	63	45	-14
3. Increase bulk density 1.4-1.6 Mg/M3	236	58	53	-6
4. Remove medic from mix	235	58	51	-8
5. Remove phalaris from mix	226	60	42	-17

18. Conclusions

The application of a pasture systems model to the aims of this research was limited to some extent by the variables available in Grassgro® and the reliability of the output when some variables were changed. The largest limitation of the model was that C4 grasses, particularly the natives, were not available as feedstock options. This effectively ruled out using Grassgro® for west and north of the Central West catchment. The program was more robust moving from west to east as Grassgro® has been validated in more eastern locations of the catchment.

The model was used to identify the optimal stocking rates (Table 1) for each of five regions in the catchment. The outputs from the model included environmental factors such as pasture production, herbage mass and deep drainage, which were shown for each region in Table 2. The program also produced gross margin budgets including income and variable costs such as shearing costs and supplementary feed costs. The gross margins for five stocking rates in each region were presented in Table 3. For the Bathurst region the gross margins were maximised at 12 hd/ha. The optimum stock rate was 4 hd/ha for the Trangie region.

Merino enterprises located at Peak Hill and Trangie required supplementary feed and pasture production was below the recommended minimum 800 kgs required to minimise soil erosion on flat country. The optimal stocking rates for these two locations to minimise soil erosion were 4 and 3 hd/ha respectively which is a reduction of 1 hd/ha from the gross margin optimum stocking rate.

The Soiloss program was used to estimate the tonnes per hectare of soil that would be lost under varying ground cover levels. The results were reported in Table 4.

Table 5 shows the results of a base case model when compared with five management changes for the optimal stocking rate gross margin stocking rate. The results of the analysis suggest that the return to increasing soil fertility was significant in each location and this was demonstrated through an increase in water holding capacity and a reduction in legume content. Changes to the topsoil bulk density were sensitive, but the impact on the gross margins was small relative to the results of the other management scenarios. A reduction in legume content had the largest negative impact of all the scenarios and the impact on each enterprise was large. Decreasing legumes reduced the gross margin by $149/ha at Mudgee. A reduction in medic reduced the gross margin by $8/ha for Trangie.

Changing pasture species from phalaris to cocksfoot to manage subsoil constraints reduced gross margins by $3 to $24/ha. The resulting feed distribution indicated that a change in pasture species would require a change in other management practices such as lambing or finishing times.

A reduction in the legume content of pastures was the factor most limiting pasture production other than rainfall. A 10 per cent reduction in the legume content has a large effect on the gross margins in some regions supporting the critical 30 per cent minimum level recommended by Ayres and Clements (2007). With the exception of Trangie and Peak Hill each of the other regions would minimise soil losses by retaining more than 800 kgs of herbage matter at the stocking rates that provided the highest gross margins assuming that best practice management recommendations were followed.

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