Central West catchment management authority

The economics of soil management in pasture systems

CASE STUDY

Wellington

1. Introduction

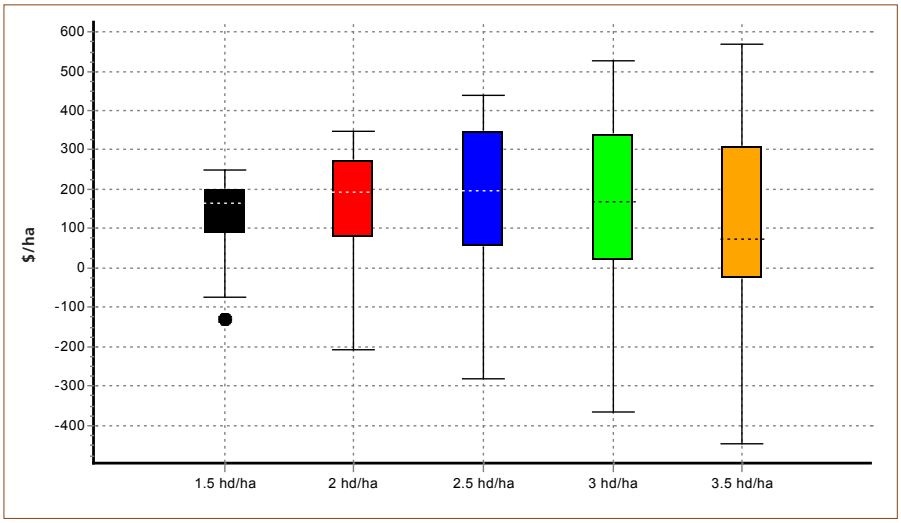
Pasture management can be a challenge in an environment with irregular rainfall and it is useful to understand some of the financial impacts that occur with different stocking rates. Overstocking occurs when the demand for pasture exceeds the supply of pasture. The consequences of overstocking have a long-term negative impact on the asset value of the property and the annual productivity of the farm system. A steer grazing system has been evaluated to identify some costs and returns associated with increasing stocking rates that have a direct impact on soil health.

Pasture supply is governed by soil type and structure, topography, nutrient level, pasture varieties, insect attack, weather and grazing pressure. The demand for pastures arises from nutritional demand by livestock, their body temperatures and breeding cycles. Pasture demand can be managed by increasing or decreasing stock numbers, altering breeding times, increasing feed availability in the form of hay or silage, or protecting areas of pasture, scrub or saltbush for drought reserves. Examining the various options for managing pastures requires a good understanding of each of the management options and the impacts of taking a particular course of action. Financial results are presented for a series of simulated management scenarios.

A pastures program (Grassgro®) was used to estimate the amount of feed that might be produced for a typical property located near Wellington. The program simulates pasture production over the period from 1986-2006. The program uses actual rainfall, evaporation, temperature, frost frequency and local soil conditions to estimate pasture productivity which is then utilised for a selected grazing method or stocking rate. A range of pasture mixes and legume percentage can be assessed within the program.

The pasture mix used in the analysis includes annual rye grass, phalaris and clover. Annual rye grass provides increasing green feed into early spring. Phalaris produces more green in late spring, summer and it hays off in early autumn. Clover was included in the mix to provide more green feed in spring and to provide nitrogen to the grass species.

Figure 1
Box plots for the gross margins associated with various stocking rates



Controlled grazing enables the manager to control the rate of feed use in each paddock according to its production capabilities. The number of paddocks needs to be developed with consideration of fencing and watering costs and the time required to move animals around the system. In the model the pasture system comprises five paddocks of 30 ha each where the cattle remain for three days before progressing to the next paddock. The total farm system was set at 150 ha. The model provided supplementary feed of grain and hay when the pasture supply fell below 400 kg of dry matter per ha.

The grazing system was set to a weaner cattle finishing enterprise where weaners were purchased at 240 kg in May and sold as yearlings at 380 kg in November using 2007 costs and returns for cattle bought and sold at Dubbo. Five stocking rate from 1.5 to 3.5 heads per hectare (hd/ha) were then evaluated on the described farm system.

2. Results

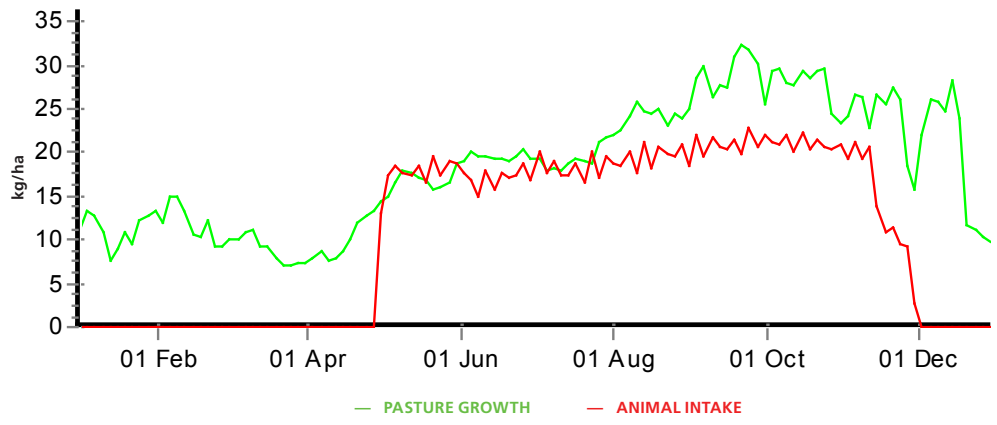
Gross margins for five stocking rates are shown in **Figure 1**. The line within each box shows the average gross margin for each stocking rate. The length of each box shows 50% of the total variability in the gross margin. 45% is represented by the 'I' bars. The final 5% of the variance is represented by the dots and stars, which are outliers (values that are well outside the typical range of values).

The stocking rate of 2.5 hd/ha shows the highest gross margin ($195/ha). Fifty percent of the time we would expect the gross margin to be between $70 and $340 as indicated by the length of the third box. Over the period of analysis the gross margin may have ranged from -$290 to $435/ha as indicated by the I-bars. The 3 and 3.5 hd/ha rates may produce a higher gross margin as indicated by the I-bar; however, the gross margin may also be significantly lower in poor seasons. The stocking rates of 1.5 and 2 hd/ha produced slightly lower gross margins with a much lower risk profile as indicated by the length of their boxes and I-bars.

2.1 Pasture production

The top line in **Figure 2** shows that the largest volume of green feed was available in the period, May to November each year. The green feed converts to dry feed over summer and very little new growth was expected in the late summer and autumn periods. Young cattle are purchased in May and sold in November each year. The lower line on the graph shows their feed demand curve in this period. Insufficient feed is available in the period January to April and if animals were present at that time they would require supplementary feed. Supplementary feed would be required in the period May to June with the 2.5 hd/ha stocking rate as shown

Figure 2
Feed supply and demand at a stocking rate of 3 hd/ha



be the lower feed demand line rising above the upper feed supply line. Feed demand reduces rapidly in November when animals are sold.

Total kilograms of pasture produced for each of the five stocking rates are shown in **Table 1**. Pasture production was shown to peak at 6822 kg/ha or 6.8 t/ha with a 2.5 hd/ha stocking rate and it decreased to 6.7 t/ha as the stocking rate rose to 3.5 hd/ha. Grazing pressure assists some pasture varieties to regenerate, which provides more feed overtime; however, the time of grazing is very important for some species to regenerate (Central West Catchment Management Authority, 2008). Several pasture varieties require a grazing break in spring to enable the plant to set seed for the following season. The five paddock grazing system provides this option.

2.2 Herbage mass

The minimum total herbage mass that was produced by the pasture mix is shown on the second line of **Table 1**. The results indicate that herbage mass decreased from 2240 kg/ha to 1011 kg/ha as stock rates increased from 1.5 to 3.5 hd/ha. To minimise soil erosion through wind and rain at least 70% ground cover should be retained on flat terrain and up to 100% ground cover on steep terrain (Rosewell, 1993). Grasses, clovers and medics provide good ground cover as they have a short canopy, which reduces both wind and water erosion. Alternatively lucerne has a high narrow canopy, which results in a bare soil surface when it is harvested for hay or when grazed heavily and this may encourage erosion. Effective ground cover varies throughout the year and its effective soil retention level depends on the plant varieties and the stage of development of species in the pasture mix. In a grass dominated pasture mix with a grazing height of 10 cm the herbage mass should exceed 800 kg/ha to minimise erosion.

Table 1
Simulation results for five stocking rates

STOCKING RATE	ha/hd	1.5	2	2.5	3	3.5
Annual pasture production	kg/ha	6706	6789	6822	6770	6705
Minimum total herbage mass	kg/ha	2240	1852	1508	1227	1011
Drainage below rooting zone	mm	26	27	28	29	30

2.3 Supplementary feed

The rise in stocking rate from 1 to 5 hd/ha increased the costs for supplementary feed from $6/ha to $66/ha. The effect of increasing supplementary feed was to reduce the gross margin and this was clearly shown in **Table 2** where the gross margin declined from $171/ha with 2.5 hd/ha to $105/ha at 3.5 hd/ha. In drought years the supplementary feed costs can increase above these long run averages.

The number of times that supplementary feed required within the analysis period is shown in **Figure 3** for the stocking rate of 3 hd/ha. In 2006 an average of 40 kg of supplementary feed per animal was required.

2.4 Soil loss and fertility

Soil is a non-renewable resource. Hence correct soil management in pasture systems, as in any other farming systems, is extremely important. Overgrazing reduces the ability of pasture to recover and leads to compaction and damaged soil structure. These are the main causes for a reduction in ground cover and its diversity. Low and irregular rainfall patterns can make this situation worse.

Loss of ground cover increases the risk of wind erosion and leads to physical, chemical and biological degradation of soils. During wind erosion the clay, silt, and organic fractions from the surface soil are removed, resulting in nutrient decline and a reduction in water holding capacity of soils (Leys, 2002). Further, a reduction of organic matter and clay contents in the soil reduces the levels of cation exchange capacity [CEC], which is vital for holding nutrients.

Among macro nutrients, phosphorus is more prone to erosion. Phosphate does not readily disperse into the soil profile. It is easily washed into waterways and streams with surface soil layers in heavy erosion events (Charman & Murphy, 2007, Central West Catchment Management Authority, 2008).

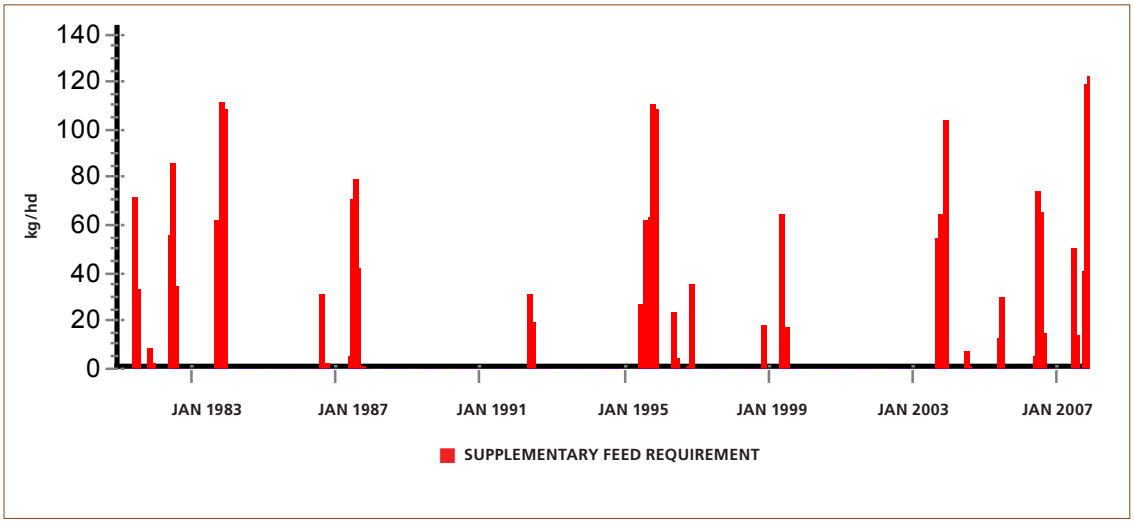
Higher levels of ground cover minimise deep soil drainage. Increased stocking rate reduces ground cover and increases drainage through the root zone **(Table 1)**. Increasing perennials or legume species can reduce ground water loss and this may also reduce nutrient leaching. Nitrogen is more

Table 2
Total income, maintenance and gross margin for each stocking rate

STOCKING RATE	hd/ha	1.5	2	2.5	3	3.5
Sale income	$/ha	1071	1395	1703	1983	2244
Total income A	$/ha	1071	1395	1703	1983	2244
Animal husbandry	$/ha	39	52	65	78	91
Replacements purchased	$/ha	716	954	1193	1431	1670
Sale costs	$/ha	110	145	179	213	246
Maintenance supplement	$/ha	6	16	28	43	66
Total expenses* B	$/ha	937	1234	1532	1833	2139
Gross margin A-B	**$/ha**	**134**	**161**	**171**	**150**	**105**

* Some expenses have been excluded from this table.

Figure 3
Supplementary feed requirements by season at the stocking rate of 3 hd/ha



prone to soil leaching relative to other nutrients (Charman & Murphy, 2007, Central West Catchment Management Authority, 2008).

Economic losses are incurred from poor soil management due to a loss of nutrients, which need to be replaced, water holding capacity and the lower productive capacity of the land. Large-scale permanent damage can lead to barren landscapes that are no longer suitable for agricultural production. The direct costs to repair or improve damaged soil structure can be high. Alternatively, well-managed pastures can lead to improved soil fertility and pasture production and returns accordingly.

2.5 Soil loss

The amount of soil lost to erosion for a range of ground cover levels has been estimated through the use of a program called Soiloss (Rosewell, 1993). The Soiloss model produced the results shown in **Table 3** for soil and slope conditions for the Wellington region.

Table 3 reveals that a change in ground cover from 85% to 80% increases soil loss from 0.82 to 1.2 t/ha (Rosewell, 1993). Hence at 85% ground cover there would be a 0.38 t/ha soil deficit. The loss of topsoil has long-term impact on the productive capacity of grazing areas. This cost is examined in the management scenarios reported below.

Table 3
Soil loss resulting from reduced ground cover

Ground cover	%	30	50	70	80	85	90
Soil loss estimate	t/ha	14	6.6	2.4	1.2	0.82	0.52

Data estimated with Soiloss for the Wellington region of NSW.

2.6 Management Scenarios

Five management scenarios were examined with the Grassgro® model to simulate a range of factors that may be applicable in setting stocking rates. The base case included the pasture and animal systems described above. This base case was compared with a 10% increase in soil fertility **(Scenario 1)**; a reduction in the field capacity from 32% to 22% **(Scenario 2)**; a reduction in the top soil from 15 to 10 cm **(Scenario 3)**; a reduction in the pasture legume content from 30% to 10% **(Scenario 4)**; and replacement of a phalaris based pasture with a cocksfoot based pasture **(Scenario 5)**. The results for the base case and each scenario are shown in Table 4.

Table 4
Comparison of five scenarios on total income, feed supplement and gross margins

SCENARIO	TOTAL INCOME $/ha	FEED SUPPLEMENT $/ha	GROSS MARGIN $/ha	GM # DIFFERENCE $/ha
Base system *	1703	28	171	
1 Increase soil fertility to 80%	1770	18	245	74
2 Reduce field capacity by 10%	1676	27	145	-26
3 Reduce top soil by 5 cm	1696	27	164	-7
4 Reduce legume content to 20%	1695	40	151	-20
5 Replace phalaris with cocksfoot	1690	26	160	-11

* Base System: The system includes 70% soil fertility, 30% legume, 15 cm topsoil, phalaris based pasture mix, and 5 cells of 30ha each.

The difference in gross margin is between the base case gross margin and the gross margin for each scenario.

Scenario 1 Soil fertility

The loss of soil fertility through leaching or soil erosion can be compared through a reduction in soil fertility from 80 down to 70% in the Grassgro® model. In the base system soil fertility was set at the 70% level. For this scenario it was increased to 80%. The 10% change in soil fertility resulted in a $74/ha ($245/ha relative to $171/ha) increase in the gross margin. Hence a reduction in soil fertility by 10% would produce an annual loss of approximately $74/ha.

Scenario 2 Field capacity

Field capacity of soil is defined as the point where 'all pores with an effective diameter not exceeding about 30 microns are filled with water' (Milthorpe & Moorby, 1986, p.20). Field capacity is the remaining water by volume after it has drained for 48 hours. A well-structured sandy clay loam might have a field capacity of 44%, a water holding capacity of 26%, and a wilting point at 18% (Williams et al, 1983, in Hazelton & Murphy, 2007). Compaction of soil by tractors, harvesters and livestock reduces the number of pores and thus reduces the capacity of the soil to absorb and hold water. A reduction in the water content of the topsoil at field capacity from 32% to 22% would have the effect of reducing the annual gross margin by $26/ha.

Scenario 3 Topsoil erosion

A reduction in the amount of soil in the 'A' horizon from 15 cm to 10 cm results in an average $7 ha/yr decline in production as indicated by comparing the gross margins in Table 4. This value does not take into account the reduction in soil organic matter or nutrient load. There may also be a significant cost incurred with cleaning dams and waterways.

Scenario 4 Legume content
It is important to maintain the legume content in pastures to provide sufficient nutrients for pasture grasses. A maximum of 30% legume is recommended (Central West Catchment Management Authority, 2008). (note: the legume content of pastures will vary in each season). If the legume content fell to 10% then the legumes may need to be re-established to provide sufficient nutrients for the grasses. The difference in gross margin between a 30% and a 20% legume content in the pasture mix was $20 ha/yr.

Scenario 5 Pasture selection for more acid soils
Soils that are more acidic may require a mix of pastures that are suitable for more hostile soils. In the base case a phalaris and rye grass pasture was mixed with a 30% legume component (Central West Catchment Management Authority, 2008). In areas that are more acid phalaris could be replaced with cocksfoot without a substantial impact on the budget. The difference in gross margin was $11 ha/yr ($160 versus $171).

2.7 Cultivation and sowing

To minimise soil loss new pasture crops should be sown directly into stubble or previous pasture areas that have been spray fallowed. A spray fallow enables annual weeds to be controlled prior to the new pasture development. By reducing the carry-over load of weed seeds newly established pastures would not need to be sprayed as often. Avoid over grazing sprayed fallows, as the presence of dead plant material is useful to minimise erosion.

The direct cost of replacing pastures is $43.83 ha/yr if it is replaced every five years; $36.85 ha/yr for every seven years; and $31.61 ha/yr if replaced every ten years. There is also the indirect cost that the pasture can only be grazed lightly in its first season, which reduces carrying capacity on the re-sown area in that year.

The cost of cultivating with a chisel plough (141 kw/190 hp tractor) is $38.54/ha whereas the cost to spray with Glyphosate (1.2 L/ha@$5/L) and Garlon® (0.1 L/ha @ $49/L) is $17.81/ha which is a $20.73/ha savings. A single seeding pass with a direct drill is recommended (Central West Catchment Management Authority, 2008).

Soil compaction is an issue caused by heavy stocking by sheep or cattle. Paddocks that have been heavily stocked during the previous two seasons will need to be opened with a direct drill with 100kg of breakout pressure on each tyne. An increase in tyne pressure requires a larger tractor to pull implements through compacted soils (Kelly & Reeder, 2000). Additional power requirements may add approximately $24,500 or $12 ha/yr to the cost of establishing pastures due to the increase in capital costs associated with larger tractors.

Seeding machines should be fitted with press wheels to firm soil in against the seed and to close the seed slot. Set the press wheel pressure to no more than 4 kg/cm width of the press wheel in the working position (Gould, 2007). The cost to add a set of press wheels to a 7.3 m (24 ft) machine is approximately $10,920 for 260 mm (10 in) row spacings or $14,430 for the same machine on 230 mm (9 in) spacings. ($10920/10 yr = $1092/yr.) Over 200 ha this equates to $5.56 /ha.

3. Summary

Graziers can maximise their returns from pastures by setting stocking rates to maintain ground cover above 800 kg/ha which has the potential to provide savings of $74/ha for soil fertility, $20/ha for maintaining legumes at 30% of the pasture composition, $7/ha for minimising production losses through soil loss. Higher stocking rates result in significant reductions to the profitability of the farm system though a reduction in production efficiency including the cost of supplementary feeding.

Soils can be improved by using minimum tillage, minimising compaction by spraying weeds rather than tilling them, and building up organic matter to increase the water holding capacity of the soil. Most importantly by increasing organic matter producers can increase water infiltration, water-holding capacity and minimise deep drainage of water and nutrients.

It is important to minimise pasture establishment cost by using the recommended establishment practices. The cost of having pasture paddocks out of production for 12 months can be substantial ($171/ha).

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