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Methodology for assessing optimal rates of pasture improvement in the high rainfall temperate pasture zone

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Abstract. Pasture improvement is a well-established technology to increase production in extensive livestock grazing industries by changing pasture composition and increasing soil fertility. The Cicerone Project farmlets located at Chiswick Research Station, near Armidale in New South Wales are providing valuable information at a credible scale on the response to three different management systems varying in levels of inputs and grazing management. The purpose of this paper is to outline a methodology for assessing the Cicerone Project and similar studies. The assessment focuses on stochastic efficiency of the different treatments. The impact of pasture persistence, climatic risk, and stochastic commodity prices on optimal rates of farm development are explored by using preliminary data from Cicerone to calibrate the GrassGro model. Essentially the farmlets modelled represent 2 technology packages. One is a moderate input package and the other is a high input package. Preliminary analysis indicates that direct comparison of the two farmlets may produce the wrong assessment, because one farmlet is operating at a suboptimal level of efficiency in a stochastic sense. This means that direct comparisons of technologies based on the field data may be biased since the technologies should be evaluated at the risk-efficient frontier. The concept of a risk efficient frontier is explained and applied to

aid in identifying the trade-offs between profit and risk, and identify differences in the efficiency of the two farmlets.

Additional Keywords: pasture establishment, stocking rate, stochastic efficiency, risk-efficient frontier, The Cicerone Project.

Introduction

Since the pasture improvement boom of the 1950s and 1960s, a continuing decline in terms of trade has continued to restrict the adoption of pasture improvement (Vere and Muir 1986). This has encouraged producers to search for alternative strategies and technologies, such as grazing management (Kemp *et al.* 2000), to increase pasture and livestock production. Recent changes in the sheep and wool enterprise profitability have resulted in an increased emphasis towards meat production (McAlister 2004) which demands higher quality nutrition compared to wool production and may require changes in the quality and seasonal distribution of pasture production at the farm level, creating new pressures to improve pastures.

The Cicerone Project Inc. was set up to investigate the sustainability and profitability of three farm management systems in the New England region of New South Wales (Gaden *et al.* 2004; Scott 2002). The experiment consists of three farmlets of around 50 hectares each; the two farmlets evaluated in this study allow comparison of high and moderate input pasture management strategies.

Whereas there has been considerable research on pasture establishment techniques, few studies of pasture improvement technologies have adequately represented the risk associated with their adoption (Bellotti and Moore 1994). Variable environmental conditions influence the success of establishment and determine the production from newly sown pastures, whilst both climate and prices ultimately affect the potential for the investment to generate positive returns above the cost of adoption.

The purpose of this paper is to describe a study into the stochastic efficiency of high and moderate input pasture systems and to investigate the impact of pasture persistence, climatic risk, and stochastic commodity prices on optimal rates of farm development using the New England region of New South Wales as an illustrative case.

Developing the pasture base

Pasture improvement is a well-established technology to increase production in extensive livestock grazing industries through introducing more productive pasture species and increasing soil fertility. The three Cicerone Project farmlets were established to investigate a range of pasture improvement and grazing management technologies. Farmlet B has been designed to represent a typical farm in the New England region with a moderate level of inputs and a flexible grazing regime. Farmlet A has a similar grazing regime to Farmlet B but aims at a higher level of production through higher soil fertility and 100% of sown pasture. Farmlet C has the same level of inputs as Farmlet B but is subdivided into four times as many paddocks, allowing intensive rotational grazing .

In order to ensure rapid differentiation between the treatments, Farmlet A experienced an average rate of pasture improvement of 20% per annum since 2000. This is substantially higher than estimated rates of pasture resowing in high rainfall zones of less than 2% per annum (Ward and Quigley 1992). Farmlet A has also experienced higher levels of pasture utilisation in comparison to the other farmlets, due to increased stocking rates relative to Farmlets B and C.

An important issue is the economic and environmental impacts of such high rates of pasture improvement and pasture utilisation on long term farm level profit. It is shown in this paper that a direct measurement of Farmlet A's productive and financial performance would not provide a fair comparison against the baseline treatment on Farmlet B. Modelling of the responses seen on the farmlets contributes to a more accurate comparison between the treatments and, in the case of Farmlet A, allows us to define optimal rates of development.

Deterministic modelling has highlighted the importance of pasture persistence on the economic merit of pasture improvement (Scott *et al.* 2000; Thornton 1989). Interactions between the post-establishment management of the pasture through adjustment of stocking rates and the response over the longer term is of great importance in determining the profitability of pasture improvement and in particular the optimal replacement period. The interaction of pasture establishment with grazing management through the application of tactical rests during the reproductive and regenerative phases of pastures have been shown to be both technically (Dowling *et al.* 2005; Michalk *et al.* 2003) and economically sound methods of maintaining pasture persistence and perenniality (Jones *et al.* in press).

The analysis of pasture improvement as a technology has largely been limited to deterministic type analyses that have identified capital requirements (Pearse 1963), the impact of imputed pasture persistence or failure of establishment (Thornton 1989; Vere *et al.* 2001), and static livestock enterprise returns (Scott *et al.* 2000). The rapid rate of pasture improvement on Farmlet A from 2000 to 2004, especially since much of the period experienced below average rainfall conditions and was associated with high levels of pasture utilisation, has highlighted the importance of considering both stochastic climatic conditions and the interaction of stocking rate on pasture persistence (Carberry *et al.* 2005; Scott *et al.* 2005).

Methods

Data from the Cicerone Project over the period 2000 to 2005 was used to calibrate 47 year simulations using the decision support tool GrassGro (Moore *et al.* 1997). These simulations allowed predictions of livestock production, which in turn were used to estimate economic returns and risk of different combinations of pasture improvement rate and post-establishment stocking rate.

Simulations of livestock production were conducted for two pasture types found on the Cicerone farmlets: (i) improved and (ii) degraded. These two pasture swards were calibrated based on data from perennial-based pastures containing predominantly introduced species on Farmlet A and degraded pastures containing predominantly perennial C4 and annual grasses on Farmlet B. These different botanical compositions approximately reflect the differences in actual botanical composition which developed on the two farmlets over the period of investigation.

Extracting data from the calibrated GrassGro model enabled total farm productivity and income to be varied based on the proportion of the area sown to introduced species. The analysis was scaled up to simulate an average property with a sheep enterprise in the high rainfall tablelands zone of New South Wales (Barrett *et al.* 2003). A farm size of 1050 hectares was assumed with existing pastures being dominated by perennial C4 and annual grasses. Soil fertility levels were assumed to be moderate with a stocking rate of 8.5 DSE/ha.

Calibration of wool and sheep meat production estimates for the period of 1958 to 2005 was based on the self-replacing Merino flock under current management in the

Cicerone Project and the responses of the different pasture types to actual climatic data for the period.

GrassGro was also used to simulate the process of pasture establishment and subsequent time to first grazing. The initial grazing of sown pastures was assumed to occur when the herbage mass had accumulated to a level of 3000 kg DM/ha.

The proportion of degraded pastures and sown pastures on the whole farm was adjusted over time depending on different rates of pasture improvement, ranging between 2% and 20% of the farm area sown per annum.

Once the simulated sown pastures became established and reached the first grazing herbage mass target, paddocks were stocked with nominal stocking rates ranging from 8.5 (the base case) to 25 DSE/ha (i.e. above the maximum actual stocking rate).

The relationship between the persistence of newly sown pasture species and post-establishment stocking rate was estimated using local long term data (Greenwood and Hutchinson 1998; Hutchinson 1992; Hutchinson *et al.* 1995). The data indicate that the higher the post-establishment stocking rate, the more rapid is the decline in the proportion of sown pasture species in the sward. In this analysis, the rate of degradation of newly sown pastures is described through an exponential decay function with the formula:

$$y = 0.96.e^{rt}$$

where r represents the rate of decline for different post-establishment stocking rates, and t is time measured in years. After attempting to simulate actual pasture degradation rates, the sown pasture species decay function was used as it best described observed changes in local pasture composition data. For the post-establishment stocking rates of 8.5, 15, 20 and 25 DSE/ha, the r values used were -0.0132, -0.0161, -0.0194, and -0.0249 respectively. At each time step the proportion of degraded pastures contributing to the changing sward was simply the difference between 100% and the proportion of newly sown species. These relationships were used to calculate annual changes in the relative productivity and profitability of the simulated degrading pastures.

The change in botanical composition was also used to estimate the optimal replacement cycle of sown pastures, defined as the point in time when the replacement of the degraded pasture generates a higher present value than the cash balance from keeping the degraded pasture for another year (Rae 1994).

Economic analysis

The costs of maintaining enterprises were based on the average costs of running the Cicerone Project flock and the long term average costs of supplementary feeds based on 50% cottonseed meal and 50% lupins. The cost of establishing improved pastures was calculated from Cicerone Project data with annual pasture maintenance costs (fertiliser) being adjusted to allow for variations in post-establishment stocking rate. The base pasture representing Farmlet B incurred maintenance costs such as fertiliser to maintain a moderate level of soil fertility in relation to available phosphorus and sulfur.

Discounted cash flow budgets at the whole-farm level were used to calculate the long term returns from variations in the rate of pasture improvement, time to first grazing, and interactions with post-establishment stocking rates across the different livestock production systems. A real discount rate of 8.4% was used, based on the average nominal overdraft interest rate and average inflation rate over the period of 1979-80 to 2003-04 (ABARE 2004).

To examine the effect of production risk and stochastic prices on optimal rates of pasture improvement and post-establishment stocking rate, a Monte Carlo simulation procedure was used. Production risk was incorporated using 45 years of GrassGro modelled enterprise production and pasture establishment outcomes (from 1958 to 2003). Price risk was incorporated through the calculation of potential gross margin outcomes with price probability distributions for wool, mutton and lamb over the 5-year period of July 1999 to June 2004. The pasture and livestock production outputs from the GrassGro simulations were used to estimate correlation matrices between the production of the base pasture and sown pasture at the various stocking rates within each year. These correlation matrices were then used as inputs in the Monte Carlo simulation, with 500 iterations being used to generate the Net Present Value (NPV) data. The formula used for calculating NPV is:

$$NPV = \sum_{t=0}^{T} \frac{\pi(PG_t, DP_t, SR, PIR)}{(1+\delta)^t}$$

where T is the planning horizon over 45 years, t is an index of time in years; π is the measure of net cash flows in year t as a function of the proportion of sown species (PG_t), the proportion of degraded pastures (DP_t), the stocking rate (SR in DSE/ha) and the rate of pasture improvement (PIR); and δ is the real discount rate.

A factorial design was used with 4 stocking rates (SR=8.5, 15, 20, 25 DSE/ha) and 10 pasture improvement rates (PIR: from 2% to 20% per annum in increments of 2%). The treatments are denoted by their SR/PIR combination. For example, 8.5/2 represents a SR of 8.5 DSE/ha and an annual pasture improvement rate of 2%.

Results

Table 1 shows a selection of NPV results from the Monte Carlo simulations of this case study analysis. Much of the literature regarding the choice between risky alternatives in agricultural production is oriented towards 'expected utility theory' (Hardaker *et al.* 2002; Rae 1994). This assumes that producers will aim to maximise their personal satisfaction or 'expected utility' based on their personal utility function, which depends on their level of risk aversion. An alternative method, that does not require assumptions of risk aversion levels to be made, is to estimate a risk-efficient frontier (Cacho *et al.* 1999). The risk-efficient frontier, shown in Figure 1, is derived from the means and standard deviations of the Monte Carlo simulation results and demonstrates the trade-offs between profit and risk. Each point within Figure 1 represents a different combination of management strategies, that is, a SR/PIR combination. The frontier, shown graphically by a solid line, defines the combinations of risk (a simplified representation using the standard deviation of NPV) and profits (represented by NPV) under different choices of SR and PIR where management is efficient. Points that do not lie on the frontier are stochastically inefficient management strategies (SR/PIR combinations).

Estimation of a risk-efficient frontier, however, does not identify the most desirable profit-risk combination; producers must make this decision by choosing a point on the frontier that reflects their personal preference. Risk-averse producers would optimally operate at SR/PIR combinations in the region on the frontier denoted by (i), whilst risk-indifferent producers would operate in the region on the frontier denoted by (ii) in Figure 1.

Discussion

Movement along the risk efficient-frontier from the risk averse to risk indifferent region results in increased post establishment stocking rates (8.5 to 25DSE/ha), increases in the rate of pasture improvement (4-6% to 6-8% per annum) and consequently an implied shortened persistence of sown pasture species. The bottom left of the frontier in Figure 1 is probably an irrational choice even for extremely risk averse producers, as a change in management strategy (PIR changing from 20% to 6% per annum) more than doubles profitability without significantly increasing risk.

With the pasture improvement rate held constant, increasing post-establishment stocking rate increases both the profitability and risk of the management combination within the tested range. As would be expected, there is some evidence of diminishing returns to increasing stocking rates due to both increasing risk and reduced production per head (data not reported here).

The optimal pasture improvement rates located on the risk-efficient frontier, increase with increasing post-establishment stocking rates. This indicates that although pasture persistence is reduced under higher stocking rates, the extra returns from the higher utilisation of sown pastures compensates for the increased frequency of pasture replacement. However, increasing the pasture improvement rate beyond the risk-efficient levels of PIR, tends to rapidly move the management combination into the region of stochastic inefficiency.

In order to compare Farmlets A and B at the same level of stochastic efficiency, the pasture improvement rate of Farmlet A needs to be adjusted so that it would move up to the risk-efficiency frontier shown in Figure 1. This analysis finds that reducing the current PIR of 20% per annum on Farmlet A to around 4% per annum would move the farmlet onto the risk-efficient frontier. This would then allow a fair comparison between the farmlets at a similar level of stochastic efficiency. Such a comparison would also find the high input farming system represented by Farmlet A to be more profitable but also more risky than the typical system represented by Farmlet B.

The identification of optimal combinations of pasture improvement and post-establishment stocking rate are appropriate only for this case study. However, the methodology described is applicable to the assessment of multiple management combinations under stochastic conditions which influence the efficiency of management strategies. The analysis also highlights the need to interpret field trial results carefully when using them to provide management advise regarding the application of different technologies.

The logical extension of this research is the investigation of the adoption of grazing management techniques and fertiliser strategies to adjust the botanical composition of pastures, their subsequent production, and comparisons with establishing pastures to further identify optimal development strategies of a farm's pasture base.

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Figure 1. Risk-efficient frontier for a self replacing Merino ewe flock specified in terms of post-establishment stocking rate and pasture improvement rate (SR,PIR%). Mean NPV represents expected profit with Risk being the standard deviation of the expected profit. (SR=8.5DSE/ha ●, 15DSE/ha ▲, 20DSE/ha ■, 25DSE/ha ◆). (i) = risk averse region, (ii) = risk indifferent region.

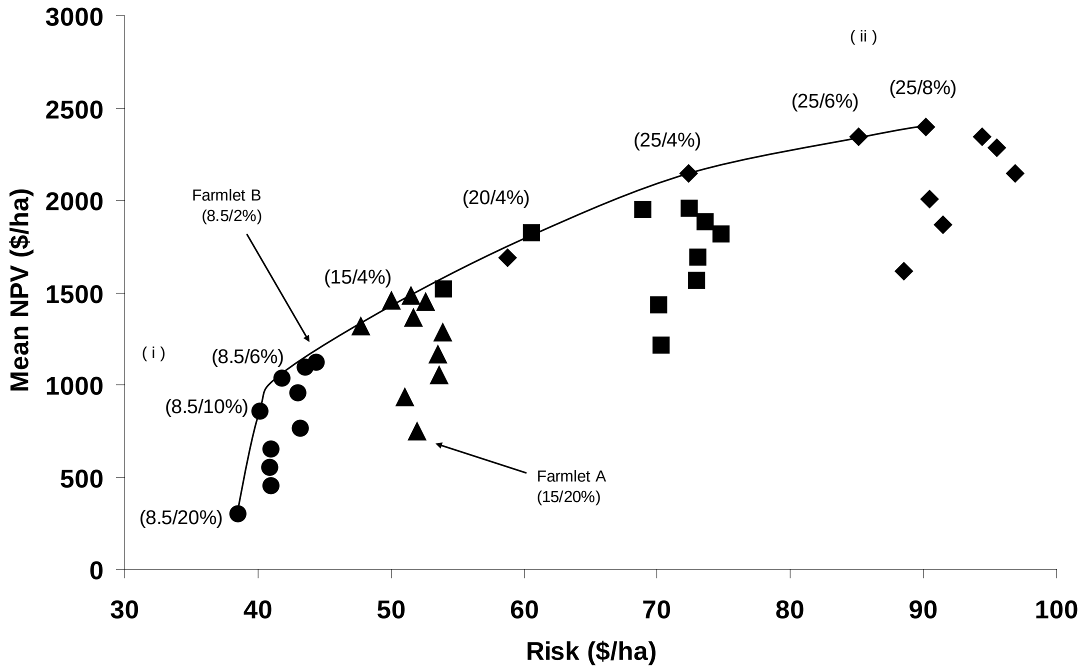

Table 1: Selected NPV results ($'000) from the 45 year stochastic simulation of the interaction between post-establishment stocking rate (SR) and rate of pasture improvement (PIR). Mean of 500 iterations with standard deviations shown in parentheses. Bolded mean NPV's are found on the risk-efficient frontier.

Stocking Rate (DSE/ha)	Pasture Improvement Rate (PIR)					
	2%	4%	6%	8%	10%	20%
8.5	1173 (46.7)	1149 (45.8)	**1083** (44.0)	1000 (45.2)	**894** (42.2)	**315** (40.4)
15	1381 (50.1)	**1527** (52.5)	1557 (54.0)	1521 (55.2)	1434 (54.3)	787 (54.6)
20	1589 (56.6)	**1913** (63.6)	2042 (72.4)	2052 (76.1)	1976 (77.3)	1272 (73.9)
25	1775 (61.7)	**2253** (76.0)	**2463** (89.3)	**2518** (94.7)	2460 (99.2)	1694 (93.0)