Abstract: The rate of pasture development in Farmlet A under the Cicerone Project has been rapid by industry standards since the farmlets were established in 2000. The success and economics of adopting such a high rate of pasture improvement is determined by a number of biophysical and economic interactions. Modelling from a base pasture situation, represented by Farmlet B, to a high input-high output system represented by Farmlet A was undertaken and extended to allow long term comparisons of various rates of pasture improvement and to study their interactions with post-pasture establishment stocking rates across different livestock production systems. Initial results indicate that the more rapid the development of a farm's pasture base to a high input-high output system the greater the profit but with a concurrent increase in the variation of expected profit (risk). Post-pasture establishment stocking rate and production is critical in determining the optimal rate of implementing a pasture improvement program.

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Pasture productivity and persistence: optimal strategies for different livestock production systems

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SUMMARY
The rate of pasture development in Farmlet A under the Cicerone Project has been rapid by industry standards since the farmlets were established in 2000. The success and economics of adopting such a high rate of pasture improvement is determined by a number of biophysical and economic interactions. Modelling from a base pasture situation, represented by Farmlet B, to a high input-high output system represented by Farmlet A was undertaken and extended to allow long term comparisons of various rates of pasture improvement and to study their interactions with post-pasture establishment stocking rates across different livestock production systems. Initial results indicate that the more rapid the development of a farm's pasture base to a high input-high output system the greater the profit but with a concurrent increase in the variation of expected profit (risk). Post-pasture establishment stocking rate and production is critical in determining the optimal rate of implementing a pasture improvement program.

Keywords: pasture improvement, risk, optimal development strategies

INTRODUCTION
Pasture improvement is a well established technology to increase production in extensive livestock grazing industries by changing pasture composition, increasing soil fertility and the productivity of the grazing system. Identifying optimal farm development paths over the long term is difficult given the complexity of the farming system within a multidimensional landscape. Interactions between rate of response to inputs, the cost of inputs and capital, and the value of livestock products determine the economic attractiveness of the different pasture improvement options and their rate of implementation. The success and profitability of pasture improvement is not only influenced by the risk of the pasture germinating and establishing, but also driven by the persistency of the pasture and its utilisation by livestock enterprises to increase whole farm production and profit over the long term.

Utilisation of pastures is largely driven by stocking rate and the management structure of the grazing enterprise. The interaction between enterprise type and its management, which is an integral part of the complex grazing system, also influences the expected returns from investing in a range of pasture improvement strategies, be it sowing new species, increasing soil fertility or grazing management. The Cicerone Project Farmlets provide valuable information on the response to different levels of inputs into a grazing system. The rate of development of Farmlet A since 2000 has been very rapid and its utilisation of pastures very high in comparison to Farmlets B and C. These raise questions of the economic and environmental impact of high rates of pasture improvement and pasture utilisation on whole farm profit and pasture persistency. The purpose of this paper is to provide a brief overview of the impact of rate of development on expected long term profitability and its interaction with different livestock production systems. The paper will then proceed to outline further research work currently being undertaken.

MATERIALS AND METHODS
Three different production systems were modelled using GrassGro (Moore, Donnelly et al. 1997) to generate wool and sheep meat production estimates for the period of 1958 to 2005. The production systems (self-replacing merino ewe flock, merino wethers and second cross lamb production) represent enterprises commonly found throughout the higher rainfall zone of NSW and in particular the Northern Tablelands. The self replacing merino flock is based on the current management and production of the Cicerone Project merino flock. The range of enterprises was used to provide an indication of the potential impact of changes in pasture quality and seasonality on long term profitability.

The base pasture used in the GrassGro modelling was calibrated using pasture composition and productivity measurements from Farmlet B in The Cicerone Project, with the modelled sown improved pastures being calibrated and based on sown pastures in Farmlet A (paddocks A2, A3, A4, and A5).
Modelling pasture establishment

GrassGro was used to simulate the success and subsequent time to first grazing. A first grazing biomass target of 3,000kg DM/ha was used to provide a proxy for estimating the risk of establishment, pasture and livestock production during the first two growing seasons of a newly sown pasture. Figure 1 shows the modelled results from GrassGro in comparison to pastures sown in Farmlet A. Pasture establishment was simulated over the period of 1957 to 2004 with data being used to calculate the time to first grazing and subsequent expected livestock production in the pastures second year.

The ratio of base pastures, sown and developing pastures, and improved pastures in a steady state were adjusted overtime depending on a prescribed rate of pasture improvement (2%-20% of farm area sown per annum) on an average sheep enterprise based property in the high rainfall-tablelands zone of NSW. On average, Farmlet A has experienced a rate of pasture improvement in the vicinity of 20% per annum since the Farmlets were setup in 2000, which is significantly higher than estimated rates of pasture resowing in high rainfall zones of less than 2% per annum (Ward & Quigley 1992).

![Figure 1: Establishing Pastures available herbage percentiles (derived from GrassGro; — 10th, - - - 30th, - - - - 50th, - - - - - 70th, - - - - - - 90th percentiles), and sown paddocks in Cicerone Farmlet A (♦ A1/A3/A4/A5; ▲ A6; ■ A1/A2; ● A5/A6).](image)

Stocking Rates

The base pasture was stocked at 3.8 ewes/ha, 3.6 ewes/ha and 6.6 wethers/ha for the spring lambing self replacing merino flock, spring lambing second cross lamb producing flock and merino wether flock respectively. These nominal stocking rates are equivalent to the stocking rate carried on Farmlet B from 2001 to 2004.

Once sown pastures became established and reached the first grazing biomass target, paddocks were assumed to be stocked with a range of nominal stocking rates for the different livestock production systems.

Economic Analysis

Median prices for wool, mutton and lambs (trade and supermarket) over the five year period of July 1999 to June 2004 were used to value production. 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 form Cicerone Project data with annual pasture maintenance costs being adjusted to allow for variations in stocking rate post-establishment. The base pasture representing Farmlet B only incurred maintenance costs.
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, its time to first grazing, and interactions with post-establishment stocking rates across the different livestock production systems. A discount rate of 8.4% was used which represents the average overdraft interest and inflation rates over the period of 1979/1980 to 2003/2004.

RESULTS and DISCUSSION

With pasture improvement and no increase in stocking rate, average pasture quality and enterprise gross margin declined for all production systems. Increased per head production resulting from the introduction of improved species and increases in the available herbage fails to compensate for the additional costs of pasture establishment and loss of production during the establishment phase. This leads to a decline in the net present value of implementing a pasture improvement program and increases the variation of future returns (Figure 2 - 3.6 first cross ewes/hectare).

Whereas, increasing the stocking rate of areas sown to improved pastures post-establishment, as expected, increased the net present value of implementing a pasture improvement program, but with only small increases in risk, measured as the standard deviation of Net Present Value (NPV).

At lower post-pasture establishment stocking rates, increasing the rate of pasture improvement did not increase the expected profit as much as is possible under higher post-pasture establishment stocking rates. Although the riskiness of increasing the rate of pasture improvement, increased proportionately with increasing post-pasture establishment stocking rates and the subsequent higher returns.

![Figure 2: Risk efficient frontiers with respect to rate of improvement (2%, 5%, 8%, 11%, 14%, 17%, 20% per annum, data points in sequence from left to right) and post-establishment stocking rates under a second cross lamb producing enterprise (● 3.6 ewes/ha; ■ 5.7 ewes/ha; ▲ 7.6 ewes/ha; ◆ 9.5 ewes/ha).](image-url)
The results suggest that rates of pasture improvement much higher than what currently occurs in industry are optimal for risk indifferent producers capable of doubling or tripling their stocking rates on sown improved pastures, above that of what they achieve on their base pastures. The data in Figure 2 for 7.6 first cross ewes per hectare indicates that the risk-indifferent optimal choice for the rate of pasture improvement, in this case, is in the vicinity of 14% per annum. Similarly, for the modelled self replacing merino flock and wether flock at similar stocking rates, the optimal rate of pasture improvement was calculated to be in the vicinity of 25% and 17% respectively. By industry standards these are very high rates of pasture development through the sowing of improved species and require additional investigation, as the analysis lacks consideration of the long term interactions between post-pasture establishment stocking rates and pasture persistency.

**Future Research work**

Issues such as restraints on available capital, interactions with long term environmental effects, pasture utilisation and persistency need to be taken into account in much greater detail than has been in this analysis. Other factors not adequately represented are the interactions between feed quality, quantity and wool quality (staple strength, length & hauteur); flock dynamics and its response to sequential strategic or tactical decisions in response to changing climatic conditions and long term pasture production. There is also a need to develop a more accurate model of perennial pasture establishment to take into account stochastic climatic conditions and variations in plant available soil moisture, establishment technique and issues of spatial density, composition and production. The integration between the effects of post-pasture establishment stocking rate and a pastures persistency and composition also needs to be incorporated into the model.

The aim of future research work will be to identify optimal decision rules that balance long term profit and the sustainability of the grazing system within a multidimensional landscape at the whole farm level. This will allow wool and sheep meat producers to improve their decision making in identifying optimal paths of property and enterprise development through the comparison of technologies/strategies used to manage the productivity and sustainability of the grazing system.

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