Optimising Management to Achieve Sustainable Economic Yields from Grasslands

Karl Behrendt
Charles Sturt University, Australia

The 22nd International Grassland Congress (Revitalising Grasslands to Sustain Our Communities) took place in Sydney, Australia from September 15 through September 19, 2013.
Proceedings Editors: David L. Michalk, Geoffrey D. Millar, Warwick B. Badgery, and Kim M. Broadfoot
Publisher: New South Wales Department of Primary Industry, Kite St., Orange New South Wales, Australia

Optimising management to achieve sustainable economic yields from grasslands

Karl Behrendt

Graham Centre for Agricultural Innovation (NSW Department of Primary Industries and Charles Sturt University), Charles Sturt University, School of Agricultural and Wine Science, Orange, NSW 2800 Australia, www.csu.edu.au

Contact email: kbehrendt@csu.edu.au

Keywords: Bioeconomic simulation, Seasonal Stochastic Dynamic Programming

Introduction

To achieve the objective of sustainably managing grasslands there is a need to consider the complex interactions within the system that determine the productive capacity of the grassland resource, as well as the risks and returns from its management. To improve the information available for decision making there is a need to account for multiple and conflicting objectives of grassland resource production, persistence, livestock productivity and profit (Behrendt *et al.* 2013a). Solutions to this complex problem may be derived using bioeconomic modelling of grasslands as exploitable renewable resources (Clark 1990). This provides a method to identify optimal decisions that result in maximum sustainable economic yields.

In the high rainfall zone of south eastern Australia, strategic decisions include the sowing of introduced species, whereas tactical decisions include grazing management (variations of stocking rate, time livestock spend in a paddock, and the corresponding rest periods) and the application of fertiliser (Behrendt *et al.* 2013b). Management actions combined with exogenous risks are expressed in the short term through grassland production, and in the long term through botanical composition. This means there are inter-temporal trade-offs between grazing system productivity and persistence of desirable species within the sward. The process represents a sequential decision problem, where producers manage the grazing system as climatic uncertainty unfolds by making both tactical and strategic decisions at intervening states of the system (Behrendt *et al.* 2013a). The optimal decisions need to be adjusted over time depending on uncertain events that influence economic returns and occur as the farm plan evolves. Such problems may be formulated and solved using stochastic dynamic programming (Kennedy 1986).

This paper describes the output from the integration of a dynamic pasture resource development (DPRD) simulation model into a seasonal stochastic dynamic programming (SSDP) model. The combined modelling process was used to identify optimal tactical and strategic decision rules that achieve maximum economic yields from a grassland resource under climatic uncertainty on a sustainable basis. The model was calibrated based on the Cicerone farmlet experiment (Behrendt *et al.* 2013a).

Methods

The framework, described in Behrendt *et al.* (2013a) and Behrendt *et al.* (2013b) finds optimal management strategies that account for embedded climate risk, technology application and management on botanical composition and pasture quality over time which, in turn, impacts on the optimal management strategies. In the DPRD, climate risk is embedded through the use of seasonal stochastic multipliers applied to a sigmoidal model of pasture growth. The effect of soil fertility (FE) is represented as relative yield restrictions based on a Mitscherlich function. Grazing pressure or livestock impact through selective grazing of desirable species determines the utilisation of desirable species and directly affects botanical composition (basal area) over time. This process is influenced by the digestibility of functional components. FE also influences both the rate of growth in the desirable population and its potential population size. The DPRD model enables pasture growth and grassland composition to respond to the actions of grazing livestock, which may result in positive or negative impacts. The problem is represented as a system of differential equations that is solved within a SSDP model.

The SSDP solution process uses four transition probability matrices, applied sequentially to represent seasonal effects within a year. The problem consists of solving a recursive equation with the objective to maximise the expected net present value of returns from a sheep production system over the long run, subject to biophysical constraints (Behrendt *et al.* 2013a). The SSDP model identifies strategic and seasonally optimal tactical decisions, in terms of pasture sowing and stocking rates as functions of the state variables, pasture mass and composition (proportion of desirable species). The slow moving state variable of soil fertility and its decision variable, fertiliser application, were not considered here due to computational limitations. Soil fertility was assumed to remain at levels typically found in the case study region. Additionally, the influence of soil fertility was studied in Behrendt *et al.* (2013b).

Results

An example of the distribution of seasonally optimal stocking rates and pasture sowing decisions for different grassland states is presented in smoothed contour plots in Figure 1. The state of the grassland at the start of a season is defined by pasture mass (*Yc*) and the proportion of desirable species that occupy the sward (*x*). Such plots present a simplified version of the 4000 optimal solutions obtained

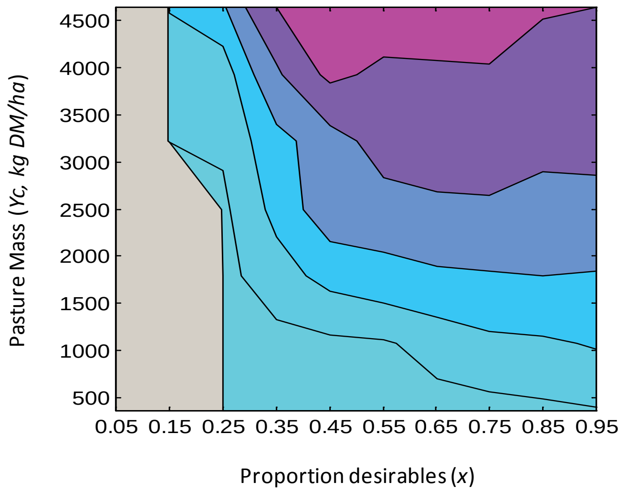

Figure 1. Optimal seasonal stocking rate and resow decision contour plots based on initial seasonal state of pasture resources with the decision variables of pasture resowing ( ), grazing rest ( ), mean *sr* of 2 ( ), 8 ( ), 15 ( ), 25 ( ) and 40 DSE/ha ( ).

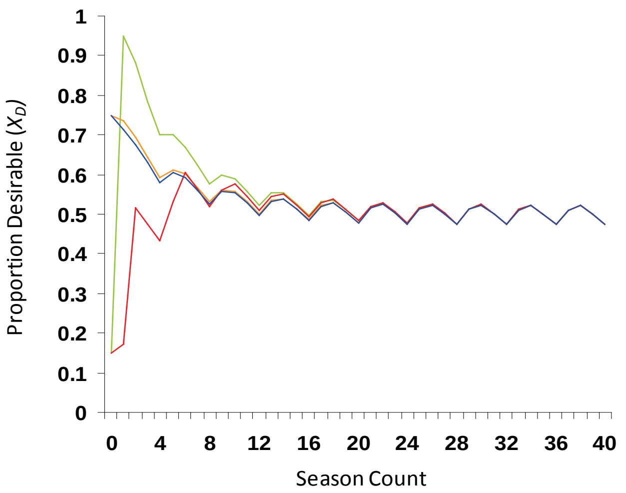

Figure 2. Optimal trajectories for the initial states of 0.15 desirable/900kg DM/ha (—); 0.75 desirable/900kg DM/ha (—); 0.15 desirable/2500kg DM/ha (—); and 0.75 desirable/2500kg DM/ha (—); using Monte Carlo simulation of seasonally optimal decisions.

for each season. Optimal stocking rate decisions are aggregated into six groups, ranging from a seasonal grazing rest to a stocking rate of 40 Dry Sheep Equivalent (DSE) per hectare. The optimal decision rules for any initial state of the grassland resource are then used to derive a time sequence of optimal states. Optimal sequences for four diverse initial autumn pasture states are plotted using Monte Carlo simulations of 40 years of climate data in Figure 2. Optimal management results in the convergence of future grassland states (composition only shown) towards an economically optimal and sustainable system. For example, the trajectory indicates that at an initial state of 900 kg Dry Matter/ha and 0.15 desirables, the optimal decision applied was to re-sow the grassland (hence increase desirables to 0.95 in the second season). For the other states, the optimal decision was to keep utilising the grasslands, albeit at different stocking rates. Convergence of botanical composition indicates that the optimal state for the grassland resource is around 50% desirables in the sward.

Discussion

The SSDP model identifies optimal seasonal stocking rate and pasture sowing polices for a defined input and livestock production system. These optimal policies are derived within a framework where the risks from a stochastic climate are embedded into the decision-making process. The optimal decisions balance short-term economic returns from grassland utilisation with the dynamic benefits and costs of maintaining a desirable botanical composition over an infinite planning horizon. Optimal decision rules direct the current grassland state towards economically optimal and sustainable states under the constraints of livestock harvesting impacts on the desirable population, concurrent impacts on the productivity of the grazing system, and the capital cost of resource renewal (re-sowing of the pasture). The SSDP process solved the grassland resource problem to a point of policy convergence, with the optimal states corresponding to that of maximum economic sustainable yield for an exploitable renewable resource. A limitation of the applied method is that externalities surrounding the management of a grazing system such as runoff and erosion have not been considered; these are the focus of future studies.

References

Behrendt, K, Cacho, O, Scott, JM, Jones, R (2013a) Optimising pasture and grazing management decisions on the Cicerone Project farmlets over variable time horizons. *Animal Production Science* **53**, (in press).

Behrendt, K, Scott, JM, Cacho, O, Jones, R (2013b) Simulating the impact of fertiliser strategies and prices on the economics of developing and managing the Cicerone Project farmlets under climatic uncertainty. *Animal Production Science* **53**, (in press).

Clark, CW (1990) 'Mathematical bioeconomics: the optimal management of renewable resources.' (John Wiley and Sons Inc.: New York USA)

Kennedy, JOS (1986) 'Dynamic Programming - Applications to Agriculture and Natural Resources.' (Elsevier: Amsterdam)