A Chance-Constrained Linear Model for Beef Policy Analysis

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A CHANCE–CONSTRAINED LINEAR MODEL FOR BEEF POLICY ANALYSIS

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Abstract

A simple linear model to evaluate different bull beef policies (BBP) by incorporating the stochastic nature of pasture yield from a database with separate chance constraints (ChC) was developed. A 100 ha farm was used, and the model was run with five different BBP and set to different levels of pasture yield risk to maximise production.ha^{-1}.year^{-1}. Summer was the most risky season, and the optimum mix of policies changed at different levels of risk. Chance constraint represents an interesting and simple alternative to include pasture variation into a linear model.

Keywords: modelling; chance-constraint; grazing; bull

Introduction

Pasture represents the cheapest source of nutrients for ruminant production, but variation of yield, both within and between seasons, introduces risk to grazing systems. Many different beef policies can be profitable, but how closely the animal feed demand and pasture supply fit together must be specially considered. Linear programming is a modelling tool that can assist in the solution of many agricultural problems (Dent et.al. 1986). However in practical situations, the farmer's plan of action normally deviates from the suggested optimum because farmers often have objectives other than profit maximisation and different attitudes to risk. There are several alternative approaches to incorporate random effects into linear programming such as target MOTAD analysis (Dake 1994) and chance-constrained programming (CHCLP) (Kall and Mayer 1996).

To the best of the authors' knowledge, CHCLP has not been used previously for cattle policy analysis. Where important historical databases of pasture production exist, they can be incorporated in these analyses. Furthermore, these models could have a potential teaching tool for evaluating different bull beef policies by incorporating the stochastic nature of pasture yield.

Material and Methods

A one-year model to estimate monthly requirements of metabolizable energy (ME) (AFRC 1993) for different beef policies and performances was developed. Five bull beef policies were tested (T: 1 to 5), and their main assumptions are shown at table 1. Three different selling dates (one month apart) were assumed for each policy (a pattern of 20, 60 and 20 % for top T, middle M and bottom B animals respectively). Sales were based on target live weight, and live weight gains (LWG) were adjusted to achieve the target sale date in a normal season.

To overcome the difficulties of comparing policies with different finishing time periods, a *Unit/policy* was developed. For each policy, the model automatically adds all needed animal classes to assure a *status quo* situation exists. Hence, the feed requirements of the *Unit/policy* was estimated by adding monthly all the animal class feed requirements per policy into a yearly feed requirement. Yield per *Unit/policy* were estimated as:

$$\text{Produced LW/unit/year (kg LW)} = S - P \pm (WLW - FLW) \qquad \textbf{(Equation 1)}$$

S = Sales (kg LW)

P = Purchases (kg LW)

WLW = wintered LW (kg at 01/07)

FLW = Final LW (kg at 30/06)

Farm assumptions for the policy comparison were: a 100 ha flat farm, with 95 % of the land area occupied with pasture and 5 % alternating between a summer and winter crop. A yield of 5000 kg DM.ha^{-1} for both forage crops was assumed. Monthly data of herbage growth accumulation, since 1985/86 to 1998/99 as recorded at N° 1 Dairy, Massey University were used. Monthly data were fitted to normal distributions and a Montecarlo simulation approach (1000 iterations) was used to sample values of pasture growth accumulation from the statistical distribution. Average and variance for each month were estimated. Similarly, correlation coefficients (CC) were calculated between each monthly yield and per annum pasture yield. No variation in forage crops was included, based on their low contribution to the whole system (4 % of total DM).

A separate chance-constrained linear model (CHCLP) (Kall and Mayer 1996) was run to select a mix of bull policies to maximize kg LW.ha^{-1}.year^{-1} as follows:

$$\text{maximize} \quad z = \sum_{j=1}^{n} c_j x_j$$

subject to

$$P\left\{b_i \geq \sum_{j=1}^{n} a_{ij} x_j\right\} \geq \alpha_i \qquad x_j \geq 0 \text{, for all } j;\ 0 \prec \alpha \prec 1$$

being **(Equation 2)**

J : bull policy

bi : Available DM. at i month in the farm

aij : DM req. of j activity at i month

α : Prob. of achieving the constraint setting

Alpha (α) of 5, 16, 25, 50 and 84 % were used for the stochastic approach of herbage yield. To fine-tune the grazing system, the model was set to make pasture reserves in some months of the year in order to maintain pasture cover at feasible level throughout the year of between 1700 and 2100 kg DM.ha^{-1}. 300 kg DM.bale^{-1} and a feeding value of hay relative to pasture of 0.85 % were assumed. Losses of 10 % and 10 MJ ME.kg DM^{-1} was assumed when this was fed back into the system (Hay is available as feed in the next month).

Results and discussion

From the pasture distribution sampling, the highest variable months were over the November to March period (results not shown). Pasture yield per annum varied between 7.4 and 14.6 ton.year^{-1}.ha^{-1}. Highest CC of each month yield-variation to per annum pasture output were for 0.47, 0.43, 0.41 and 0.37 for December, March January and October respectively. The lowest CC were –0.8, 0.10 and 0.12 for June, August and September.

Figure 1 shows the different mixes of policies to optimise kg LW. $ha^{-1}.year^{-1}$ at distinct levels of certainty of herbage output. When a low level of risk is selected (up to 0.5), the model included T3 as the main option. However, in order to maximize per ha yield at a higher level of risk (0.16), policies which are more demanding during late spring-summer (policies 1 and 2) were mainly selected. High risk conditions systematically decreased the level of pasture reserves and were associated with a higher utilisation of grass by increasing stocking rate.

By accepting a higher level of risk, output per ha increased, shown by the following linear equation:

$$\textbf{kg LW. ha}^{-1}\textbf{ : 1520.8 (53.5) – x 948.8 (76.5)} \quad \textbf{R}^2\textbf{: 0.98} \quad \textbf{P<0.001}$$

x: level of certainty **(Equation 3)**

CHCLP represented an acceptable tool to analyse the trade-off between alternative bull policies while considering seasonal distribution of pasture and in future pasture quality. Although it would be desirable to take into account the covariance´s between the pasture yield in different months within a model with joint chance constraints, this was discarded because to solve such problems special purpose solvers would be needed (Kall and Mayer 1996), decreasing the friendly nature of this simple model.

This CHCLP model provides an acceptable tool both for teaching purposes and exploring productive alternatives. Although the economic optimisation was beyond the objectives of this exercise, when this was attempted (not shown), the selected mix of classes was completely different to those presented in Figure 1. Thus, economic and financial information should be added before suggesting a particular policy mix.

Risk in quantity-quality of pasture yield has shaped farming practices, and farmers have developed different strategies to cope with this variation, such as flexibility of slaughter date, changing stocking rate, feeding supplements etc. (Pleasants et.al. 1995). This model can be used to test the productive feasibility of different bull beef policy alternatives, and by including their economic and financial information, other strategies to improve the flexibility of the system could be evaluated.

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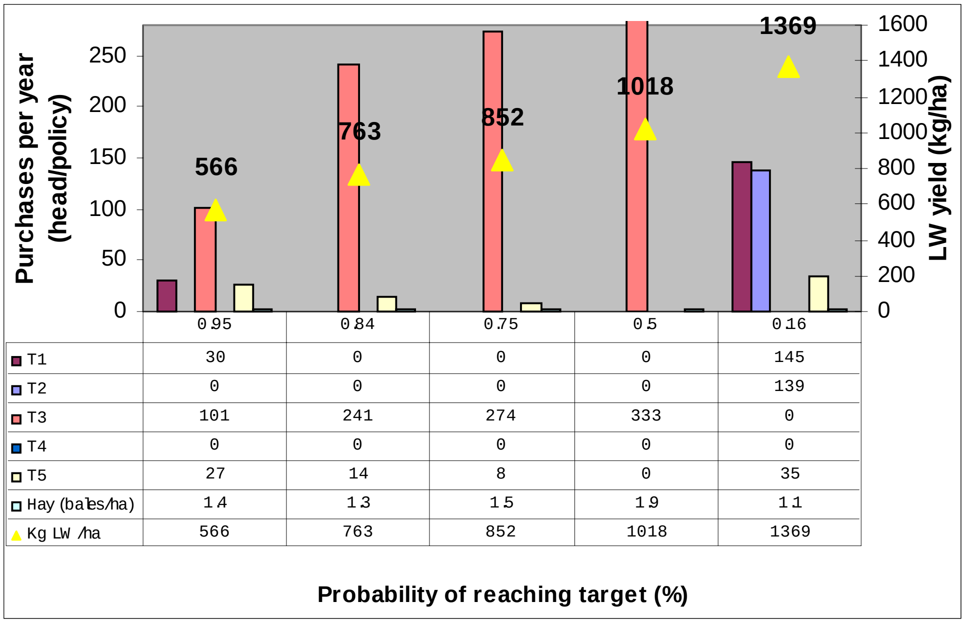
Table 1: Summary of assumptions in the five bull beef policies

Value/Policy (+)	1	2	3	4	5
Initial LW (kg/head)	100	100	100	380	365
Month of purchase	Nov.	Nov.	Nov.	Aug.	Mar.
LW of wintered animals					
1Ry bull (kg/head)	349	285	188	-	468
2Rybull (kg/head)	-	-	473	-	-
Live-Weight at sale (kg/head)	600	550	650	600	650
Month of sale (*)	Dec.	Feb.	Jan.	Feb.	Dec.
Produced LW (kg/unit/year)	495.4	446.0	544.5	217.8	282.1
Meat/unit/year (kg Cwt)	252.7	227.5	227.7	111.1	143.9
INTAKE					
Winter (DM kg/unit)	842	601	1221	561	884
Spring (DM kg/unit)	1428	1186	1862	1046	861
Summer (DM kg/unit)	672	1249	1123	389	266
Autumn (DM kg/unit)	711	525	1031	0	755
Whole year (DM kg/unit)	3652	3560	5237	1995	2766

(+) Including top, middle and bottom animals

(*) Represents the sale of middle animals (60 % of sales)



	0.95	0.84	0.75	0.5	0.16
T1	30	0	0	0	145
T2	0	0	0	0	139
T3	101	241	274	333	0
T4	0	0	0	0	0
T5	27	14	8	0	35
Hay (bales/ha)	1.4	1.3	1.5	1.9	1.1
Kg LW /ha	566	763	852	1018	1369

Figure 1: Different mixes of policies (purchases per annum) and bales.ha^{-1}.year^{-1} to optimise LW. ha^{-1} year^{-1} at distinct level of certainty of herbage yield.