An equation to determine demand-constrained pasture restoration area

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Introduction

Pasture restoration is a major part of the Brazilian NAMAs (Mozzer 2011) and INDCs (Brazil, 2015) and is operationally encouraged through a government-funded bank credit line for low carbon agriculture (Mozzer 2011). Beef production is the major grassland based activity in Brazil. Therefore, pasture restoration area targets should harmonize with projected demand for beef in order to avoid under and over production and negative impact on prices. Pasture restoration area has been previously estimated by large mathematical programming models (Oliveira Silva et al., 2016) but the development of a single equation model is useful to improve understanding and transparency of the estimates and the interpretation of such large models' results. The objective of this work is to develop an equation to determine pasture restoration area based on beef demand and to use it to analyze the responses of pasture restoration to their conditioning factors in the Brazilian context.

Material and Methods

An equation to estimate pasture restoration area (R, ha) as function of beef demand (D, kg CWE.yr^{-1}) was deduced as follows. Let N be the number of animals (N, heads) in a given pasture area. The variation in animal numbers ($N_f - N_i$) in a given period can be described by equation (1).

$$N_f - N_i = \delta N + N_i - N_{out}, \tag{1}$$

where, Ni and Nf are the number of animals at the beginning and at the end of a period of time, respectively; δN_R is the difference between the number of animals before and after recovering a pasture area (R, ha); N_{in} and N_{out} are the number of animals in areas where grasslands have expanded and contracted, respectively. Stocking rate (S) is defined as ratio between number of animals and grassland area (A, ha), i.e. $= \frac{N}{A}$, therefore $N = A.$. So:

$$\delta N_R = R.(S_r - S_d) = R.\,\delta S, \text{and,} \quad (2)$$

$$N_{in} - N_{out} = \delta A.S_h \quad (3)$$

Substituting (2) and (3) in (1), and isolating R:

$$R = \frac{\delta N - \delta A.Sh}{\delta S} \quad (4)$$

Hereafter we assume production and demand are in equilibrium. Beef production is the product of the number of animals and production per animal (C, kg CWE.head^{-1}.yr^{-1}), i.e. $D = C.N$. Note that for the analysis herein, C represents the lifecycle average productivity of the herd. The variation in D is due to variations in N and in C as described in equation (5):

$$\delta D = \delta N.C_i + Ni.\,\delta C + \delta N.\,\delta C \quad (5)$$

A multiplier P, which is the proportion of production variation due to variation in N is useful to study the pathways of intensification. In a high time resolution, $\delta N.\delta C$ is very small relative to the other two components (lower than 1/50 for Δt = 1yr in the Brazilian conditions). So we can define P as, according to (6).:

$$\delta D.P = \delta N.C_i \therefore \delta N = \frac{\delta D}{C_i}.P \quad (6)$$

Also, let's define the ratios of final over initial, demand (α_D) and animal numbers (α_N), according to equations (7) and (8).

$$\alpha D = \frac{Df}{D_i} \therefore \delta D = Di.(\alpha D - 1) \quad (7)$$

$$\alpha N = \frac{N_f}{N_i} \therefore \delta N = N_i.(\alpha N - 1) \quad (8)$$

Replacing appropriately the definitions in equations (6), (7) and (8) in equation (4), and assuming the average stocking rate for expansion and contraction grassland areas (S_h) is equal to the initial stocking rate, i.e. $S_h = \frac{D_i}{C_i.A_i}$, one can calculate R as in equation (9):

$$R = \frac{D_i}{\delta S.Ci}\big((\alpha_D - 1).P - (\alpha_A - 1)\big) = \frac{D_i}{\delta Yi}\big((\alpha_D - 1).P - (\alpha_A - 1)\big) \quad (9)$$

where $\delta Y_i = \delta S.C_i$ is the difference in productivity between restored and degraded pastures.

Results and Conclusions

According to Equation 9, the main factors defining the area of pasture restoration are the initial demand and its rate of growth, the overall variation in pasture area, the difference in productivity between recovered degraded areas and the rate of expected variation in animal performance.

Results of a sensitivity analysis of the rate of increase of demand to the specified factors, fixing initial demand (D_i) to 10.0 MMT CWE, i.e. approximately the Brazilian current national production. The results highlight the importance of growth in beef demand to achieve the NAMAs target rates of pasture restoration in Brazil and suggest that if a high proportion of production increase is due to animal performance improvement, NAMA restoration targets may turn out to be unattainable (Figure 1). Comparing Figure 1 (a), (b) and (c) it is also possible to evaluate that pasture area expansion may also impair the target achievement.

Applying the expected range of Brazilian beef demand growth rates (1.25 – 2.00 $\%.yr^{-1}$), results presented in Table 1 indicate target rates of pasture restoration in Brazil (1.9 M $ha.yr^{-1}$) would most likely be achieved in scenarios of pasture area contraction (i.e. $\alpha_A < 1.0$), associated with moderate levels of improvement of animal performance ($\leq$ 50% of total productivity gain) and change in productivity of the recovered areas ($\leq$ 80 kg $CWE.ha^{-1}.yr^{-1}$).

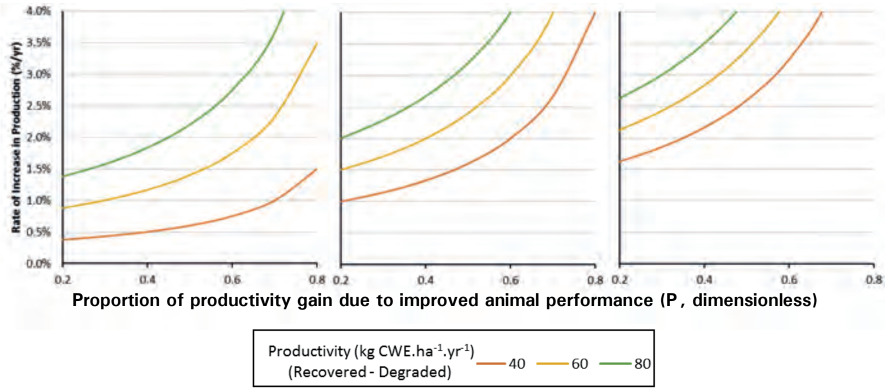

Figure 1. Rate of beef demand growth (αD) required to achieve pasture restoration rates of 1.9 Mha.yr^{-1} for different rates of variation in area (αA), difference in productivity of recovered – degraded pastures (δY) and proportion of production gain due to improved animal performance (1-P). αA values of 0.995, 1.000 and 1.005 correspond a variation of approx. (-0.79, 0 and +0.79 Mha.yr^{-1}).

Table 1. Intervals of area recovered (M ha.yr-1) for different levels of α, δY and P. Lower and upper limits correspond to annual rates of growth in demand of 1.25% and 2.00 %, respectively. Intervals in red indicate the range is lower than rates for pasture restoration proposed in the Brazilian NAMAs (direct + crop-livestock).

	Proportion of productivity gain due to variation in animal performance (1-P)								
	25%			50%			75%		
	Area variation (α)								
δY (kg.ha.yr-1)	-0.5%	0	0.5%	-0.5%	0	0.5%	-0.5%	0	0.5%
40	[3.6 , 5.0]	[2.3 , 3.8]	[1.1 , 2.5]	[2.8 , 3.8]	[1.6 , 2.5]	[0.3 , 1.3]	[2.0 , 2.5]	[0.8 , 1.3]	[-0.5 , 0.0]
60	[2.4 , 3.3]	[1.6 , 2.5]	[0.7 , 1.7]	[1.9 , 2.5]	[1.0 , 1.7]	[0.2 , 0.8]	[1.4 , 1.7]	[0.5 , 0.8]	[-0.3 , 0.0]
80	[1.8 , 2.5]	[1.2 , 1.9]	[0.5 , 1.3]	[1.4 , 1.9]	[0.8 , 1.3]	[0.2 , 0.6]	[1.0 , 1.3]	[0.4 , 0.6]	[-0.2 , 0.0]
100	[1.4 , 2.0]	[0.9 , 1.5]	[0.4 , 1.0]	[1.1 , 1.5]	[0.6 , 1.0]	[0.1 , 0.5]	[0.8 , 1.0]	[0.3 , 0.5]	[-0.2 , 0.0]

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