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Developing a nationally appropriate mitigation measure from the greenhouse gas GHG abatement potential from livestock production in the Brazilian *Cerrado*

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ABSTRACT

Brazil is one of the first major developing countries to commit to a national greenhouse gas (GHG) emissions target that requires a reduction of between 36.1% and 38.9% relative to baseline emissions by 2020. The country intends to submit agricultural emissions reductions as part of this target, with livestock production identified as offering significant abatement potential. Focusing on the *Cerrado* core (central Brazilian savannah), this paper investigates the cost-effectiveness of this potential, which involves some consideration of both the private and social costs and benefits (e.g. including avoided deforestation) arising from specific mitigation measures that may form part of Brazil's definition of Nationally Appropriate Mitigation Measures (NAMAs). The analysis used an optimisation model to define abatement costs. A baseline projection suggests that beef production in the region will emit 2.6 Gt CO_2e (CO_2 equivalent) from 2010 to 2030, corresponding to 9% of national emissions (including energy, transport, waste, livestock and agriculture). By implementing negative-cost measures identified in a marginal abatement cost curve (MACC) by 2030, the 2.6 Gt CO_2e could be reduced by around 24%. Pasture restoration, involving avoided deforestation, offers the largest contribution to these results. As the Brazilian *Cerrado* is seen as a model for transforming other global savannahs, the results offer a significant contribution by identifying alternatives for increasing productivity while minimizing national and global external costs.

1. Introduction

Global demand for livestock products is projected to grow by 70% by 2050 (Gerber et al., 2013). This is expected to generate significant additional pressure on producers and on natural resources. Sustainable management (or intensification) will require increasing yields and efficiency in existing ruminant production systems, minimizing competition of land used for food and feed, while maximizing ecosystem services, including mitigation of greenhouse gas (GHG) emissions (Gerber et al., 2013; Soussana et al., 2013; Thornton and Herrero, 2010).

Tropical regions are implicated as potentially offering major opportunities to increase beef productivity and emissions mitigation, as current productivity levels are still relatively low and emission intensities correspondingly high (Opio et al., 2013; Gerber et al., 2013).

More productive pastures can increase soil carbon stocks, providing one of the largest terrestrial carbon sinks (Follett and Reed, 2010; Neely et al., 2009), in a pool that is a more stable form than the aerial components of forests (Soussana et al., 2010). But potential carbon sequestration in soils under grasslands far from offsets the loss of above ground vegetation in the majority of tropical areas, and therefore natural vegetation should be preserved.

Brazil is the world's second largest beef producer — 9.3 Mt yr^{-1} (14.7% of the world's total), and the largest exporter in 2012–13 (FAO, 2014). Production is predominantly pasture-based in a grassland area of approximately 170 Mha (IBGE, 2014), mostly in a humid or sub-humid tropical climate.

But beef production can entail significant trade-offs, that must be managed to minimize external costs. These include the controlled expansion of agricultural area, associated deforestation, cost-effective greenhouse gas mitigation, and land competition between food and biofuels.

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Analysis of historical data (Martha et al., 2012) and scenario studies conducted by the World Bank (de Gouvello et al., 2011) suggest that improving beef productivity has the highest potential to buffer the expansion of other agricultural activities, avoiding further deforestation. Increasing pasture productivity can also boost soil carbon sequestration, particularly when carried out in currently degraded grasslands (Braz et al., 2013; Ruviaro et al., 2014). In addition, increasing productivity through feed supplementation may significantly reduce direct methane emissions (Berndt and Tomkins, 2013; Ruviaro et al., 2014).

In this context and based on its previous National Plan on Climate Change, at the Conference of the Parties 15 (COP 15), Brazil has proposed Nationally Appropriate Mitigation Actions (NAMAs) as part of its commitment to the United Nations Framework Convention on Climate Change (http://www.mmechanisms.org/e/namainfo/index.html). Over the period 2010–2020, the NAMAs establish targets for the reduction of Amazon deforestation by 80% and by 40% in the *Cerrado* (Brazilian savannah), through the adoption of pasture recovery (15 Mha), and from integrated crop–livestock–forestry systems (4 Mha). With these cattle-related measures, Brazil expects to reduce net emissions by between 101 and 126 Mt CO_2e, by 2020, which account for 61–73% of all mitigation in agricultural practises by the NAMA route. The NAMA proposal is enacted as part of the ambitious ABC (Agricultura de Baixo Carbono — Low Carbon Agriculture) programme, which offers low interest credit lines to farmers adopting mitigation technologies (Mozzer, 2011).

This paper investigates the cost-effectiveness of key livestock mitigation measures applicable in the *Cerrado* core (central Brazilian savannah); a region that contains around 35% of the Brazilian herd (Anualpec, 2010). The region is considered as central in Brazil's ascendance in global production (The Economist, 2010; The New York Times, 2007) and is still regarded as the most important region for expanding beef production in Brazil (Ferraz and Felício, 2010). It is seen as a potential model for transforming other savannahs (Morris et al., 2012).

The analytical focus is significant because there is currently little research clearly demonstrating that mitigation through livestock management can be delivered at relatively low cost. The paper offers the first bottom-up cost-effectiveness analysis using an optimisation model for Brazilian beef production. The measures evaluated are pasture restoration, feedlot finishing, supplement concentrates and protein and nitrification inhibitors. The analysis uses the outputs of a multi-period linear programming model to develop a bottom-up or engineering marginal abatement cost curve (MACC), to represent the relative cost-effectiveness of measures and their cumulative abatement potential above a baseline of business as usual (Moran et al., 2010). The analysis examines the direct emissions reductions attributable to measures enacted within the notional farm gate rather than wider life cycle impacts (i.e., post farm gate), and accounts for both the private and social costs and benefits (e.g. including avoided deforestation).

The paper offers new insights for regional policy and is structured as follows. Section 2 outlines the modelling structure and relevant optimisation assumptions underlying the cost-effectiveness analysis. Section 3 describes the MACC calculation, while Section 4 sets out results. Sections 5 and 6 offer a discussion and conclusions.

2. Modelling methods for mitigation cost-effectiveness

2.1. Model overview

Abatement potential and cost-effectiveness of measures were derived using a multi-period linear programming model (see Appendix: Supplementary material for detailed mathematical description) that simulates a whole cycle (cow–calf, stocking and finishing) beef production farm, accounting for: (i) herd dynamics, (ii) financial resources, (iii) feed budgeting, (iv) land use: pasture recovery dynamics and crops, and (v) soil carbon stock dynamics.

The model optimises the use of the farm resources (capital, cattle, land) while meeting demand projections and maximizing profit. In this context the model is used to simulate beef production treating the *Cerrado* region as a single farm. The farm activities (i–iii) are modelled using monthly time steps, while (iv & v) are modelled using annual time steps. The model represents animals in age cohorts k; a steer of age cohort $k = 1$, is a calf aged 6 months, and 189 kg of live weight (LW). After 3 months in the system, age cohort k is transferred to age cohort $k + 1$, now with 222 kg of LW. The final weight is 454 kg, corresponding to $k = 9$ (33 months), when the animal is sold and removed from the system.

The same cohorts apply to heifers, although these can also accommodate breeding rates, where a heifer generates 1 calf per 18 month cycle, comprising 9 months of pregnancy, 6 months of lactation (Millen et al., 2011), plus 3 months of non-lactation and non-pregnancy. Half of the calves born are allocated to steers and the other half are allocated to heifers, both of age cohort $k = 1$. After 4 cycles, the cows are removed from the system and slaughtered, i.e., used to meet demand.

The model also simulates feedlot finishing, and thus allows the reduction of the finishing time. It can remove a proportion of steers from exclusive grazing, inserting the animals into feedlot systems; generally only males are confined in Brazil (Millen et al., 2009; Costa Junior et al., 2013). For all cattle categories, i.e., male, female, male in feedlot and breeding females, the corresponding age cohort is associated with specific parameters: weight, mortality rate, dry matter (DM) intake, selling and purchase prices, emissions factors for CH_4 from enteric fermentation and emissions factors for N_2O from excreta. The associated coefficient values are detailed in Tables S1 and S2 (Appendix: Supplementary tables).

The gross margin of the *Cerrado* single region farm is maximized and calculated as the difference between the income and expenses. Income derives exclusively from the sale of finished cattle, 454 kg of LW for steers and 372 kg of LW for heifers. Farm expenses are composed of investment and maintenance costs. Maintenance costs are (i) farm maintenance and (ii) animal non-feed maintenance. Costs for (i) include working animals, machinery and equipment, veterinary equipment, telephone device, fuel, taxes and fees, totalling US\$ 25.00 $ha^{-1}yr^{-1}$ (see Appendix: Supplementary Table S8 for details). Costs for (ii) were calculated for each age cohort and it is composed of cost of mineral salt and expenses with health (vaccines), and animal identification (Appendix: Supplementary Table S1).

2.2. Land use dynamics

The model simulates land use dynamics by allocating the total area across pastures or crops; the latter being used for grain and silage production to be used for the formulation of ration for feedlot and supplementation for grazing cattle. The model allocates land into pasture, soybean and corn. In the case of pasture, the model allocates land into different productivity levels. Pasture degradation and restoration rates are key model processes that have a bearing on overall system productivity and hence emissions intensity of production.

2.2.1. Grassland degradation

Pasture degradation can be defined as the loss of vigour and productivity of forage. To represent the degradation process, we define six levels of dry matter productivity (DMP): *A*, *B*, *C*, *D*, *E* and *F* (Table 1), where level *A* is the pasture of highest productivity, and level *F* is fully degraded. If no action is taken to maintain or improve productivity of a fraction of the area in a given level, it is relocated to a lower productivity level. So, after a period of time (assumed as two years herein) level *A* degrades to level *B*, *B* degrades to *C*, and so on, until pasture *F*, thus completing a 10 years full degradation (with no management interventions).