Institution: University of Edinburgh / Scotland's Rural College		
Unit of Assessment: 6		
Title of case study: B: Innovative modelling provides crucial evidence that underpins Brazil's international climate commitments and continuation of national support for sustainable agricultural practices		
Period when the underpinning research was undertaken: 2014 – 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Dominic Moran	Chair of Agricultural & Resource Economics	1999 – present
Rafael De Oliveira Silva	Lecturer / Chancellor's Fellow	2018 – present (PhD student 2014 – 2017)
Period when the claimed impact occurred: 2014 – 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Underpinning Research Using innovative bio-economic models, we showed: 1) that restoring degraded pasturelands can reconcile the competing goals of livestock production with reduction of deforestation and greenhouse gas (GHG) emissions; 2) a subsidy policy deployed by the Brazilian Ministry of Agriculture (MAPA), targeting pasture restoration, could cost-effectively achieve the stated targets for GHG emission reduction; and 3) that reducing meat consumption may in some cases increase GHG emissions.

Significance and Reach of Impact: Our models provided evidence for:
1) The livestock sector contribution to Brazil's Nationally Determined Contribution to the Paris Climate Agreement (2015). Estimates derived in our analysis directly underpin Brazil's pledge to reduce overall GHG emissions to 43% below 2005 levels by 2030, mostly through reduced deforestation achieved by restoring 15,000,000-20,000,000ha of degraded pastureland (representing approximately 10% of Brazil's 170,000,000ha of pastureland).
2) Improving and supporting the next phase (2020-2030) of MAPA's Low Carbon Agriculture programme, which provides financial incentives for farmers to adopt sustainable agricultural practices, including pasture restoration.
3) A shift in the view of the Intergovernmental Panel on Climate Change towards the more nuanced position that reduced meat demand may not always lead to the anticipated reductions in deforestation and GHG emissions.

2. Underpinning research

The Challenge: Intensifying agriculture while reducing GHG emissions
Brazil faces the challenge of reconciling international commitments on GHGs and biodiversity conservation with maintaining economic growth in the agricultural sector through meeting global demand for beef. These are inextricably linked, as one-third of Brazil's GHG emissions come from agriculture and associated land use change, i.e., conversion of natural vegetation to agricultural cultivation. In 2015, agriculture accounted for 429,000,000t of CO_2-equivalents (CO_2e), and land use change accounted for 332,000,000 tonnes CO_2e of a total of 2,280,000,000t of CO_2e (from The Greenhouse Gas Emission and Removal Estimating System).

The Brazilian Government is addressing this dual challenge through sustainable agricultural intensification (SAI) policies. Between 2015 and 2018, we informed MAPA's SAI policies by developing bio-economic models to compare the cost-effectiveness of various SAI policies at farm and regional scales.

Pasture restoration can reduce GHG emissions while increasing beef production
Our first analysis showed the effects of improving farm system profitability and productivity in terms of beef output per hectare, while reducing GHG emissions. The results highlighted the important role of pasture restoration including chemical and mechanical treatment of the soil, correction of soil acidity, removal of invasive species, and application of micronutrients and minerals to improve

the performance of existing *Brachiaria* grasses on poorly managed or degraded pasturelands [3.1].

Restored pasturelands reduce GHG emissions by both sequestering carbon into the soil and increasing the efficiency of cattle feed production, thus avoiding the need to clear additional forest areas for grazing. This avoidance of deforestation equates to reduced emissions.

Analysis of existing GHG reduction measures shows pasture restoration is the most cost-effective way to reduce GHGs

We next refined our model to evaluate the GHG reduction potential and cost-effectiveness of existing measures supported by the Brazilian Government: direct and indirect pasture restoration combined with feed supplementation, promoted by subsidised loans offered to farmers via MAPA's Low Carbon Agriculture programme (*Agricultura de Baixo Carbon;* ABC). This analysis used a model parameterised for the main production region in Brazil: the *Cerrado* biome, or Brazilian savannah, and compared non-ABC supported measures (such as irrigation and feedlots) with existing ABC measures. The results demonstrated that optimal pasture restoration was again the largest contributor to reducing emissions and that restoration was cost-effective at a regional scale [3.2; 3.3].

Overall, the analyses suggested that restoring degraded pasturelands could cost-effectively reduce emissions from the livestock sector by 24% by 2030 compared with a 'business as usual' scenario, while intensifying beef productivity by 12% [3.2; 3.3]. For the most efficient beef producers, up to 85% of cattle emissions could be reduced via pasture restoration [3.1].

Commissioned analysis to understand the feasibility of SAI measures

The first phase of the ABC programme, between 2010 and 2020, was part of Brazil's Nationally Appropriate Mitigation Actions, which targeted 80% reduction of deforestation by 2020 (relative to 2005 levels), through restoration of 15,000,000ha of degraded pastures (representing approximately 10% of Brazil's 170,000,000ha of pastureland). However, there was no underpinning economic analysis of the feasibility of this target, nor any information on the relative cost-effectiveness of different SAI measures, or the overall extent of emissions reduction that might be achievable through adoption of the cost-effective measures by farmers.

In preparation for the 2015 Paris Climate Agreement talks at COP21, signatories were asked to present plans for their Nationally Determined Contribution (NDC) for reducing global GHG emissions. Brazil's NDC seeks to reduce GHGs to 43% below 2005 levels by 2030, mostly by ending Amazon deforestation. To derive the livestock contribution to this target, and to assess the measures required to achieve it, MAPA commissioned a cost-analysis planning for the second phase of ABC, between 2020 and 2030.

We carried out this analysis and identified that restoration of 16,200,000 – 18,200,000ha of degraded pasture would be required to achieve the target reduction of emissions from the livestock and land use change sector. Our analysis also suggested that this could be achieved cost-effectively within the time-frame, using measures already included in the ABC programme [3.4].

Thus, our research identified cost-effective and feasible ways to achieve the target for GHG emission reduction, and in so doing, provided the crucial evidence underpinning the livestock contribution to Brazil's NDC negotiations at COP21 (see below).

Reducing beef demand may increase GHG emissions in some cases

We also used the same models to investigate the role of changes in beef demand or consumption on GHGs from livestock production systems. This work revealed the counterintuitive result that reducing demand for beef could in fact increase GHG emissions, owing to reduced farmer incentives to implement pasture restoration practices. Conversely, increasing demand could reduce GHGs, provided that effective deforestation control policies are in place and that pasture restoration increases [3.5]. The counterintuitive result was enabled by our application of an innovative "consequential LCA - life cycle analysis", in which GHG emissions per kg of product is

sensitive to demand variations. This approach contrasts with the mostly commonly used "attributional LCA" approach, in which GHGs per kg of product are assumed to be fixed regardless of demand levels.

3. References to the research

[3.1] De Oliveira Silva, R., Barioni, L. G., Hall, J. A. J., Moretti, A. C., Fonseca Veloso, R., Alexander, P., Crespolini, M., Moran, D. (2017). Sustainable intensification of Brazilian livestock production through optimized pasture restoration. *Agricultural Systems*. 153, 201-211. doi: 10.1016/j.agsy.2017.02.001

[3.2] De Oliveira Silva, R., Barioni, L.G., Albertini, T.Z., Eory, V., Topp, C.F.E., Fernandes, F.A., Moran, D. (2015). Developing a nationally appropriate mitigation measure from the greenhouse gas GHG abatement potential from livestock production in the Brazilian Cerrado. *Agricultural Systems*. 140, 48–55. doi: 10.1016/j.agsy.2015.08.011

[3.3] De Oliveira Silva, R., Barioni, L.G., Moran, D. (2015b). Greenhouse Gas Mitigation through Sustainable Intensification of Livestock Production in the Brazilian Cerrado. *EuroChoices* 14, 28–34. doi: 10.1111/1746-692X.12079

[3.4] De Oliveira Silva, R., Barioni, L.G., Queiroz Pellegrino, G., Moran, D. (2018). The role of agricultural intensification in Brazil's Nationally Determined Contribution on emissions mitigation. *Agricultural Systems*. 161. doi: 10.1016/j.agsy.2018.01.003

[3.5] De Oliveira Silva, R., Barioni, L.G., Hall, .A.J., Folegatti Matsuura, M., Zanett Albertini, T., Fernandes, F.A., Moran, D. (2016). Increasing beef production could lower greenhouse gas emissions in Brazil if decoupled from deforestation. *Nature Climate Change*. 6, 493–497. doi: 10.1038/nclimate2916

4. Details of the impact

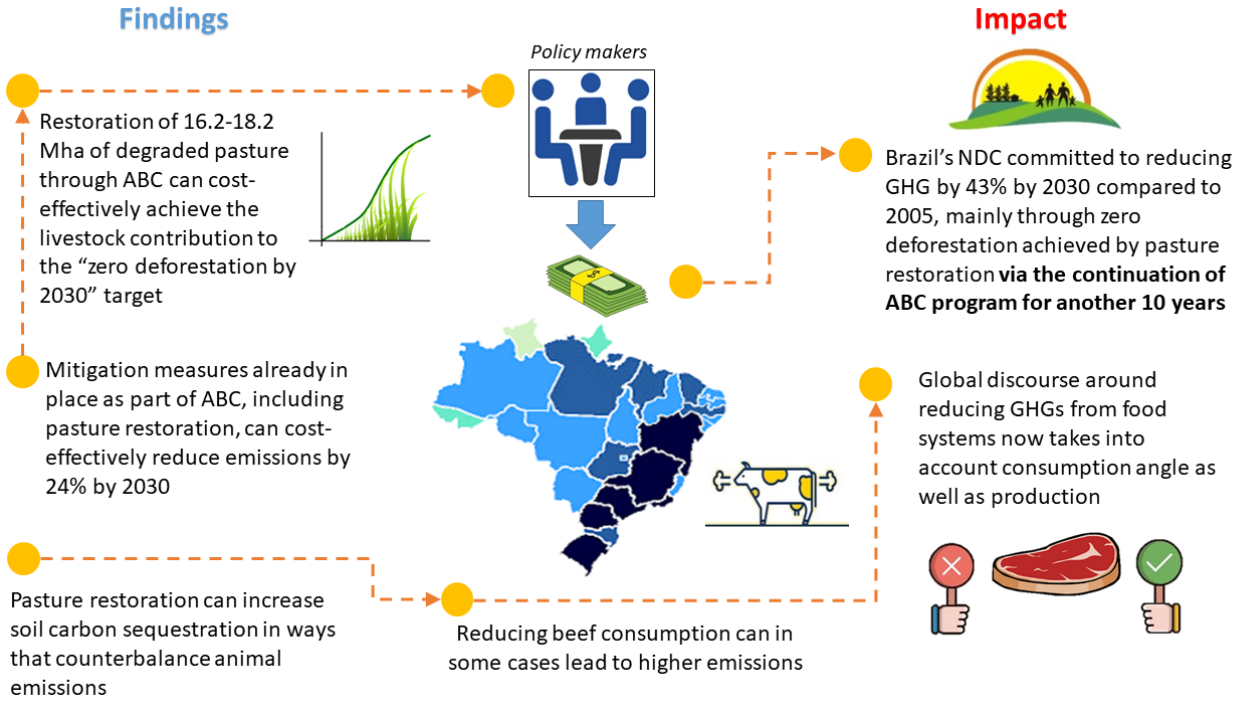

Figure 1. Summary of the research and how it leads to impact.

Impact on Brazil's NDC to reducing global GHGs

The global policy agenda on GHG reduction requires governments to seek cost-effective ways to reduce emissions. A key step towards this was the 2015 Paris Climate Agreement, where signatories outlined their approach in the form of NDCs.

For Brazil, defining cost-effective GHG reduction involved accounting for trade-offs between economic growth, livestock emissions, and protecting globally valuable ecosystems. Our analysis [3.5] was commissioned by MAPA to inform this, and a report was submitted to them in 2014. This analysis provided evidence that pasture restoration is a cost-effective method for delivering significant emissions reductions. The Director of Sustainable Production and Irrigation at MAPA stated that this research: "*specifically supported the formulation of the livestock contribution to the Brazilian Nationally Determined Contributions (NDC) on greenhouse gas mitigation, offered at COP21*. […] *Their work on the NDC provided cost-effective figures on the adoption rates of sustainable livestock practices that supported the negotiations at COP21*". [5.1]

Using pasture restoration cost-analysis figures lifted directly from our report, Brazil's NDC pledges to restore 15,000,000ha of degraded pasturelands by 2030 as the key measure to reconcile livestock production with stewardship of Brazil's tropical forests [5.2]. Through this and other actions, Brazil seeks to reduce its overall GHG emissions to 37% below 2005 levels by 2025, and 43% below 2005 levels by 2030, mostly through mitigation of land use change. In so doing, Brazil became the first middle-income country to provide an absolute emissions cut in its NDC [5.3].

MAPA and the Brazilian Agricultural Research Corporation (EMBRAPA) continue to support the NDC pledges, and have used our research to guide the national debate on climate commitments. The Director of the Department of Sustainable Agriculture and Irrigation at MAPA states that the research has "*contributed to a more nuanced and better-informed debate on the nexus of livestock production and deforestation control. I have specifically referred to this study and summarised the main findings in meetings with President Bolsonaro*." [5.1].

Impact on national agricultural policy in Brazil

As well as supporting Brazil's NDC formulation, our research has informed MAPA's policy by providing evidence for the cost-effectiveness of its Low Carbon Agriculture programme, ABC [3.4]. This programme is extended through rural banks to provide subsidised loans to incentivise uptake of sustainable practices. Prior to our research, there was no evidence on the cost-effectiveness of these practices, and the second phase of the programme (2020-2030) was uncertain. The Director of the Department of Sustainable Agriculture and Irrigation at MAPA confirms that our "*work on the NDC provided cost-effective figures on the adoption rates of sustainable livestock practices that supported* […] *the continuation of the ABC programme for another 10 years (2020-2030).*" [5.1]. Furthermore, the Assistant Secretary of Agriculture confirms that "*Previous research by Moran and Barioni has informed our initial policy design and we are keen to maintain collaboration for the next phase of the ABC Program*" [5.4].

Based on MAPA's annual projections for rural credit, the Brazilian Government will spend BRL2,500,000,000 (GBP340,000,000; 08-20) on the ABC programme in 2020-21, and GBP340,000,000,000 between 2020 and 2030 [5.5]. This represents a significant boost to global GHG mitigation and biodiversity conservation efforts.

The global significance of cost-effective pasture restoration in achieving SAI is also increasingly acknowledged by the international community. In April 2020, The United Nations (UN) cited paper [3.1] as evidence of the potential of pasture restoration in its Environmental Programme synthesis report "*Growing popularity of alternate food systems for environment and health*" [5.6].

Impact on global discussion on GHG emissions and meat consumption

Our counterintuitive finding that reduced livestock demand could actually increase GHG emissions was publicised in 64 mainstream media around the world, including the BBC, the Scotsman, Science Daily, Eco Daily, Science Trends, Eurekalert, Carbon Brief, Farmers Guardian and On Farm, among other media outlets in Brazil, China, Vietnam and Iran [5.7]. Through this coverage,

our research contributed to a more nuanced debate around the role of reducing meat consumption on reducing GHGs, by challenging previous assumptions that reduced consumption was uniformly beneficial. Our paper [3.5] was the first scientific report to challenge this assumption, highlighting the potentially negative systemic consequences of reduced demand.

Reflecting this changing direction, and citing [3.5] 3 times, the 2019 Intergovernmental Panel on Climate Change (IPCC) report on Climate Change and Land, for the first time, took a more balanced view of the production versus consumption debate. It concluded: "*The extent to which the mitigation potential of dietary choices can be realised requires both climate change and health being considered together. Socio-economic (prices, rebound effects), political, and cultural contexts would require significant consideration to enable this mitigation potential to be realised*." [5.8]. This same section, entitled "*Can dietary shifts provide significant benefits?*" highlights our paper [3.1] as one of the key examples of cases where a significant benefit is not seen: "*Studying optimised beef production systems intensification technologies in a scenario of no grasslands area expansion, de Oliveira Silva et al. (2016) found marginal GHG emissions to be negligible in response to beef demand in the Brazilian Cerrado. This was because reducing productivity would lead to increased emission intensities, cancelling out the effect of reduced consumption*." [5.8].

The IPCC was created by the UN to provide global policymakers with objective scientific assessments on climate change. Evidence from our research has led to a conspicuous change in direction of its advice, which now includes commentary on the role of consumption and related sustainability policy, whereas previously IPCC advice had been confined to the effectiveness of production measures.

5. Sources to corroborate the impact

[5.1] Letter of support from the Director Department of Sustainable Agriculture and Irrigation at MAPA

[5.2] Brazil's NDC to the Paris Climate Agreement

[5.3] The road from Paris: Brazil's progress towards its climate pledge (Natural Resources Defense Council Issue Brief, November 2017)

[5.4] Letter from Assistant Secretary of MAPA

[5.5] MAPA's rural credit projection for 2020-21

[5.6] Growing popularity of alternate food systems for environment and health – UN Environment Programme Foresight Brief no. 015 April 2020

[5.7] List of media coverage with links to articles

[5.8] IPCC Report on Climate Change and Land, August 2019 (Chapter 5; quotes on p91)