Economics of Greenhouse Gas Mitigation Strategies in a North-Eastern Brazilian Beef Production System

K. Agethen
Thünen Institute of Farm Economics, Germany

Rogerio M. Mauricio
Universidade Federal de São João, Brazil

C. Deblitz
Thünen Institute of Farm Economics, Braunschweig, Germany

The XXIV International Grassland Congress / XI International Rangeland Congress (Sustainable Use of Grassland and Rangeland Resources for Improved Livelihoods) takes place virtually from October 25 through October 29, 2021.

Proceedings edited by the National Organizing Committee of 2021 IGC/IRC Congress
Published by the Kenya Agricultural and Livestock Research Organization

Economics of greenhouse gas mitigation strategies in a north-eastern Brazilian beef production system

Agethen, K.[*]; Mauricio, R.M.[†]; Deblitz, C.[+]
*Thünen Institute of Farm Economics, Braunschweig, Germany; † Universidade Federal de São João del-Rei, Brazil, + Thünen Institute of Farm Economics, Braunschweig, Germany

Key words: GHG mitigation; silvopastoral system; farm economics; beef production

Abstract
The state of Maranhão, Brazil, has been among the country's fastest-growing cattle regions in recent years and it now faces important conflicts for beef production. Pasture degradation, low cattle productivity, and land-use changes due to agriculture and forestry expansion are key challenges. Additionally, beef production systems are a focus for emissions reduction, particularly in the context of increasing deforestation and its impact on global warming. A sustainable intensification of currently used pastures, enhancing economic viability and reducing environmental effects of beef production can help to mitigate the climate impact. Since economics is an important incentive in the decision-making processes of farmers, we analysed the effects of greenhouse gas (GHG) mitigation strategies on performance, economics and emissions in a representative north-eastern Brazilian beef production system. Improved pasture and herd management, feed supplementation and Silvopastoral Systems (SPS) were included. Based on a case study, we applied six strategies to the production system, covering the complete cycle from cow-calf (CC) to finishing cattle (FIN). We compared the improved production scenarios to the baseline representing the *status quo* of beef production in Maranhão. Our production-economic analysis shows a significant increase in land, labour and capital productivity, resulting in increased whole farm profitability. The scenario is long-term profitable, covering direct costs, depreciation and opportunity costs. Applying IPCC methodology, we found a reduction of GHG emissions per kg live weight added by 29 % in CC and by 45 % in FIN. Considering the increased stocking rate, enhanced carbon sequestration via SPS systems are necessary to counterbalance the increased emissions per land unit. Our results confirm the possibility to offset beef-production-related emissions by SPS. With regard to effects and economic implications, our findings contribute valuable knowledge on available, appropriate and feasible pathways for upscaling sustainable beef production.

Introduction
Agriculture and land use (LU) are important sources of greenhouse gas emissions globally. Especially in countries where agriculture has a high importance for the gross domestic product, it is a challenge to comply with the goals set by the Paris Agreement. In Brazil, agriculture, land use und agriculture-related land use changes play an important potential role in this regard (Azevedo et al. 2018). Besides the establishment of new cropping areas, beef production and the emergence of new pastureland are important drivers of the expansion of the agricultural use areas. The International Panel on Climate Change (IPCC) addresses LU as a major role for climate change mitigation (IPCC 2019a). In this context, multifunctional land use systems such as silvopastoral systems (trees, shrubs, grass, animals) have attracted recent attention. These systems combine diversified land productivity with climate adaptation and benefit biodiversity. They sequester more carbon than conventional pasture systems and can release pressure on ecosystems by increasing land productivity (Mauricio et al. 2019). However, their integration into Brazilian beef production is still in an initial phase. With this case study research, we sought knowledge on silvopastoral systems and their likely impact on farm economics and greenhouse gas emissions of diversified farms in Maranhão.

Methods and Study Site
We compare two farming systems. The baseline production system describes the typical beef production in Imperatriz, Maranhão based on data established by CEPEA (see reference list). In the state of Maranhão, beef production usually takes place in a two-stage system, where CC (cria) and FIN (recria-engorde) are separated from each other. Despite the fact that the beef production takes place in the Amazon biome, the share of natural vegetation on these typical farms is only 30 percent. The improved scenario (SPS) is based on a real farm, located near the city of São Francisco do Brejão. It integrates cow-calf and finishing on the same property and 50% of its area is reserved for natural vegetation. On 430 ha, pastures are managed with a permitted natural regeneration of native trees. On 70 ha, a silvopastoral system with eucalyptus row plantings, legumes and improved grasses has been established. Compared to the baseline production scenario, the improved production scenario integrates subdivision of pastures, rotational grazing practices, legume integration, native

tree regeneration and eucalyptus plantation, feedlot finishing and improved fertility management. In addition, the animals receive clean water and supplementary mineral feeding and pasture areas are established with a mixture of grass species and legumes. The farm characteristics of the baseline and SPS systems are displayed in Table 1.

Table 1: Farm characteristics of the baseline scenario and the SPS scenario

Farm characteristics	Baseline	SPS scenario
Land coverage	70% open pasture, 30% natural vegetation (forest)	43% pasture with legumes and natural regeneration, on this area annually 1,5% is doubled cropped with maize before pasture renewal, 7% silvopastoral systems with eucalyptus row planting, improved pasture and legumes, 50% natural vegetation (forest)
Stocking rate	CC: 0,4 Animal units (AU) / ha, FIN: 0,7 AU / ha	CC: 2,25 AU / ha, FIN: 3,7 AU / ha
Pasture species	70% Panicum *maximum, Brizantha brizantha cv Marundu* + 30% Panicum *maximum cv Mombaca*	50% Panicum Brizantha, *Marundu + 25%* Panicum *Mombaca + 25%* Panicum *maximum cv Massai grass, Mucuna pruriens established as double crop of 20% of area, Thitonia diversifolia and Glyricidia sepium established as double crop on 5% of area*
Animal management systems	Pasture grazing	Pasture grazing, feedlot finishing

The economic performance for the farming systems have been calculated using the TIPI-Cal tool (Deblitz; Hemme et al. 1997). For ease of comparability, both production scenarios have been projected to a total farm size of 1000 ha (including the area reserved for natural vegetation), integrating cow-calf and beef finishing. The greenhouse gas emissions have been calculated by following the 2019 refined methodology of IPCC (IPCC 2019b). Animal activity data, feed characteristics and land management information are in Table 2.

Table 2: Animal performance, feed characteristics and land management

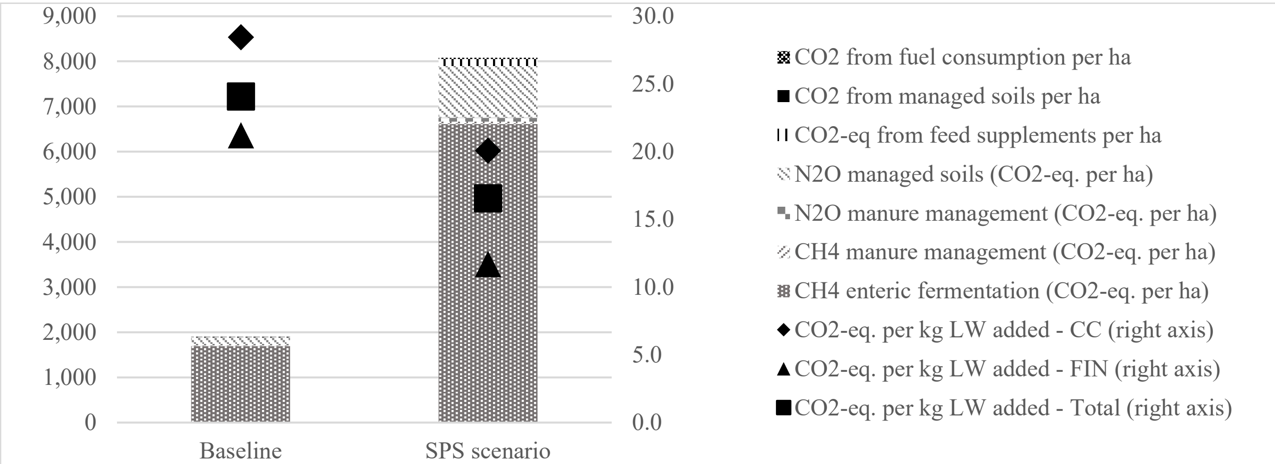
	Baseline	SPS scenario
Age at first calving	36 months	36 months
Replacement rate	10%	18,5%
Pregnancy rate	60%	80%
Weight at weaning	160 kg	200 kg
Daily weight gain	360 g/day	720 g/day
Age at slaughter	41 months	22 months
Feeding periods	Pasture + minerals	CC: Mixed pasture + minerals for 12 months + protein during wet seasons FIN: Mixed pasture + minerals for 12 months + protein during wet seasons, 3 months grain finishing with protein supplement
Feed digestibility	CC: 55%, FIN: 55 %	CC: 56%, FIN: 60 %
Protein content of feed ration	CC: 7,6%, FIN: 8,5 %	CC: 8,5%, FIN: 10,3 %
Pasture management	Renewal all 17 years (CC), all 10 years (FIN)	Renewal all 5 years (CC), all 10 years (FIN)
Pasture inputs	Partial re-seeding, no fertilizer, no soil improvement, cleaning (chemical)	Partial re-seeding, phosphate fertilizer, soil improvement (Dolomite)

Results

Greenhous gas emission analysis

We anticipate higher greenhouse gas emission from the beef production activity (Figure 1). This is linked to the higher stocking rate, the thus increased number of animals, the increased performance, increased emissions from manure management during feedlot finishing and also to the increase in supplements purchased off-farm. Besides, we also see an increase in emissions from land management due to the higher amount of excretions by the animals, the increase in pasture renewal and soil improvement activities. Nevertheless, the emission intensity per kg LW added decreases to 71% in the CC production and 55% in the FIN production.

Figure 1. Annual greenhouse gas emissions in kg CO_2 equivalents per ha, and per kg liveweight (LW) added (CH_4: 28 CO_2-eq., N_2O: 265 CO_2-eq.)



We assume an increase of soil carbon due to improved pasture management following the IPCC default values for LAC soils shifting from moderately degraded (CC) and nominally managed (FIN) to improved grasslands with medium inputs. Additionally, we assume a carbon sequestration potential of the eucalypt plantations of 4.75 Mg c/ha/year (Figueiredo et al. 2017). Together with the increased biomass growth of pasture and bushes, the carbon capture of the SPS system outweighs the increased emissions from the increased animal herd (see **Table 3**). The additional effects of native tree regeneration as well as avoided deforestation are expected to improve the carbon balance further.

Table 3. Annual sequestration potential in kg CO_2 per ha cultivated area

	Baseline	**SPS scenario**
Soil sequestration	0	1772 kg
Biomass sequestration	13366 kg	79583 kg
Sequestration in Eucalyptus	0	2436 kg

Farm economics analysis

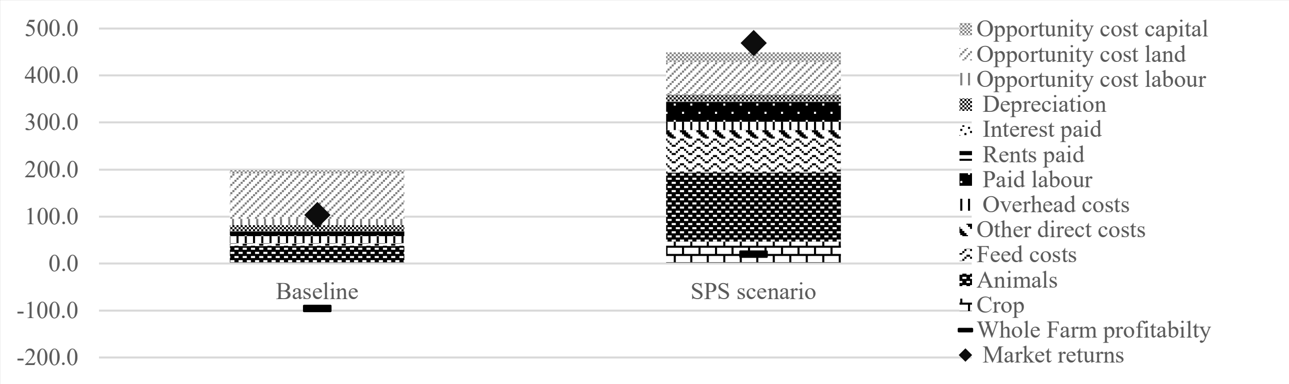
The baseline production scenario can be summarised as low-input-low-output production system. Land costs represent a significant part of the total costs. This production system is only profitable in the short-term, not being able to remunerate opportunity costs for land and labour. The SPS scenario is profitable in the long-term. However, it requires high capital investment in forage production, animal production and labour force. The results of the economic analysis are displayed in Figure 2.

Discussion

Our findings confirm the positive aspects, silvopastoral systems can provide in comparison to conventional grassland-based production: A reduced emission intensity for beef production, increased carbon sequestration in soil and biomass alongside with positive economic indicators making beef production sustainable, also economically.

The farm economic analysis indicates major challenges of the establishment of these production systems. Although the overall revenue is positive for silvopastoral systems, they require substantially more capital investment than conventional beef production systems. Where credit access is not well established and external investment is not commonly recognised, this imposes an important barrier to the spread of even economically beneficiary production methods. Additional labour force required for the management of pastures and animals might pose an additional challenge to farm owners. Training and knowledge transfer have not yet been considered. The same applies for the analysis of fall-out risks in case weather events interfere the establishment of pastures and tree plantations. The harvest costs and the expected returns from Eucalypt trees have been excluded in this analysis.

Figure 2. – Whole farm costs, returns and profitability in 1000 USD



Beyond the farm scale, our results need to be carefully considered, as they bear the risk of rebound effects. The higher land productivity risks to be an even stronger driver of the further expansion of agricultural area into natural ecosystems, to name one potential threat. Any support for the establishment of silvopastoral systems should therefore foresee complementary measures to limit loss of natural habitats, e.g. via the implementation and enforcement of protection measures. In the case of the study region, SPS offer a great opportunity for combining economic growth with compliance to national laws at farm level.

Acknowledgements

The authors would like to acknowledge the substantial support by Ernesto Reyes, Julián Chará and Mauroni Cangussú for the establishment of the SPS farm scenario. Special thanks go to Giovanni Penazzi and the team from CEPEA, who gave critical insights into typical beef production systems in the region of Maranhão.

References

Azevedo T.R. de, Costa Junior C., Brandão Junior A., Cremer M.D.S., Piatto M., Tsai D.S., Barreto P., Martins H., Sales M., Galuchi T., Rodrigues A., Morgado R., Ferreira A.L., Barcellos E. Silva F., Viscondi G.d.F., Dos Santos K.C., Cunha K.B.d., Manetti A., Coluna I.M.E., Albuquerque I.R.d., Junior S.W., Leite C. and Kishinami R. 2018. SEEG initiative estimates of Brazilian greenhouse gas emissions from 1970 to 2015. Sci Data 5:180045

CEPEA, CNA. CUSTO DE PRODUÇÃO DA BOVINOCULTURA DE CORTE EM IMPERATRIZ/MA: not publicly available, available at <https://www.cepea.esalq.usp.br/br/metodologia-boi-leite.aspx>

Deblitz C. Model profile TIPI-CAL / TYPICROP, available at <https://www.thuenen.de/en/infrastructure/the-thuenen-modelling-network/models/model-profile-tipi-cal-typicrop/> [accessed on 31.1.2021]

Figueiredo E.B. de, Jayasundara S., Oliveira Bordonal R. de, Berchielli T.T., Reis R.A., Wagner-Riddle C. and La Scala Jr. N. 2017. Greenhouse gas balance and carbon footprint of beef cattle in three contrasting pasture-management systems in Brazil. Journal of Cleaner Production 142:420–431.

Hemme T., Isermeyer F., Deblitz C. 1997. TIPI-CAL Version 1.0: ein Modell zur Politik- und Technikfolgenabschätzung für typische Betriebe im internationalen Vergleich [online]

IPCC, 2019a. IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse gas fluxes in Terrestrial Ecosystems [online] [accessed on 12.8.2019]

IPCC, 2019b. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4: Agricultre, Forestry and Other Land use. IGES, Japan.

Mauricio R.M., Ribeiro R.S., Paciullo D.S.C., Cangussú M.A., Murgueitio E., Chará J. and Estrada M.X.F. 2019. Silvopastoral Systems in Latin America for Biodiversity, Environmental, and Socioeconomic Improvements. In: Lemaire G, César de Faccio Carvalho P, Kronberg S, Recous S (eds) Agroecosystem diversity: Reconciling contemporary agriculture and environmental quality. London: Academic Press, pp 287–297