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Title: CARBON NEUTRAL BRAZILIAN BEEF: AN ANALYSIS OF ITS ECONOMIC VIABILITY FOR LIVESTOCK SUSTAINABLE INTENSIFICATION

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CONGRESS SUB-THEME: STRATEGIES FOR AGRICULTURAL GROWTH

CARBON NEUTRAL BRAZILIAN BEEF: AN ANALYSIS OF ITS ECONOMIC VIABILITY FOR LIVESTOCK SUSTAINABLE INTENSIFICATION

Abstract

This study analyses the economic viability of Carbon Neutral Brazilian Beef (CNBB), proposed by EMBRAPA, as an alternative for sustainable intensification of beef farming in Brazil. A 12-year cash flow was built for two integrated crop-livestock-forestry systems (ICLF) in the Cerrado region, following the guidelines of CNBB protocol. Both included soybean and cattle, but ICLF1 had 227 eucalyptus trees/ha while ICLF2 had 357 eucalyptus trees/ha. Investment analysis showed both systems were economically viable, with ICLF1, with less trees, performing better than ICLF2. Two scenarios under CNBB protocol, considering premium beef prices and costs assumed either by farmers or by the meat processing companies, indicate CNBB can add value to beef production and generate additional income, while contributing to the environment and to animal welfare. Further analyses must follow, to set the guidelines for additional development of the CNBB market.

Keywords: Agroforestry; Economic analysis; Integrated crop-livestock-forestry systems; Silvopastoral systems; Sustainable farming systems.

Introduction

Concerns over the impact of cattle production on the environment have been raised worldwide in the recent years. The challenge of increasing agricultural production for a growing population, while protecting the environment demands a shift in the current paradigm towards sustainability. How is it possible to continue growing agriculture efficiently, in terms of the use of natural resources; responsibly, in social ways; and economically viable for farmers, without compromising future generations?

The use of technology and sustainable farming systems is part of the solution: the so-called *agricultural sustainable intensification*. In Brazil, land-saving technologies allowed beef cattle productivity to grow 122% between 1996 and 2006, while the total pasture area reduced (Martha Junior, Alves and Contini, 2012). According to Martha Junior, Alves and Contini (2011), if the Brazilian beef productivity remained the same of 1950's, additional 525 million hectares would be required to produce the same level of 2006.

Main criticisms regarding the environmental impact of the Brazilian beef sector include deforestation[1], pasture degradation and, more recently, greenhouse gas (GHG) emissions. In Brazil, beef cattle is still predominantly extensive with low carrying capacity (around one head per ha), and, in some cases, resulting in pasture degradation. Pasture degradation has a twofold effect on GHG: (1) it reduces cattle liveweight gains, especially during the dry season, increasing the emissions per kilogram of meat produced; and (2) it results, occasionally, in soil degradation, which leads to further carbon losses both at the soil and at the grass level (Boddey et al., 2012; p. 52-55). In turn, research has shown that grasslands have a considerable capacity to sequester and store carbon and can "compensate for significant amounts of global carbon emissions" (FAO, 2009), if well managed. Therefore, further sustainable intensification will allow the Brazilian beef sector to free more land for other uses and, possibly, reduce the total cattle herd, while diminishing considerably its total GHG emissions.

Given this scenario, and considering Brazil's voluntary commitment at COP 15 to reduce GHG emissions by 36-38% by 2020 (Mello, 2015), the government launched the National Plan for Low Carbon Emissions in Agriculture, the so-called "ABC Plan". This public policy, based on rural credit at "low" interest rates, was implemented in 2010 to promote practices to recover degraded pasture, the implementation of integrated farming systems (IFS), amongst others.

In this context, the Brazilian Agricultural Research Corporation – EMBRAPA, along with universities and the private sector study, develop and promote integrated farming systems (IFS). IFS consists of different combinations of crops, livestock and forestry, in

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[1] Despite the environmental impact associated with deforestation, it is out of the scope of this study and, thus, not discussed in any extent.

intercropping, succession or rotation, such as: crop-livestock (ICL), crop-forestry or agroforestry (ICF), livestock-forestry or silvopastoral (ILF) and crop-livestock-forestry or agrosilvopastoral (ICLF).

According to Pereira et al. (2018), the "diversification using IFS is possibly the major paradigm shift in Brazilian agriculture, since the green revolution in the 1960's", and may result in rapid increase in beef, crops and wood products altogether. The current area with the various types of IFS in Brazil reached 11.5 M ha (83% ICL, 9% ICLF, 7% ILF and 1% ICF) (EMBRAPA, 2016).

The main economic, social and environmental advantages and disadvantages of IFS are summarized by Dantas and Moraes (2016, pp. 1939-1940), based on several authors, and include:

Advantages: (1) carbon sequestration; (2) improvement of livestock performance; (3) increase of organic matter; (4) provision of ecosystems services; (5) income diversification; (6) higher machinery, labor and input use efficiency; (7) reduction of agrochemicals; and others.

Disadvantages: (1) information asymmetry on IFS; (2) higher labor expertise; (3) cost of land use conversion; (4) use of different machinery; (5) lower yield due to the presence of trees; (6) difficulties to manage the systems[2]; and others.

Further biophysical advantages of using IFS include improvement in microclimate and animal welfare (Karvatte Junior et al., 2016) and in pasture quality (Almeida et al., 2014).

Considering the possibility of carbon sequestration to offset cattle's enteric methane emissions (CH_4) under particular types of IFS, EMBRAPA proposed, in 2015, the "Carbon Neutral Brazilian Beef" – CNBB (Alves et al., 2017). CNBB protocol requires the integration of cattle with trees, whereby these are able to remove enough atmospheric CO_2 to neutralize the bovine methane emissions. Research shows that, in Brazil, fast-growing trees, like eucalyptus, can produce up to 25 $m^3$of wood/ha/year, when densities range from 250 to 350 trees/ha (Ofugi et al., 2008 apud Alves et al., 2017; p.12). This wood production can provide an annual sequestration of 5 t C/ha, which, in turn, offsets GHG emissions of, approximately, 12 adult cattle. However, CNBB certification requires wood to be sold as high value-added product (HVAP) such as timber, laminates

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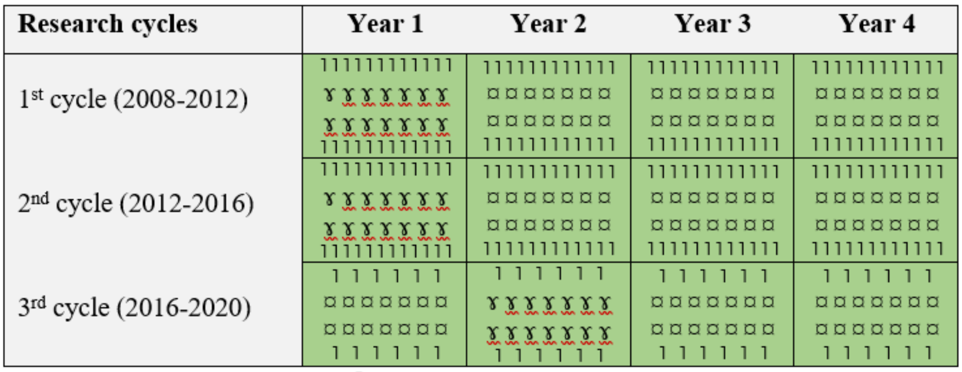
[2] See Costa et al. (2014) to find this and other limitations for IFS adoption.

and veneers for furniture and building purposes, given their long shelf-life (i.e. long carbon immobilization) (Alves et al., 2017). For a complete description of CNBB, please refer to Alves et al. (2017), and for the first CNBB case study check Almeida et al. (2016).

Despite major biophysical advantages, further adoption of IFS, particularly CNBB, relies on available and reliable economic viability analysis. This is particularly important for IFS with trees, given their long-term horizon and associated uncertainties. Somewhat limited literature has been produced so far about the economic viability of integrated farming systems in Brazil. Some examples include: Costa et al. (2012) and Pereira et al. (2015, 2018). None of these addresses the economic viability of CNBB. This study fills this void, by presenting the biophysical performance and the first attempt to assess the economic viability of two ICLF systems, discussing possible scenarios for CNBB.

Methods

Two experimental plots with IFS, of six hectares each, were implemented during the 2008/2009 season, in Campo Grande/MS, Brazil, to test their capacity to recover degraded pasture in Savannah-like regions in Central Brazil. Both included cattle, crops and trees (ICLF systems) and consisted of two consecutive cycles of four years: one year with soybean followed by three years with beef cattle, always carried out between the rows of eucalyptus trees (*Eucalyptus grandis* × *E. urophylla* hybrid) (Figure 1). ICLF1 combined crop-livestock with 227 trees/ha, planted in single rows, with 2 m between trees and 22 m between the rows. IFCL2 had 357 trees/ha, also sown in single rows and 2 m between trees, but 14 m between rows. A third four-year cycle is on its course, but with a slight modification: it started with pasture, followed by soybean and then two years of pasture will follow up, until 2019/2020 season. Unforeseen circumstances delayed the programmed trimming on the 8th year, resulting in the postponement of the crop plantation. Figure 1 presents graphically the schedule of these activities.



Research cycles	Year 1	Year 2	Year 3	Year 4
1st cycle (2008-2012)	˥˥˥˥˥˥˥˥˥˥˥˥ ɤɤɤɤɤɤɤ ɤɤɤɤɤɤɤ ˥˥˥˥˥˥˥˥˥˥˥˥	˥˥˥˥˥˥˥˥˥˥˥˥ ¤¤¤¤¤¤¤ ¤¤¤¤¤¤¤ ˥˥˥˥˥˥˥˥˥˥˥˥	˥˥˥˥˥˥˥˥˥˥˥˥ ¤¤¤¤¤¤¤ ¤¤¤¤¤¤¤ ˥˥˥˥˥˥˥˥˥˥˥˥	˥˥˥˥˥˥˥˥˥˥˥˥ ¤¤¤¤¤¤¤ ¤¤¤¤¤¤¤ ˥˥˥˥˥˥˥˥˥˥˥˥
2nd cycle (2012-2016)	˥˥˥˥˥˥˥˥˥˥˥˥ ɤɤɤɤɤɤɤ ɤɤɤɤɤɤɤ ˥˥˥˥˥˥˥˥˥˥˥˥	˥˥˥˥˥˥˥˥˥˥˥˥ ¤¤¤¤¤¤¤ ¤¤¤¤¤¤¤ ˥˥˥˥˥˥˥˥˥˥˥˥	˥˥˥˥˥˥˥˥˥˥˥˥ ¤¤¤¤¤¤¤ ¤¤¤¤¤¤¤ ˥˥˥˥˥˥˥˥˥˥˥˥	˥˥˥˥˥˥˥˥˥˥˥˥ ¤¤¤¤¤¤¤ ¤¤¤¤¤¤¤ ˥˥˥˥˥˥˥˥˥˥˥˥
3rd cycle (2016-2020)	˥ ˥ ˥ ˥ ˥ ˥ ¤¤¤¤¤¤¤ ¤¤¤¤¤¤¤ ˥ ˥ ˥ ˥ ˥ ˥	˥ ˥ ˥ ˥ ˥ ˥ ɤɤɤɤɤɤɤ ɤɤɤɤɤɤɤ ˥ ˥ ˥ ˥ ˥ ˥	˥ ˥ ˥ ˥ ˥ ˥ ¤¤¤¤¤¤¤ ¤¤¤¤¤¤¤ ˥ ˥ ˥ ˥ ˥ ˥	˥ ˥ ˥ ˥ ˥ ˥ ¤¤¤¤¤¤¤ ¤¤¤¤¤¤¤ ˥ ˥ ˥ ˥ ˥ ˥

Legend of graphic representations: ˥ - trees; ɤ - soybean; ¤ - cattle

Figure 1. Activities scheduled within each four-year cycle for the experimental IFS (2008-2020).

The experimental area was prepared, subsoiled and cultivated twice, and had applications of 3 t/ha of limestone, 1 t/ha of gypsum, preplant herbicides and 300 kg/ha of 05-25-15 (Nitrogen-Phosphorous-Potassium (NPP)) fertilizer. Soybean was cultivated from November to March, during seasons 2008/2009, 2012/2013 and 2017/2018. After harvest, palisade grass (*Urochloa brizantha* Piatã) was sown. In the first cycle, Nellore (i.e. *Bos indicus*) heifers (160 kg of liveweight) were introduced in the experimental plots after trees had reached 7 cm in diameter (May/2010). For this reason, hay was produced meanwhile as an alternative source of income for farmers. From the second cycle onwards, the experimental protocol introduced annual pasture fertilization with 05-25-15 NPP (300 kg/ha) and urea (110 kg/ha), given a reduction in carrying capacity.

During the third cycle, a thinning was carried out reducing 50% of the trees in ICLF1 and 75% in ICLF2, with densities lowering to 114 and 89 trees/ha, respectively. The new spatial arrangements were 22 x 4 m for ICLF1 and 28 x 4 m for ICLF2.

Varying stocking rates were applied to keep around 1,800 kg Dry Matter (DM)/ha of forage ("put-and-take" system). Cattle weight and grazing period were controlled to estimate the annual average weight gain. The biophysical production and the average commodities prices received by farmers in 2017 are shown in Table 1.

Table 1 – Commodities yield and average prices[1] (2017).

Commodities	***Yield (unit/ha)***		***Prices (USD/unit)[2]***
	ICLF1	***ICLF2***	
Hay	t		
Palisade grass hay (Year 1)	4	4	47.77
Cash Crops	t		
Soybean (Year 1)[a]	2.10	2.10	316,28
Soybean (Year 5)[a]	2.28	2.04	316,28
Soybean (Year 9)[a]	2.40	2.28	316,28
Beef (annual averages)	kg of live weight (kg LWT)		
Cycle 1 production (yrs 2 - 4)[a]	374	323	1.37
Cycle 2 production (yrs 6 - 8)[a]	381	245	1.37
Cycle 3 production (yrs10-12)[b]	426	426	1.37
Wood	m^3		
Charcoal (thinning - year 9)[a]	58	94	10.03
Charcoal (logging - year 12)[b]	130	78	10.03
Timber (logging - year 12)[b]	35	30	32.97
TOTAL WOOD YIELD	223	202	

[1] Average exchange rate (2018): 0.264 BRL:USD (www.xe.com/pt/currencytables/).
[2] The measuring unit is shown on the yield columns (e.g. USD 32.97/m^3 for timber).
[a] Experimental data; [b] Estimated data.

As the data above suggest, in ICLF1 soybean and beef production increased throughout the three experimental cycles, while in ICLF2 the production of both first reduced, and then increased in the third cycle. This result was due to the high density of trees in ICLF2 during the first two experimental cycles, with shade limiting the grass and crops development. Once a severe thinning was undertaken, beef and soybean production responded, accordingly. Preliminary results indicate that ICLF1 tends to produce more wood in total, than ICLF2 due to a less competitive environment for the trees development in the first case (Table 1).

For the economic analysis, a 12-year cash flow was prepared considering the revenue generated by the production systems and all operating costs, including seeds/seedlings, fertilizer, chemicals, labor, ant control, thinning (year 9) and logging (year 12) of trees. Typical investment parameters were then calculated, such as net present value (NPV), annualized net present value[3] (aNPV), internal rate of return (IRR), benefit-cost ratio

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[3] Given the uneven annual discounted net benefit presented by both ICLFs through the 12-year cash-flow, we also used the annualized net present value (aNPV), which shows a series of equal cash flows during the project lifetime.

(B/C) and discounted payback period in years (PBK). An annual discount rate of 7%[4] was used in the investment analysis.

Given our aim of analysing the economic viability of IFS under CNBB protocol, and considering that no farm-level data were available, we assumed land, machinery and buildings were fixed and equally demanded by the ICLF systems, being disregarded in the economic analysis. To minimize possible underestimations, we used the opportunity costs of labor (e.g. payment of occasional work hours, at 20.93 USD/day) and of services (e.g. machinery rental). The latter is available in Richetti (2016), and was corrected for inflation (2.95% in 2017).

Beef operating costs were estimated at 0.51 USD/kg LWT. Marginal analysis of beef production was carried out, considering only additional revenue and costs associated with meat produced exclusively while animals remained in the experimental area, and did not include animal purchase.

As suggested by Olson (2011), the simulation of scenarios is helpful to understand the potential benefits and drawbacks of future interventions or plans. Thus, we developed two scenarios to assess the potential economic benefits of CNBB: (1) with additional costs for farmers; (2) without additional costs for farmers (e.g. meat processing companies sponsoring CNBB). In scenario 1 (SCE1), additional costs of USD 0.77 head/year were estimated based on current Brazilian certification services, including reports and on-farm inspections. Considering the carrying capacity of ICLFs varied from one to four head throughout the years and the cycles, the total certification cost per hectare ranged from USD 0.77 up to USD 3.08 and were accounted for in the alternative cash flow. In scenario 2, these costs were paid for by the slaughterhouses. In both scenarios, a premium price after state-tax[5] for CNBB was considered: 3.5% and 2.5% for SCE1 and SCE2, respectively. Results are presented in the next section.

Results

The implementation costs were 5.6% higher for ICLF2 than ICLF1, reaching USD 978.91 and USD 1,033.77, respectively, due to the number of trees in each system. When

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[4] A ten-year bond from the Brazilian government offers a 10% nominal return (or 7.05%, without inflation), while savings account gives 6.9% nominal return (3.95%, without inflation). Both options have been used as opportunity cost for capital, in IFS research.

[5] A 12% rate is charged upon beef price in Mato Grosso do Sul as a state-tax on circulation of goods and services (so called, *ICMS*).

compared to the recovery costs of pasture alone, around USD 900, the increase in expenditures represents close to 9% and 15% for ICLF1 and ICLF2, respectively. This additional cost can be quite prohibitive for farmers, particularly small landowners, possibly explaining the low adoption of IFS including trees (Embrapa, 2016).

The annual net benefit (revenue less costs) also presented a different behaviour for ICLF1 and ICLF2 (Figure 2). The original tree density not only impacted the implementation costs, as discussed before, but also the entire dynamics of cash inflow and outflow, given its direct interference on the other products yields. The annual net benefit became even negative in some years, for ICLF2, due to the continuing costs, including ant control and pruning, decoupled from major revenues from cattle or soybean.

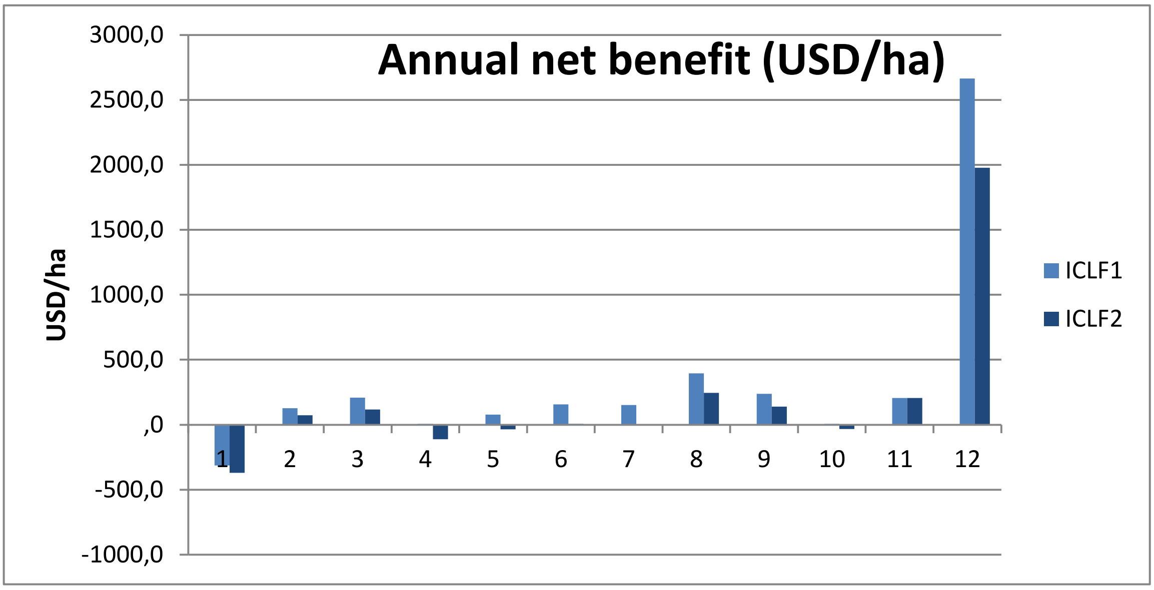

Figure 2 – Cash flow of ICLF1 and ICLF2, implemented in Mato Grosso do Sul state, Brazil.

An investment analysis showed ICLF1, in general, performed better than ICLF2, since it presented higher NPV, aNPV and B/C, and lower Payback period, as shown in Table 2. This result suggests that the less trees in the IFS, the better the economic performance, *ceteris paribus*. However, caution is needed for generalizations, since previous research of these ICLFs found opposite results (Costa et al., 2012). Commodity markets have fluctuating prices, according to climate conditions, world stocks, disease outbreaks, harvest frustration and economic crisis around the world. Until 2016, beef and crops lower prices and wood higher prices impacted significantly on these IFS cash flows, in favour of the tree-intensive system, whose revenues from timber over compensated any possible yield losses from other activities.

Table 2 – Investment parameters of two IFCL systems, in Mato Grosso do Sul state, Brazil (2017).

Parameters	**ICLF1**	**ICLF2**
NPV (USD/ha)	2,011.92	941.69
aNPV (USD/ha)	268.97	125.89
B/C	2.12	0.82
IRR (%)	48%	N.A.*
PBK (yr)	3.2	9.9

*N.A.: not available.

Source: Prepared by the authors.

The high IRR for ICLF1 should also be interpreted in the context of no initial investments on infrastructure and land purchase in our cash flow. If these were accounted for, IRR would certainly be much smaller (possibly between 10% and 15%). We were unable to calculate the IRR for ICLF2 due to several signal reversions. According to Rae (1994), this leads to inconsistent results.

As our findings indicated, both ICLF were economically viable. Nonetheless, to produce CNBB farmers may incur in additional cost and get, potentially, premium price for the meat produced under this protocol. To get new insights on CNBB potential, some complementary investment analyses were undertaken, simulating scenario 1 (SCE1), where farmers pay for certification costs themselves, and scenario 2 (SCE2), where certification costs are paid for by slaughterhouses accredited for beef exports[6] (Table 3). Considering an average beef price of USD 1.37/kg LWT in Brazil, in 2017, and state-taxes of USD 0.16/kg LWT, the premiums were considered upon the net beef price of USD 1.21/kg LWT.

Table 3 – Investment parameters for IFS under scenarios with no CNBB protocol (current scenario), a paid CNBB protocol (SCE1) and a free CNBB protocol (SCE2).

	Current scenario		***SCE 1***		***SCE 2***	
Parameters	**ICLF1**	**ICLF2**	**ICLF1**	**ICLF2**	**ICLF1**	**ICLF2**
NPV (USD/ha)	2,011.92	941.69	2,177.00	1,074.04	2,141.46	1,043.92
aNPV (USD/ha)	268.97	125.89	291.04	143.59	286.29	139.56
B/C	2.12	0.82	2.27	0.92	2.24	0.90
IRR (%)	48%	N.A.	52%	N.A.	51%	N.A.
PBK (yr)	3.2	9.9	1.9	7.8	1.9	9.2

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[6] This is one of the alternatives under consideration within the private sector.

Both ICLF remained economically viable under SCE1 and SCE2. Under CNBB, both scenarios were more attractive economically than the current situation, even when farmers need to pay for certification fees. In general, the premium price helped to reduce the period required to payback investments and to increase the net present value of the above IFS.

Discussion

Our findings indicate there is potential for further development and uptake of CNBB by farmers, as an alternative for farming sustainable intensification in Brazil. The introduction of the protocol, in general, improved the economic returns of the IFS, by means of added-value beef production. However, the additional benefits from CNBB cannot justify, by themselves, the decision to join the Programme. The production system must be economically viable on its own, with CNBB being an extra reward for farmers, since the payments for CNBB are still under discussion and remain unclear. Moreover, any additional costs with the CNBB implementation and maintenance must be lesser than the potential premium prices to be received by the farmers, otherwise adoption levels may be disappointing.

Besides the possibility of premium prices for CNBB adopters, farmers can additionally apply for other meat quality programmes. Since the animal welfare is ensured under CNBB protocol and the production of early steers is stimulated, farmers may enjoy extra payments, such as TRACES and HILTON quota, provided by exporter plants. In Mato Grosso do Sul state, they can also benefit from “PROAPE-MS”, a state programme that returns to farmers part of the state taxes for complying with best management practices at the farm-level and producing particular types of carcasses (SEMAGRO, 2018).

It is worth noting that the Carbon Neutral Brazilian Beef (CNBB) protocol may also add value to other products, including timber. CNBB allows for the payment of premium price for certified wood under silvopastoral or agrosilvopastoral systems, allowing trees to neutralise the cattle methane emissions (Almeida et al., 2016). Planted forests also contribute to reduce the pressure for deforestation, providing relevant environmental services (e.g., avoided GHG), as pointed out by Costa et al. (2018). Brazil’s intention to become a “world reference in carbon trade” (GEF, 2013; p. 14) may allow for further developments in the environmental services domain.

A recovery of the Brazilian forestry sector from the economic crisis is required and will certainly help to increase wood demand (The Economist, 2016) and stimulate farmers to consider these sustainable productions systems. Additional credit through the government "ABC plan" is readily available and the uptake is increasing rapidly.

Nonetheless, the implementation costs of IFS with trees, lack of knowledge on tree management and the uncertainties regarding wood-based markets in Brazil are still major barriers for new entrants, as evidenced by the low number of adopters of ICLF, ILF and ICF (Embrapa, 2016). Moreover, the introduction of trees is recommended in weak soils and cheap land, which limits a wide adoption of such integrated systems.

Given the uncertainties still present in IFS, and in CNBB, in particular, further economic research should address different scenarios, including macroeconomic trends.

Conclusions

Generally, the introduction of trees as a component of IFS provides additional income for farmers and welfare for cattle. The CNBB protocol adds value to beef production and opens other possibilities for capitalization on the diversified production from IFS. Given the early stage off CNBB, further analyses must be undertaken to set the guidelines for additional development of the CNBB market.

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