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# Summary

# Carbon Neutral Brazilian Beef: A New Concept for Sustainable Beef Production in the Tropics

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## Introduction

Agriculture in Brazil, as well as worldwide, has been striving to meet the increasing demand for food, timber, fibers and bioenergy. While larger production is necessary, restrictions for expansion over natural environments increase. For the Brazilian beef industry, the current trend is towards little increase on herd numbers, despite reduction on grazing areas. This will lead to intensification of sown pastures, optimizing use of inputs, along with improved management, feeding and introduction of technologies like integrated systems.

There is also a growing concern from the sector towards environmental preservation and the need for a more efficient use of inputs and natural resources if future demands are to be met. Therefore, agriculture will have to play its role on sustainability, resulting in socio-economic and environmental benefits.

Such expectations, especially from the international community, offer additional opportunity for the Brazilian beef chain. To add value on exports, some aspects must be addressed. For instance, animal welfare, water and soil conservation, while mitigating greenhouse gases emissions (GHG). The last one through carbon sequestration can become an environmental service provided by grazing areas.

Today, Brazil is able to supply such services through production systems that include a forestry component integrated to cattle ranching. For instance, Brazilian Government created in 2010 the Plano ABC (Agricultura de Baixa Emissão de Carbono), a low carbon emissions agriculture plan, stimulating implementation of integrated crop-livestock-forest systems (ICLF) as one of the strategies to mitigate GHG emissions from agriculture. The official plan ensures credit for projects adopting this technology (BRASIL, 2012).

For almost three decades, Embrapa develops integrated systems for different biomes together with universities, other research institutions and the private sector. Aim is to reclaim, diversify and improve pastures management.

Considering the importance of carbon fixed in such systems, the need for a brand or a trademark associated with the concept of these systems emerged, ensuring a distinct product that incorporates some of the mentioned parameters, especially related to mitigation/neutralization of GHG emissions and environmental sustainability.

## Technology Concept: Carbon Neutral Brazilian Beef

Embrapa developed in 2015 the concept “Carbon Neutral Brazilian Beef”, CCN for short in Portuguese, which is represented by a label referring to beef cattle produced under integrated systems with mandatory presence of a forestry component.

This concept aims to support implementation of more sustainable cattle systems, especially regarding environment, through introduction of trees that are able to neutralize emissions related to methane emitted by cattle.  It ensures added value for beef produced under such systems.

This concept aims also to spread the strategic importance of sustainability to the associated production chains (i.e. grains and forestry). It motivates farmers to integrate systems, optimizing use of inputs and other production factors, resulting in synergistic positive effects.

## Trademark Concept

The label "Carbon Neutral Brazilian Beef" (Figures 1 and 2) is a concept-trademark, followed by a protocol with basic requirements, developed by Embrapa to enable a certification testifying that beef produced under given verifiable/certifiable parameters have its GHG emissions neutralized by the trees introduced through silvopastoral (Forestry Livestock - IFL) or agrosilvopastoral (Crop-Livestock-Forestry - ICLF) systems.

This trademark was registered by Embrapa at the Brazilian Patents Office "Instituto Nacional da Propriedade Industrial (INPI)" under the numbers 907078982; 907079156 and 907079270, with its versions in Portuguese (Figure 1) and English (Figure 2).


Figure 1. Label "Carne Carbono Neutro", version in Portuguese.


Figure 2. Label "Carbon Neutral Brazilian Beef", version in English.

This label can be used for fresh, frozen or processed beef, either for domestic or exports Market. It must comply with the basic parameters here presented, regarding production systems, origin and quality as well as its indications of use.

The use of this trademark will be granted to regulatory and/or representative bodies related to the beef chain, always under supervision and technical support from Embrapa.

## Distinctive Elements of the Concept-Trademark

The turning arrow means fixation, neutralization and cycling of carbon, remembering the letter "C".

The green color means neutralization of GHG emissions by beef production systems through carbon sequestration and fixation on trees, represented by a branch with two leaves.

The black color represents the system's own GHG emissions, which are represented by a Bos indicus cattle hump, typical for the tropics.

## Technical/Productive Parameters to Comply With the Carbon Neutral Brazilian Beef Label

Major goal of this label is to certify that meat originated under the given standards had cattle's enteric methane emissions neutralized during its own production process by the trees introduced in the farming system. It also ensures that due to tree shade, cattle was under thermal comfort, indicating high level of animal welfare.

Baseline scenarios for implementing silvopastoral (ILF) or agrosilvopastoral (ICLF) systems are: I) pastures with no trees and II) pastures with scattered native trees. However, pre-existing trees will not be accounted for carbon sequestration. Only trees introduced in the system will count over the baseline (original) system.

For ILF and ICLF projects, recommendations from the Plano ABC (Brasil, 2012) must be followed ensuring that the area where the system will be established is georeferenced and there is animal traceability.

For implementing integrated systems, it is recommended to follow instructions on farming techniques given by Castro and Paciullo (2006), Porfírio-da-Silva et al. (2009) and Serra et al. (2012).

It should be noticed that soil on the area should be tested when implementing the project as well as annually during its lifetime. These analyses, over time, should indicate soil carbon contents equal to, or greater than those of the initial analysis, thus attesting that producing beef in these systems did not decrease soil carbon stocks. These analyses will serve as a complementary indicator of GHG emission mitigation. These values will not be computed in the system's carbon balance in this first version of the CCN requisites.

Since these are not high-input systems and do not include feedlot finishing, GHG emissions from using nitrogen fertilizers, limestone, and from animal wastes will not be considered until measurement methodologies in Brazil are consolidated.

In this sense, initiatives of ILF and ICLF systems would have potential to be classified as projects under the Clean Development Mechanism (CDM) and/or remunerated for provision of environmental services, due to contribution of trees to remove atmospheric $CO_2$, among others benefits.

Special attention should be given to forages implementation and management, since inadequate management may lead to pasture degradation, what is not allowed under this label. Technical information regarding grass management under ILF/ICLF systems can be found in Almeida et al. (2012), Fontaneli et al. (2012), Costa and Queiroz (2013) and Paciullo et al. (2015).

The forestry component to be implemented must have validated equations to determine amounts of carbon fixed. It must also be managed in such a way that part of the wood produced in the system is used for high value-added products (HVAP) such as timber, laminates and veneers, which are used in products with longer shelf-life i.e, longer carbon immobilization, such as furniture and building wood. This part will be used for calculating emissions neutralization.

In Brazil, ILF/ICLF systems with fast-growing trees, such as eucalyptus, at densities of 250 to 350 trees/ha, planned for tree harvest starting at eight years from planting, are able to produce wood at rates of 25 $m^3$/ha/year (Ofugi et al., 2008). In terms of total potential for GHG mitigation, this corresponds to annual carbon sequestration around 5 t C/ha, roughly equivalent to GHG emissions neutralization for around 12 adult cattle. Carbon effectively fixed in HVAP, accounting for the label must be calculated.

Wood originated in systems that are granted with “Carbon Neutral Beef” label, must abide to the concept-trademark. Certified wood, and only this, must generate HVAP and furniture, ensuring neutralization of GHG from livestock.

Compared to traditional systems, besides producing wood and mitigating GHG emissions, ILF/ICLF systems also improve animal welfare by providing greater thermal comfort. According to recent findings, it is necessary to maintain an area of tree crown cover between 10% and 30% (vertical projection of crowns) over the grazing area to allow improvement of animal thermal comfort. ILF and ICLF systems improve biodiversity and land use efficiency. Finally, they add value and diversify income from grazing areas.

In terms of management, cattle may enter the system after trees are big enough to resist harm, avoiding growth hindrances and/or loss on commercial value. Usually, trees with diameter at breast height (DBH) of 6.0 cm can withstand cattle with no need of extra protection. During initial tree growth, if local conditions allow, the area can be used for commercial crops, as well as for fodder production, as silage and/or hay, always observing proper nutrient replenishment.

Cattle on ILF/ICLF systems kept from breeding to finishing (complete cycle) or just growing and finishing can qualify for the label, provided they meet requirements presented in this document.

Animals may be fed with minerals, protein, protein-energy and/or energy supplements on pastures. In the growing phase, it is recommended to use mineral and protein supplement (1 to 2 g/kg live weight-LW) or protein-energy supplement (3 to 5 g/kg LW). For finishing, any of the aforementioned supplement types can be used, but it is recommended using energy supplements (6 to 12 g/kg LW) to speed up carcass fat dressing. The daily limit of supplement should be up to 12 g/kg live weight, so that the forage remains a significant part of feed intake. Further details on feeding can be found in Medeiros and Gomes (2012).

To calculate carbon credits, it is assumed that feed additives to promote growth will not affect emission factors under different supplementation strategies. When castrating males, preference should be given to immunocastration vaccine, that better suits animal welfare principles.

Animal health management must comply with current legislation regarding mandatory vaccines and following its calendar for each region. Obligatory grace periods, specific for each product/medicine must be observed.

## Qualifying for Carbon Neutral Beef Label

In terms of beef output, it can be accounted for receiving the CCN label the hot carcass weight produced during the period animals were kept in the system, considering a minimum of 90 kg carcass per head. For this, animals must be weighed when entering and leaving the system. Weight gain will be estimated considering 50% carcass yield over initial live weight for males up to 400 kg and females up to 300 kg.

For the purposes of certification, it will be accepted females and castrated males having, at the time of slaughter, 0; 2 and 4 maturity teeth (referring to the exchange of the incisor teeth) and medium fat dressing (3 to 6 mm thickness) or uniform (6 to 10 mm fat thickness) according to the Brazilian Cattle Carcass Grading System. Non-castrated males qualify for the label provided they are slaughtered with 0 or 2 maturity teeth and have required fat dressing as above mentioned.

For accounting methane emissions of grazing animals, CCN label adopts the reference value of the Intergovernmental Panel on Climate Change (IPCC, 2006) for Brazil (Latin America) or, preferably, when available, values supported by Embrapa's PECUS Network (http://www.cppse.embrapa.br/redepecus/).

In the future, as the label evolves, other sources of GHG emissions from the system might be considered.

For accounting carbon fixed in trees, it will be used the protocol proposed by Oliveira et al. (2011), as well as its future updates.

The quantities of methane emitted by animals and carbon sequestrated in tree trunks will be converted to CO2 equivalent (CO2 eq.) to determine the balance.

## Steps to Obtain the CCN Label

In short, to receive and use the "Carbon Neutral Beef" seal, the final product (beef and its derivatives) must comply with all the prerequisites and parameters inherent to the general concept established in this document (and its updated versions), in which the minimum conditions necessary to be entitled the label are listed here. These are:

**Commitment to implementing an ILF/ICLF system project based on the ABC Plan and guideline documents from Embrapa:** The system must necessarily start from a production system based on pastures established with herbaceous forages (baseline);

**Technical assessment of the carbon emission:** based on farming indexes, considering GHG emissions per animal, indicated in the reference document from the Intergovernmental Panel on Climate Change (IPCC, 2006) or the PECUS Network (baseline);

**Calculation of fixed carbon:** from regular (annual) forest inventories. Carbon stocks fixated in the system's trees will be calculated according to methodologies to estimate carbon sequestration by trees from Embrapa Forests (Arevalo et al., 2002; Zanetti, 2008; Oliveira et al., 2011);

**Calculation of emissions neutralized:** carbon balance (in $CO_2$ eq.) will be estimated from the technical assessment of methane emissions from animals and carbon fixed in tree trunks from the ILF/ICLF system;

**Carbon stock guarantee:** products from the tree component must ensure that carbon fixed in them and accounted for as neutralized GHG remain immobilized (furniture and HVAP) for a minimum period of years according to current regulations;

**Concession of use for the concept-trademark label:** Embrapa itself or its legally authorized partners will grant use of the “Carbon Neutral Beef” label for beef and its derivative products only and exclusively originated from production processes here described;

**System’s audit:** it will be carried out by independent auditors, linked to companies accredited by public or private agencies, at Federal, State or Municipal levels.

## Options for Accounting Enteric Methane in ILF/ICLF Systems

Emissions estimates can be made following a simplified procedure, based on recommendations from the Intergovernmental Panel on Climate Change (IPCC, 2006), either Tier 1 or Tier 2, or, in a more specific approach, through simulation, using models from NRC (2000) with some adjustments, and using an equation of enteric methane emission developed by the Pecus Network (Medeiros et al., 2014).

The report of the Intergovernmental Panel on Climate Change (IPCC, 2006) provides two simplified options (Tier 1 and Tier 2) for estimates of enteric methane emission, especially recommended for national inventories, since these are general assessments. The reference value for enteric methane emissions (Tier 1) is fixed for Latin America at 56 kg/animal/year.

Results of methane emissions obtained for medium-frame castrated cattle, consuming forage with different digestibility (55% to 65%), using Tier 2, indicate a methane emission factor around 70 kg/animal/year, higher than the fixed value used in Tier 1.

Measurements performed on Nellore heifers under an ICLF system, with eucalyptus and Brachiaria brizantha cv. BRS Piatã, using the SF6 technique, obtained 66 kg CH4/animal/year (Gomes et al., 2015).

The Pecus Network, has developed the first empirical equation of methane emissions (Medeiros et al., 2014) based on domestic data from Brazil, published between 2003 and 2012 (n=50). In this set of data, 60% were related to grazing cattle and 80% to Nelore zebu cattle. This equation, with its coefficients and standard errors (in brackets), is described as follows:

$$CH_4 \text{ (kg/day)} = -0.1011 (\pm 0.02903) + 0.02062 (\pm 0.002834) \times DMI + 0.001648 (\pm 0.000417) \times FDN$$

Where:

$CH_4$ = enteric methane emission,
DMI = dry matter intake (% PV),
NDF = neutral detergent fiber (%).

With this equation, a simulation was performed, estimating emissions from one animal grazing all year around, entering the system with about 280 kg live weight in January and leaving it in December with 430 kg, resulting in an average live weight of 355 kg. Using a *Brachiaria brizantha* sown pasture and considering values for NDF data and digestibility obtained in simulated grazing by hand plucking at the Embrapa Beef Cattle (Euclides and Medeiros, 2003), it was possible, with the same animal model used in the Tier 2 simulations (NRC , 2000), to estimate the animal's dry matter intake (DMI) and its performance. The DMI value was used in the empirical equation from Pecus Network, together with the respective NDF values in order to estimate the methane emission, with nutritional values extracted from Euclides and Medeiros (2003).

Observing results from this simulation (Table 1), it is evident that values are between 57 and 82 kg $CH_4$/year, with a mean of 66 kg $CH_4$/year. There is, therefore, a convergence for values between 56 and 82 kg $CH_4$/year, which can be adopted as a basis for estimating neutralization of methane emissions from beef produced in the tropics.

**Table 1. Simulation of methane emissions ($CH_4$), from the empirical equation from Pecus Network, for grazing cattle.**

| Month | TDN (%) | NDF (%) | DMI (%PV) | ADG (kg/d) | $CH_4$ (kg/d) | $CH_4$ (kg/ year) |
|---|---|---|---|---|---|---|
| **January** | 57,25 | 73,65 | 2,18 | 0,573 | 0,155 | 57 |
| **February** | 56,00 | 74,50 | 2,14 | 0,496 | 0,161 | 59 |
| **March** | 55,05 | 73,90 | 2,10 | 0,437 | 0,163 | 59 |
| **April** | 54,10 | 73,30 | 2,07 | 0,379 | 0,165 | 60 |
| **May** | 53,75 | 74,90 | 2,06 | 0,357 | 0,171 | 62 |
| **June** | 53,40 | 76,50 | 2,04 | 0,336 | 0,177 | 64 |
| **July** | 51,60 | 74,20 | 1,97 | 0,229 | 0,170 | 62 |
| **August** | 49,80 | 71,90 | 1,88 | 0,127 | 0,161 | 59 |
| **September** | 55,55 | 71,80 | 2,12 | 0,468 | 0,186 | 68 |
| **October** | 61,30 | 71,70 | 2,27 | 0,822 | 0,209 | 76 |
| **November** | 59,90 | 72,25 | 2,24 | 0,730 | 0,217 | 79 |
| **December** | 58,50 | 72,80 | 2,21 | 0,650 | 0,224 | 82 |

TDN = total digestible nutrient; NDF = neutral detergent fiber DMI = dry matter intake; ADG = average daily gain.

Thus, there are four values that can be used as reference for estimating methane emissions:

1) The fixed value from IPCC Tier 1: 56 kg $CH_4$/animal/year;

2) The estimated value using IPCC Tier 2: 70 kg $CH_4$/animal/year;

3) The average annual value using the empirical equation from Pecus Network: 66 kg $CH_4$/animal/year;

4) The average value obtained from ICLF systems at Embrapa Cattle: 66 kg $CH_4$/animal/year.

## Accounting for Carbon Stored in Trees

Among the farming components of ILF/ICLF systems, forestry is the one with the greatest potential for carbon accumulation. Through tree growth, atmospheric $CO_2$ is sequestered. Thus, by removing $CO_2$ from the atmosphere, trees generate a positive balance for the farming system, neutralizing GHG released by the other components, especially enteric methane from cattle.

For quantifying and monitoring carbon accumulated by trees from an ILF/ICLF project, the first step is a forest inventory (Hush et al., 1993) in order to determine the actual and potential tree growth and thus estimate carbon accumulated in tree trunks.

The SIS series software (SisEucalipto, SisPinus, SisTeca, SisAcacia, SisAraucaria, SisBracatinga and SisCedro) developed by Embrapa allow calculating stocks of wood available at the time of evaluation and for each future year in terms of total volume and volume per type of wood destination. Consequently, they also help determine amounts of carbon sequestered from the atmosphere and kept immobilized on trees, since they estimate tree biomass and carbon accumulated in different parts of the plant. These software can be used free of charge, upon registration at the website http: //www.catalogosnt. cnptia.embrapa.br/.

A study conducted at Embrapa Beef Cattle estimated the potential to neutralize GHG in two ICLF systems, with 227 and 357 eucalyptus trees per hectare at 36 and at 72 months after tree planting (Ferreira et al., 2012; Ferreira Et al., 2015). In the 227 trees/ha system, neutralization potential increased from 7.1 animal unit per hectare per year (AU/ha/year) at 36 months to 10.8 AU/ha year at 72 months, whereas in the 357 trees/ha system, neutralization potential rose from 12.8 AU/ ha/ year to 17.5 AU/ha/ year, respectively. Calculations considered the whole trunk for carbon sequestration. If smaller portions were considered for carbon fixation, results would still indicate an accumulated carbon balance higher than the carrying capacity for these pastures.

However, it is important to notice that increase in tree density leads to decrease in forage production, mainly due to shading. When managing ILF/ICLF systems, one can use pruning (removal of branches) and thinning (removal of trees) to reduce shading. These, duly planned, increase light incidence on pastures and, consequently, improve forage production. This also provides additional income from forest products harvested. Therefore, when the same level of forage supply is maintained in ILF/ICLF systems, and considering that these systems provide forage of better nutritional value, higher individual animal performance is expected when compared to single pastures. However, weight gains per area are lower. This characteristic, inherent to systems with a forestry component, demands careful pasture management to avoid overgrazing, since in these systems, forage faces higher competition from trees. In this case, management errors may lead to faster degradation processes, especially in the dry season.

## Case Study at Embrapa Beef Cattle

Embrapa Beef Cattle, located in Campo Grande, MS, has set a long-term experiment (2008-2020), with ICLF systems using eucalyptus. In 2008, after one season soybeans farming  to reclaim a former traditional grazing area, Eucalyptus urograndis (clone H-13) was planted in two densities: 227 trees/ha (spacing 22 x 2 m) and 357 trees/ha (spacing 14 x 2 m), followed by Piatã grass seeding. Cost of implementation per hectare, including inputs and services were R$ 2,074.00 and R$ 2,218.00, respectively (non-adjusted 2008 monetary values). With sales of soybeans harvest (average yield 2,100 kg/ha) and hay harvest (average yield 4,000 kg/ha), in September/October 2009, implementation costs were amortized 85% and 79% respectively. If a new soybean crop had been planted in 2010, or in 2009 and there were an inter-seasonal maize or sorghum crop, the implementation costs for the ICLF project would probably have been amortized 15 months after planting eucalyptus, leaving behind a high quality pasture for grazing cattle.

These data show that costs of implementing ICLF systems are not necessarily limiting for cattle farmers, where infrastructure like fencing and animal purchases should not represent extra investments (Almeida et al., 2015).

In the same experiment, cattle started grazing in May 2010 and remained there until August the same year. In a period of 80 days (full dry season), animals had an average daily gain of 654 g LW, and pastures supported 1.5 AU/ha stocking rate. In August 2010, the Piatã grass pasture was evaluated. Crude protein contents in the leaf and in the stem were higher in grass from shaded than plain-sun areas, being 11.4% x 8.5% and 2.8% X 1.9%, respectively. For the leaf, higher in vitro digestibility of organic matter was observed in shaded grass than from plain-sun, being 63.2% and 54.1%, respectively. This indicates higher nutritive value of pasture under shade.

From November 2010 to May 2011 (162 days), supplying only dry minerals for cattle, these systems showed, on average, 1.76 AU/ha stocking rate and live weight gain of 115 kg/ha. In the first year of grazing, there was no difference on yield per animal and per area between both ICLF systems. However, forage availability was lower in the ICLF system with more trees when compared to an integrated crop livestock (ICL) system, which served as control, having only 5 native trees/ha). In the second grazing year, from July 2011 to July 2012, it was observed that in both ICLF systems (227 and 357 trees/ha) animal production (live weight gain) was 459 and 334 kg/ha respectively, corresponding to 85 % and 62% of production from the control ICL system. All systems were fertilized with 50 kg N/ha in 2012.

These systems had an intermediate soybean season (no-till seeding) in 2012/2013. Thus, animal performance was evaluated for a period of only 132 days, from November 2013 to March 2014 (Table 2). Pastures were fertilized with 75 kg/ha N plus 200 kg NPK (formula 0:20:20). No difference was observed in gains per animal between systems. However, regarding gain per area, the ICLF with lower tree density did not differ from the ICL system, while the ICLF system with higher tree density had lower performance, reflecting lower forage availability caused by shading. It is noteworthy that in the subsequent dry season, , animals had to be removed from the ICLF systems for a period of 2 and 4 months, respectively, due to limitation on forage availability.

**Table 2. Forage mass, stocking rate, average daily gain and live weight gain in three integrated systems during 132 days in the rainy season of 2013/2014.**

| System | Forage mass (kg/ha DM) | Stocking rate (AU/ha) | Average daily gain (g/animal/day) | Live weight gain (kg/ha) |
|---|---|---|---|---|
| ICL | 4,267 a | 3.36 a | 520 a | 240 a |
| ICLF227 | 3,618 a | 2.96 a | 529 a | 230 a |
| ICLF357 | 2,613 b | 2.14 b | 508 a | 168 b |

Averages followed by the same letter in the column belong to the same grouping by the Scott-Knott test ($P > 0.05$). Source: Gamarra et al. (2014).

Ferreira et al. (2012; 2015) evaluated potential for neutralization of enteric methane emissions from these systems through the tree component. Considering that the average stocking rate of the ICLF system with 227 trees/ha in 2014 was 2.2 AU/ha/year and the average stocking rate of Brazilian pastures is close to 1.0 AU/ha/year, it can be stressed the ability of livestock systems combined with forestry (ICLF) to mitigate GHG emissions.

Table 3 shows results of enteric methane emission and animal performance from ICLF system with 227 eucalyptus trees per hectare.

In addition, as preliminary work for future carbon stock calculations, Macedo et al. (2015) observed carbon concentrations in the system's soil, in the 0-20 cm layer, which increased from 1.83 g/cm³ C in 2008 to 2.33 g/cm³ C in 2014.

**Table 3. Emission of enteric methane and animal performance in an ICLF system.**

| Period | Animal/ha | ADG (g/cab)[1] | g $CH_4$/head/day[2] | kg$CH_4$/kg ADG |
|---|---|---|---|---|
| Rainy season (210 days) | 3.27 | 566 | 189 | 0.334 |
| Dry season (155 days) | 3.33 | 189 | 170 | 0.887 |

[1] Average daily gain (ADG) of Nelore cows with average live weight of 471 ± 8 kg.
[2] Methane emission ($CH_4$) per animal per day. [3] Methane emission / average daily gain. Source: Adapted from Gamarra (2015) and Gomes et al. (2015).

The ICLF systems of this experiment were planned for a 12-year forestry cycle (*eucalyptus*), with three years cattle grazing and an intermediate soybeans harvest every three years. Eight years after planting, a thinning toke place, removing 50% of trees to advance revenues and allow light between tree rows, favoring growth of subsequent crops and forage. At year 12, all remaining trees will be harvested and sold as lumber.

Considering only the forest product, the ICLF system with more trees has potential for higher revenues, however, it also has lower revenues from crop farming and livestock.

Costa et al. (2012), studying the economics of these systems, though having it as tool for pastures reclamation, concluded that: (1) ICL requires less resources for implementation, as well as generates positive net benefit from the first year. This is attractive for farmers with low investment power or farmers that are not willing to apply for credit. It also seems adequate for farmers interested in short term turnover or farmers that cannot bear negative cash flow for longer periods; and (2) the ICLF requires more investment for implementation, which may be a barrier to its adoption. In addition, net cash flow is sometimes negative for ICLF, given the expected decrease in beef production per area due to shading. However, the long-term profile of these systems, which includes significant revenues generated by eucalyptus, results in higher returns for invested capital.

## Final Comments

There are favorable prospects for development of farming initiatives promoting mitigation of GHG and receiving environmental certification. Labelled sustainable products can have added value, improving economic viability of such farming systems.

Technologies for farming focusing sustainable intensification, through crop-livestock-forestry and silvopastoral systems are already available for farmers all over Brazil, even considering peculiarities of each region. Likewise, scientific methodologies for monitoring GHG dynamics in beef cattle systems are advanced. These aspects make certification possible and, therefore, show the real benefits of such systems.

Combining these factors around a label makes the Carbon Neutral Brazilian Beef an initiative with high potential to promote the sustainability of the Brazilian beef industry.

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