Valuing externalities of cattle and soy-maize systems in the Brazilian Amazon;

Application of the TEEBAgriFood Evaluation Framework

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Photo credit: Embrapa Meio Ambiente

Acknowledgements

Besides the stakeholder consultation presented below, the authors express their appreciation to Juliana Teston, currently a Food and Agriculture manager at WWF-Brasil, and to Lisandro Inakake de Souza, Project Coordinator - Climate as Agriculture Supply Chain at IMAFLORA. Many others participated in interviews as stakeholders in the two value chains, for which we also express sincere thanks, including: Cid Ferreira Sanches, Cynthia Moleta Cominesi, Eduardo Sachetti, Francisco A. Ferreira, Lucas Rafael Cargnin, Marcos Augusto Garbui, Michael Lewin Feibelmann, Olímpio Motta, Orcival Guimarães and Rafaela Amorim. We also express appreciation to Pauline Fabre, Coordinator of Sustainability of Carrefour-Brazil for her willingness to share the group's experience. Finally, we express sincere appreciation to our four reviewers (Marcio Selva, Judson Valentim, Dominic Moran and Walter Pengue) for their incisive and useful comments, for whose response only we remain responsible.

Stakeholder consultation

The team engaged with leading stakeholders associated with the two value chains under study including those involved in both commodity roundtables (Round Table on Responsible Soy-RTRS and Working Group on Sustainable Ranching-GTPS). In addition, the principal technical institutes and NGOs engaged in efforts to improve production systems in soy and cattle ranching (e.g., EMBRAPA, ILPF Network, Instituto Centro de Vida (Programa Novo Campo), PECSA, The Nature Conservancy, Imaflora, WRI, Amigos da Terra-Amazonia Brasileira, FGV-Ces, and others) were contacted with regard to the research. The study also contacted representatives of major agribusiness groups which have made progressive efforts to improve production systems and terms of trade with producers. We are grateful for the willingness of all our interviewees to participate in the study and to share their knowledge and expertise.

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List of Abbreviations

@ (arroba)	15 kg of meat, based on equivalent carcass weight when used to measure cattle for sale
ABIOVE	Associação Brasileira de Indústrias de Óleos Vegetais (Brazilian Association of Vegetable Oil Industries)
APP	Área de Proteção Permanente (Permanent Protection Area)
AU	Animal Unit (a measure of stocking rate)
BACEN	Banco Central do Brasil (Central Bank)
CO_2e	carbon dioxide-equivalent GHG emissions
CONAB	Corporação Nacional de Abastecimento (National Supply Corporation)
CW	live beef cattle carcass weight, usually 50% of overall cattle live weight
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária (Brazilian Agricultural Research Corporation)
GHG	Greenhouse Gas
GTPS	Grupo de Trabalho de Pecuária Sustentável (Working Group on Sustainable Livestock)
IBAMA	Instituto Brasiliero de Recursos Naturais Renováveis e Meio Ambiente
IBGE	Instituto Brasileiro de Geografia e Estatística (Brazilian Institute for Geography and Statistics)
ICV	Instituto Centro de Vida
ILPF	Integrated crop-livestock-forestry systems (termed with the acronym ILCS in English)
IMAFLORA	Instituto de Manejo e Certificação Florestal e Agrícola (Institute of Forest and Agricultural Management and Certification)
INPE	Instituto Nacional de Pesquisa Espacial (National Space Research Institute)
LR	Legal Reserve (Reserva Legal)
MAPA	Ministério de Agropecuária e Abastecimento (Ministry of Agriculture, Livestock and Supply)
MMA	Ministério de Meio Ambiente (Ministry of the Environment)
NGO	Non-governmental Organization
NTS	No-till production system
PECSA	Pecuária Sustentável da Amazônia, S.A.
PRONAF	National Credit Program for Family Farming (Programa Nacional de Agricultural Familiar)
SINDAN	Sindicato de Indústrias Nacionais de Produtos Animais (National Union of Animal Products Industries)
TNC	The Nature Conservancy

1. Introduction

This study responds to the need for field-based testing of the TEEBAgriFood Framework developed by UN Environment and collaborating institutions (TEEB 2018). The regional focus of the proposed study on the Brazilian Amazon is justified by the following factors:

1. The Amazon basin constitutes the world's largest contiguous tropical forest biome, providing vast biodiversity and ecosystem services whose actual and potential benefits for people are largely unmeasured and undervalued (May *et al.* 2013). The region harbors an estimated 45 thousand species of plants and vertebrate animals, representing approximately 10% of planetary diversity, including many species endangered with extinction endemic to this biome (MMA 2012).
2. Many of the pressures that affect ecosystem integrity within the biome and global services derived from the Amazon are transboundary in nature, i.e. they are strongly affected by global demand for beef and feed meals, and their effects are also global insofar as they contribute to irreversible biodiversity loss (IPBES 2018; Joly *et al.* 2019); the biome also represents a net sink for globally impacting greenhouse gases (GHG) but this equilibrium is being undermined (IPCC 2018).
3. Over 526 thousand rural households received lots in agrarian reform settlements in the Legal Amazon since the 1970s (IPAM 2016, Schneider and Peres 2015). Along with spontaneous or directed colonists, most such households eke out a precarious livelihood highly dependent on stable ecosystem services.
4. The Amazon region is under tremendous pressure from global and national economies to produce goods reliant on extraction of value from natural capital stocks, including agribusiness (beef, soy, corn, cotton), timber, minerals and infrastructure development (roads, energy, oil and gas, hydroelectricity, etc.) as well as land speculation (Sparovek *et al.* 2019).
5. The recently installed Brazilian federal executive, while clearly responsive to the beneficial role of the agricultural sector in the national economy, seeks to remove obstacles to its further expansion into the Amazon region by relaxation of both environmental regulation and protection of traditional peoples, heedless to domestic and global concern for the potential socio-environmental consequences of such an expansion into fragile forest ecosystems (Ferrante and Fearnside 2019; Nature 2019).

All of these factors undermine ecosystem stability and resilience, as well as the Amazon's unique social and cultural integrity, threatening the region's attainment of the Sustainable Development Goals (SDGs).

Furthermore, Brazil's Commitments (NDCs) to the Paris Climate Accords (Brazil 2015), signed into national law in 2016, rely primarily on a reduction in carbon emissions associated with land use change and deforestation in the Amazon and Cerrado (savanna) biomes associated with agriculture and livestock. This scenario is consistent with the national GHG emissions inventory (MICT 2015) which showed a steep downturn in deforestation rates in the Amazon from 2004-12 that stemmed chiefly from command-and-control strategies (Assunção *et al*. 2013). According to sectoral analysis in SEEG (2018), the decline in deforestation related emissions has been substituted by increasing relative GHG emissions from land use change and forests.[1]

This NDC scenario therefore called for expansion in livestock production to be achieved by intensifying grazing systems at higher stocking rates rather than by allowing further deforestation. The strategy called for “zero net illegal deforestation”, by promoting restoration of degraded sites to enable landowners to abide by the national Forest Code. It also relies on continuing improvement in predominant soy-maize production systems, to avoid their infringement on forest areas (Gibbs *et al.* 2015), and to provide feedstocks for renewable bioenergy (ethanol and biodiesel), which would increase to 18% of the overall energy mix by 2030 according to the NDC (Brazil 2015).

However, these shifts are seriously threatened today, as deforestation rates have risen once more, in the wake of economic and budgetary crisis and political and regulatory insecurity. Livestock intensification is widely touted as the answer to this dilemma (Silva *et al.* 2017). Yet, although beef productivity increased markedly due to use of improved pasture grasses and rotational grazing (Martha Jr. *et al.* 2012), grazing density has not increased at a rate fast enough to stabilize land use at the forest frontier. Indeed, while a scenario for intensification of land use practices is feasible in theory, its costs are significant and given the absence of forest governance, the tendency is toward continuing expansion at the frontier (Strassburg *et al*. 2015). The strengthening of commitments in value chains are important elements to ensure the transition of beef and soy to more efficient production models, with less environmental degradation and GHG emissions.

Based on experience and literature reviewed in this study, the promotion of low carbon farming practices has the potential, *ceteris paribus,* to increase productivity without additional deforestation, allowing conservation and restoration of natural resources and ecosystem services. This also tends to make agrarian systems more resilient to climate change impacts – avoiding their vulnerability to droughts, pests, floods, etc. (FAO 2018). The technical validation and endorsement of these practices is connected to the valorization of the biodiversity present within the productive systems and the ecosystems in which they are established. Of course, there is always the danger that greater productivity and returns on capital will stimulate further expansion of such systems at the frontier; land use regulation, credit restrictions and positive incentives for environmental compliance will be needed as critical parts of the policy mix.

1. Objectives of the Framework Test

This study examines the current structure, function and related externalities of the two principal food supply chains operating in Brazil’s Legal Amazon region: soy-maize and beef cattle, with respect to two primary applications of the TEEBAgriFood (2018) Evaluation Framework:

1. ***Farming typology comparison***

Evaluation of externalities arising from operations at different scales and enterprise mixes from smallholder cattle raising to large-scale ranching; and

[1] Brazil’s NDC made important commitments to the land-use and agricultural sector, including: i) restoring and reforesting 12 million ha of multi-purposes forests; ii) restoring an additional 15 million ha of degraded pasturelands; iii) enhancing 5 million ha of integrated cropland-livestock-forestry systems; iv) strengthening and enforcing the implementation of the Forest Code, at all governance levels, among others (Brazil 2015).

2. Alternative policy scenario evaluation

1. Evaluation of the impact of "Business-as-Usual" (BAU) practices in large-scale soy-maize and along the above cattle ranching typology on natural and human capital and associated flows; and
2. Simulation of actor response to adjustment in financing to incentivize sustainable livestock intensification and improved soy-maize practices.

1. Methodology

The study tested procedures for evaluation of significant impacts and externalities of specific commodity value chains, as well as the ecosystem services arising from forest retention in the Amazon, with reference to the TEEBAgriFood Evaluation Framework (Sukhdev *et al*. 2016, TEEBAgriFood 2016, TEEBAgriFood 2018). The study adopted the value transfer approach (Brouwer 2000), applying the TEEBAgriFood evaluation framework to address the externalities prevalent along two value chains in the Amazon biome of Brazil: beef cattle and soy-maize.

Specifically, regarding policy scenario evaluation, the study focused on the potential use of external cost evaluation to inform proposals for adjustment in financial incentives (e.g. interest rates, eligible practices, investment horizons) and specific practices promoted by public credit schemes such as the Low Carbon Agriculture (ABC) credit facility offered by the National Development Bank (BNDES) as well as by public and private banks (Bank of Brazil (BB), the Bank of Amazonia (BASA), Santander, among others). Such credits are connected to the corresponding ABC plan[2] administered by the Ministry of Agriculture, Livestock and Food Supply (MAPA 2019). The investigators obtained feedback from stakeholders associated with the two eco-agri-food systems under study (see Acknowledgements) as to their relative sensitivity to such financial instrument adjustments when it comes to making investment decisions. For this purpose, a set of questionnaires was developed and applied in interviews with selected agribusiness, banking, technical assistance, governmental and NGO stakeholders during the study.

The study refers to recent efforts by leading scientists, NGOs and policymakers to identify the current Business-As-Usual (BAU) trajectories and to consider and apply alternative scenarios in pilot projects focused on pasture and herd management and sustainable soy-maize systems currently and potentially adopted in the Amazon region. As a disclaimer, the study addresses the secular societal inequalities present in the Brazilian economy but does not aim to redirect its highly concentrated agribusiness complex that provides an important share of the country's income and competitive position in global commerce. Nevertheless, it does identify trends and opportunities for greater sustainability that are apparent in the eco-agri-food systems under study.

2. Identification of externalities for evaluation

In accordance with the Terms of Reference, the specific stock and flow characteristics of each value chain were appraised in quantitative or qualitative form and inserted in the TEEBAgriFood Framework assessment table (see Table 4) in combination for each of the two value chains.

[2] Plan for Mitigation and Adaptation to Climate Change for a Consolidation of a Low Carbon Emissions Economy in Agriculture - known as the ABC Plan. The ABC plan is one of the sectoral plans that establishes the National Policy on Climate Change in Brazil.

1. Measurement of externalities

1. Broad parameters of social and economic development in Brazil including income and land distribution, serve as a backdrop to the evaluation of externalities adopted in this study. However, the impact of the eco-agri-food chains evaluated on macro variables in Brazil as a whole has not been measured.
2. Measurement tools adopted to quantify externalities consistent with TEEBAgriFood Foundations, Chapter 7. Indicators of impact (e.g., soil loss or CO_2eq emissions per ha in pastures or cropland; and/or per kg beef, sack of soy or bushel of maize; and biodiversity loss using deforestation as a proxy) were tested specific to each respective value chain. Representative values were obtained from the literature but not expanded to the region unless so provided by the source, due to significant variation in underlying conditions.
3. Interview schedules for actors in each supply chain, including producers' associations, processors and farmers in Mato Grosso state, selected due to its central role as the largest producer of soy and beef cattle in Brazil.

2. Policy recommendations

1. Consideration of how the existing policy framework affects incidence and level of externalities, both positive and negative;
2. Simulation of potential effects on externalities of adjustments in financial incentive parameters, with reference to stakeholder perceptions; and
3. Improvements in public policy instruments and in directives assumed by business coalitions and roundtables related to sustainability commitments in value chains to make them more effective and to upscale.

3. SECTOR AND TRADE CONTEXT

1. Brazil's agricultural and livestock sector

Among all economic activities in Brazil, agribusiness stands out as the single most important sector of the national economy, whose growth is a buoy to the rest of the economy although its relative importance to overall income has eroded over the last two decades (Figure 1). Between 2017-2018, agriculture and livestock contributed 21.6% to national GDP (CEPEA 2018a), having declined from a relatively stable level of 26-30% from 1996 to 2002.

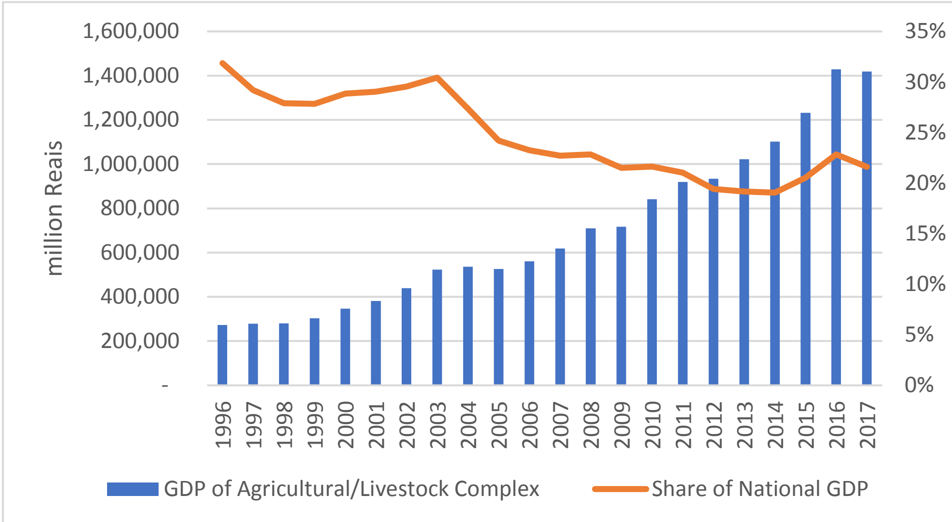

Figure 1: Agribusiness GDP and participation in Brazil's GDP (%). Source: CEPEA 2018a

The number of workers employed in the agricultural and livestock sector has been declining in Brazil over the past decades, as is also the case in industry (MTE 2018), reflecting the overall development of the economy and increasing mechanization. It may also reflect the growing sectoral importance of livestock production which uses relatively less labor than agricultural activities. Employment in the North region which includes most of the Amazon biome is nearly two-thirds informal, lacking contracts or obeying minimum wages. Thus, while formal employment may be on the downswing as measured by labor statistics, part of the rapidly growing population in the Amazon region[3] is absorbed by rural settlements and serves as part of a fluid temporary workforce that assists the process of crop and pasture expansion into forest areas. These processes are exacerbated by the fragility of land tenure by smallholders in much of the region (Menezes 2018).

Livestock alone represented 31% of Brazilian agribusiness GDP in 2017 (ABIEC 2018). Data on the accumulated production value in 2017 indicate that approximately R$ 263.9 billion (approx. US$ 79.4 billion[4]) comes from livestock, with 73.7% represented by beef cattle and 26.3% by dairy cattle (CEPEA 2018b).

In 2017, the soy complex generated a total of R$ 103.2 billion (approx. US$ 31 billion) (CEPEA 2018a). According to statistics from the National Supply Company (CONAB 2017), in 2016/17 the cereal, legumes and oilseed crop attained a volume of 238 million tons, a 14.5% increase on that obtained in 2014/15 (207.8 million tons), showing a continuation of the upward trend prior to the crisis of 2015/16 (Figure 2).

Brazil is currently the second largest soy producer in the world after the USA. In the 2016/2017 harvest, soy occupied an area of 33.9 million hectares in the country, with a total production of 113.9 million tons, based on an average yield of 3,362 kg/ha. Soy occupies 56% of all cropland in Brazil (CONAB 2017). In the 2017/2018 harvest a total of 117 million tons were produced (EMBRAPA 2018). The three states that

[3] The total population of the North region nearly quintupled to nearly 16 million while the rural population doubled between 1970 and 2010, making this region the only part of Brazil which showed rural population growth over the period (IBGE 2019).
[4] 1 USD = BRL 3.322 in 2017 (https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates). The remainder of this report adopts this exchange rate for 2017.

produced the greatest volume of soy were successively (in tons produced, area planted and yield): 1) Mato Grosso - 31,887 million tons - 9,519 million hectares (3,350 kg/ha); 2) Paraná - 19,070 million tons - 5,444 million hectares (3,503 kg/ha); and 3) Rio Grande do Sul - 16,968 million tons - 5,692 million hectares (3,354 kg/ha) (EMBRAPA 2018).

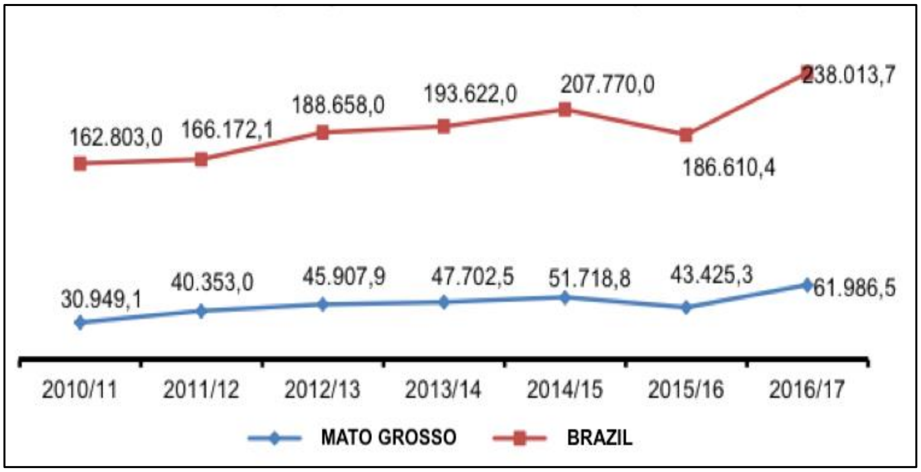

Figure 2: Production of cereals, legumes and oilseeds in Brazil (million t): 2010-2017. Source: CONAB (2017).

Maize is typically produced on the same fields as soy, as a second crop after soy harvest (called *safrinha*), taking advantage of nutrient, pest control and soil synergies between the two crops under no-till. This increases farm income as well as providing ground cover in the post-harvest period (Ferreira 2015). Maize produced in rotation with soy now constitutes over 70% of the national crop (CONAB 2018).

In 2017 the internal consumption of soy in Brazil was of 59 million tons; the export of soy as grain was 68.1 million tons (US $ 25.7 billion); the export of feed meal was 14.2 million tons (US$ 5.0 billion); the export of oil was 1.3 million tons (US $ 1.0 billion) totaling US$ 31.7 billion (CONAB 2018, Agrostat 2018), with a 45.9% share in world trade. Most internal demand for soy is destined toward domestic consumption as cooking oil and for biodiesel (Figure 3; Table 1), while maize is primarily destined for feed and, increasingly, ethanol production.

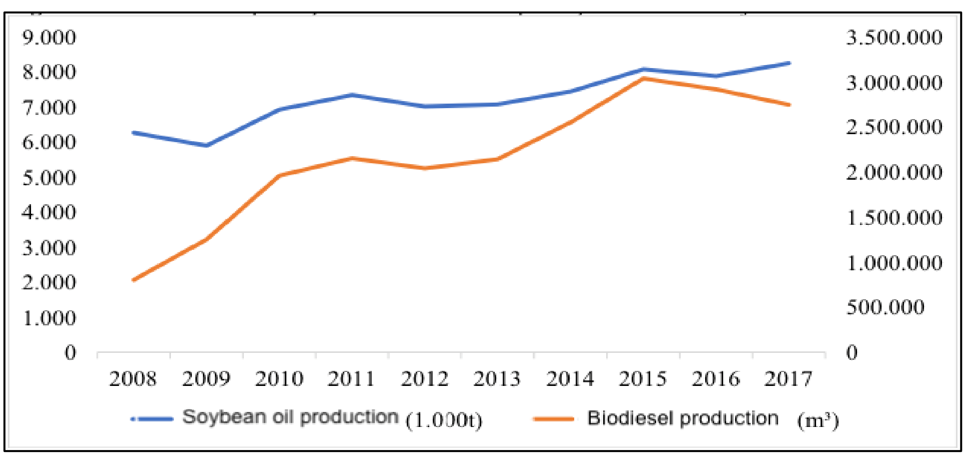

Figure 3: Production of soy oil and biodiesel in Brazil between 2008 and 2017. **Source: ABIOVE, Brito, 2018.**

Table 1: Soy production and processing, soy meal, oil and biodiesel produced from 2008 to 2017 [5]

Year	Production of soy (1.000t)	Soy processing (1.000t)	(%)	Soy Meal output (1.000t)	Production of Soy Oil (1.000t)	Production of biodiesel (m^3)
2008	59,936	32,325	53,93	24,502	6,267	801,320
2009	57,383	30,426	53,02	23,287	5,896	1,250,577
2010	68,919	35,506	51,52	26,998	6,928	1,960,822
2011	75,248	37,270	49,53	28,322	7,340	2,152,298
2012	67,920	36,434	53,64	27,767	7,013	2,041,667
2013	81,593	36,238	44,41	27,621	7,075	2,142,990
2014	86,397	37,622	43,55	28,752	7,443	2,551,813
2015	96,994	40,556	41,81	30,765	8,074	3,038,835
2016	96,199	39,531	41,09	30,229	7,885	2,918,031
2017	113,800	41,800	36,73	31,400	8,250	2,747,951

Source: ABIOVE, Brito, 2018.

Ethanol derived from maize is flourishing in Mato Grosso, where four out of five maize-based Brazilian ethanol distilleries are currently located, using either solely maize or alternating with sugarcane. The latter option enables part of the industry's fuel demand to be met by bagasse, while the distilleries that rely on maize alone are actively stimulating the planting of eucalyptus for fuel (Petroli 2019). Although the net energy balance of maize is not comparable to sugarcane ethanol, the byproducts of maize distillation offer additional economic benefits, including maize oil and distillers' dry grains (DDG), which alone or with solubles (DDGS) have become important protein additives to feed grain (UNEM 2019).

As for beef, the national cattle herd size exhibits a range of values between 170 and 221 million,[6] with an average of around 210 million head, giving Brazil the second largest beef stock in the world after India. This herd is distributed over approximately 164 million hectares of pasture and 2.5 million establishments (IBGE 2018), leading to an average national pasture occupancy rate of 1.34 head/ha and a corresponding stocking rate of 0.94 AU/ha (ABIEC 2018). The offtake of 39.2 million head/year yields 9.71 million t carcass weight equivalent per year (IBGE 2018a). Of this production, about 79% is absorbed in the domestic market, and 21% is destined for export, while 790,000 head/year are exported live on the hoof mainly to Muslim countries (ABIEC 2019). Brazil itself is one of the world's largest per-capita beef consumers at 42.2 kg/capita/yr (Ibid).[7]

Brazil is the largest beef exporter in the world, followed by India, Australia and the USA. Beef exports accounted for 3.2% of total Brazilian exports in 2017, up 9.6% in volume and 13.9% in sales over the previous year and are fundamental for maintaining the positive trade surplus in Brazil along with that of agribusiness as a whole (ABIEC 2018). In 2018, a record 1.35 million tons of beef with a value of US$ 5,6

[5] Biodiesel requires about 7.5 pounds of soy oil per gallon of final product. 1 ton of soy oil yields 293 gallons of biodiesel. 1 m^3 of biodiesel = 264 gallons. 2.7 million m^3 of biodiesel (Table 1 - 2017) is equivalent to about 3 million t of soy oil. Converting to soy, at crushing rates of 0.197 oil/t of soy, the amount required to produce 2.7 million m^3 of biodiesel is 15.2 million t, or 13.3% of national soy production or 36.4% of soy processed (author's calculations based on conversion factors from the industry).

[6] Estimated variously at 171 million based on the 2017 agricultural census (IBGE 2018a), 190 million (ANUALPEC 2017), 214 million based on the annual livestock statistics PPM for 2017 (IBGE 2018b), 218 million (FAOSTAT 2018), 219 million (PANAFTOSA 2018) and 221 million (ABIEC 2018).

[7] OECD (OECD Data 2018) showed that Uruguay and Argentina kept their place as the world's champion beef-eaters at over 40 kg/capita/yr, followed by Brazil (26.5 kg), the USA (25.8) and Paraguay (25.4). This consumption reflects the impact of the global recession (many switched to chicken to keep meat on the table).

billion were exported (ABIEC 2019). According to the Mato Grosso State Institute of Agricultural Economics (IMEA 2018),[8] export revenues in 2017 from beef were US$ 125.6 million, an increase of 55.6% over the previous year, surpassing the increase of 35.52% of overall Brazilian beef exports. The state accounted for 20.7% of all Brazilian beef exports in that year.

2. Current characteristics of value chains under consideration

This study applies the TEEBAgriFood framework to two principal eco-agri-food systems widely considered instrumental in land use change in the Brazilian Amazon: 1) **multi-scale cattle ranching** for beef and co-products, and 2) **large scale soy-maize systems** for feed, oil, ethanol, sucrose and other foodstuffs.

For the analysis of the two chains, all segments involved in the production process were evaluated. The impacts at the various stages of the agrifood chains were taken into account, considering use of inputs up to the product ready for consumption. Natural and social capital impacts are also analyzed.

With respect to the livestock chain, the study is focused on beef cattle farming activities, although many smaller enterprises also include dairy production at different scales. The production of male animals from smallholder agriculture also responds to the needs of beef fattening systems. In the Amazon region this dynamic is very intense and involves small, medium and large farmers. In the region, 3,586 settlements occupy 41,8 million hectares (8% of the regional territory), of which 37% of this area had been deforested by 2014 primarily to raise beef cattle (IPAM 2016). The study hence derived a typology of cattle raising systems at different scales, including small-scale cow/calf operations, medium and large-scale beef cattle fattening operations. The state of Mato Grosso has been selected as a case study for an in-depth focus, given its importance as the largest soy producer in Brazil as well as the largest cattle herd and principal source of deforestation in the Amazon.

Besides considering the responses to finance options at different scales, the study contemplates the evaluation of a typology of systems that integrate livestock with agricultural production systems (ILP), more specifically with the soy-maize chain. These systems have arisen due to the different forms and strategies of land use in the Amazon and Cerrado regions of Brazil. We also considered integrated crop, livestock and forest (ILPF), and livestock and forest (silvipastoril) systems, as well as the growing importance of no-tillage systems (NTS) and nitrogen-fixation in soy-maize rotations.

From the detailed analysis, hypotheses are raised about the possible responses of these segments in a scenario that contemplates financing for adjustments in the productive system and, primarily, in the maintenance of forest reserves and in the restoration of degraded pastures.

1. Cattle ranching

Over the past 20 years, growth in cattle ranching in Brazil has occurred primarily in the Legal Amazon region, where over 38% of the national cattle herd is now found (IBGE 2018a; Smeraldi and May 2009). In the period 1990 - 2015, the regional herd in the Amazon grew at a rate of 5% per year, while the Brazilian

[8] https://www.beefpoint.com.br/mt-se-torna-o-maior-exportador-de-carne-bovina-do-brasil/. Accessed 19 November 2018.

herd as a whole grew only 1.7% per year (IBGE 2018a). The states of the Legal Amazon[9] have a cattle herd close to 81 million head (at least 40% of the national herd), reared on approximately 71 million ha of pasture (ABIEC 2018; IBGE 2018a). The state of Mato Grosso is the largest national producer, with approximately 31 million head according to ABIEC (2018), representing 14% of the national herd. In addition to Mato Grosso, other states in this region contribute significantly to national beef production, including Pará with 18 million and Rondônia with 10 million head of cattle (IBGE 2018a, ABIEC 2018).

The scale of ranching operations differs considerably, with smallholders occupying < 100 ha at one end, medium sized ranches from 200-1000 ha, and large ranches of 10,000 ha or more at the high end. Smallholders typically engage in cow/calf operations, providing heifers for fattening on larger properties or feedlots, or engaging in dairy production (restricted to those close to urban areas). Medium- and large-scale ranches specialize in extensive grazing, but increasingly these systems are becoming more intensive with feedlot finishing (see further details below). Cattle are typically grazed at stocking rates of <1 AU/ha, though it is feasible to attain levels of 3-4 AU/ha with pasture rotations, use of improved pasture grasses and genetic improvement of the herd. These improvements also portend significant reductions in GHG emissions both due to reduced area required per kg of liveweight gain (Strassburg *et al.* 2015) or due to improvement in nutritional properties, affecting methane levels emitted during enteric fermentation.

A typology of cattle ranchers in the Amazon can be derived from the characteristics of their production systems and in the producers' socioeconomic conditions, in their adopted technological level, in the production area sizes and in their herd size.

Brazilian beef cattle evidence a wide range of production systems. These range from extensive livestock, supported by native and cultivated pastures of low productivity and low use of inputs, to so-called intensive livestock, with high productivity pastures, pasture feed supplementation and feedlots. However, whatever the production system, the activity is characterized by the predominance of pasture use (Cezar 2005). EMBRAPA's National Center for Beef Cattle Research generally describes production systems according to the diet employed, including definition of extensive, semi-intensive, intensive and confinement systems (Ibid.):

1) Extensive system

Exclusively based on pasture regime, both native and cultivated pastures. Pastures are the only source of energy and protein foods. This system represents most of the livestock production in Brazil. Planted pastures may be complemented with pasture legumes to improve productivity and diet.

2) Semi intensive system

The semi-intensive system is that based on pasture food (native and/or cultivated) plus mineral supplementation with energy and protein foods. Supplementation is carried out at various stages of the operation: breeding, rearing and fattening. There are some modalities in semi-intensive systems such as the use of “Creep feeding” which consists of supplementing calves from the weaning phase. Another

[9] The Legal Amazon is composed of the states of Northern Brazil (Acre, Amazonas, Amapá, Pará, Rondônia, Roraima and Tocantins) combined with Maranhão and Mato Grosso, which are located in the Northeast and Center-West regions, respectively, according to IBGE regional divisions.

method adds to the mineral salt mixture an amount of protein concentrate (crushed corn, soybean meal, etc.) to ensure adequate nutrition during dry and/or wet seasons. Another mode is the supply of concentrate in troughs placed in pastures.

3) Intensive system

The intensive system is characterized by the confinement model aiming, in most cases, toward the finishing of the animals that go to slaughter. Intensive systems can also be characterized by intensive use of pastures, i.e. systems that use high stocking rates and intensification in the use of inputs, either in pasture fertilization or in food supply, always aiming at high weight gains.

4) Intensive confinement

The most commonly used system for the fattening and finishing phase of animals before slaughter is that of intensive confinement – a system in which animals are enclosed in facilities within a defined space and receive massive feed and concentrate in the trough over an established period.

Research based on data from the 2006 agricultural census in the entire Legal Amazon region, showed that the feeding of the herds occurred almost exclusively on the basis of extensive grazing on pastures, native and/or cultivated. Properties occupied an average of 45% of their total area with pastures, and 14% with crops. Only 40% rotate cattle among their pastures. The result is an average pasture stocking rate of only 0.83 AU/ha. Only 5% on average adopted cattle confinement as part of their systems.

In summary it was found that nearly 55% of the municipalities exhibit a low technology of cattle raising and only 9% can boast higher levels of technology. This was demonstrated in the low rate of adopting use of mineral salt (35% of producers); less than 2% adopted artificial insemination. Other factors include the low rate of application of fertilizers to pastures (6.5%), since in most of the Amazon ranchers manage their pasture fertility by burning. The state of Mato Grosso had the largest number of municipalities with higher technological level, followed by Rondônia, Tocantins and Pará State (Santos *et al*. 2017).

A second typology was developed with a focus on cattle ranching at various scales in the south of Pará, based on land tenure, the scale of the property and herd size. These aspects were not found to be correlated necessarily with the adoption of a feeding regime, though the adoption of confinement necessarily requires a greater degree of capitalization. The main criteria adopted for the typology were land area, predominant type of labor (family or salaried) and productive capital (effective herd, racial profile of the herd and diversification or not with crops). Three types of ranchers were identified: i) Under-capitalized Family Farmer; Capitalized Family Farmer and Employer Farmer (Claudino *et al*. 2016).

Of the three categories identified, the Under Capitalized Family is the most expressive, corresponding to 44.3% of the sample of 61 ranchers; having areas of up to 150 hectares and herds of up to 120 head. The Capitalized Family Farms represent 34.4% of the sample and have areas of 100 to 350 hectares and herds of 100 to 500 head, with a mixed herd profile (suitability for both meat and milk), or two specialized herds, one for beef for calf production and one for milk production. The group of Employers are 21.3% of the sample and have areas between 400 and 3,000 hectares, and the herds vary between 500 and 3,000 head, specialized in beef, whether for raising, rearing and/or fattening, with few cases of milk production

(Claudino *et al*. 2016). Family Farming groups produce calves and milk that are sold to the Employer Farming category.

At the time of the 2017 agricultural census, in Mato Grosso, the mean pasture area on ranching establishments was 236 ha, with an average herd size of 260 head. The state has the lowest proportion (42%) of establishments under 50 ha engaged in cattle production in Brazil, where the average is 76%; many of these smaller establishments were engaged in milk production (38% of all cattle raising establishments). Some of these smaller units engage chiefly in cow/calf operations as suppliers of calves to larger operations. Among establishments under 50 ha, 55% sold animals for whatever purpose in 2016.

Besides beef and milk, the cattle industry also produces hides for leather and tallow that is used in production of biodiesel fuel. Brazil has enacted a legal framework that was recently increased from B5 to B10, i.e. a minimum 10% addition of biodiesel at the pump. Furthermore, a relatively small share (less than 2% of overall beef exports) of live cattle has been exported annually from Brazilian ports to destinations in the Middle East where they are slaughtered and processed in accordance with Islamic customs. Live cattle exports have been supplanted to some extent by Moslem rites performed on site in Brazilian slaughterhouses. There are thus several distinct value chains involved in the cattle industry, and interventions must therefore be differentiated to suit this.

Approximately 62% of all land use change in the Brazilian Amazon has been traced to conversion of native forests to plant pastures dedicated to cattle grazing (INPE 2014).[10] In large scale ranches, trees are felled and burned for direct conversion to pasture, while in smaller scale systems such as agrarian settlements, pastures may be planted in succession after one or two annual crop cycles (Börner *et al.* 2010). Timber is frequently exploited prior to the initial conversion; the proceeds therefrom assist in financing the clearing operation. Land rents associated with access to roads and urban areas are among the principal determinants of the velocity of forest conversion to pasture (Reis 2017).

Despite recent advances, cattle ranching in the Amazon still shows low technological indices. Therefore, the investment in innovations to promote livestock intensification, considering the diversity of climate and soils, is a fundamental question. Most cattle operations are carried out on extensive pastures planted after slashing and burning original forests. Pastures are fenced with barbed wire on their perimeters, but pasture rotations are not commonly practiced. Stocking rates are commensurately low, averaging 1.1 head/ha in Mato Grosso, a level that is common in the Center-West and Amazon basin as a whole except for Acre and Rondônia (IBGE 2018a), possibly due to the relatively recent settlement of the latter states, and their greater predominance of more intensive smallholdings and greater prevalence of dairy production among such farms. The greater stocking capacity of these latter states may also be explained by their relatively higher proportion of planted pastures in comparison to other states in the region (Valentim and Andrade 2009).

Pasture area in the State of Mato Grosso increased from 1985 to 2005; after this period, the tendency was to maintain the total pasture area, with a small reduction in the area of pastures in the state between

[10] The TerraClass data (INPE 2014) show that around one-third of previously deforested land is in the process of secondary forest regeneration, which bodes positively for ecosystem service rejuvenation in the long run. Only about 5.9% were converted to cropland. See: http://redd.mma.gov.br/images/gttredd/alessandragomes_terraclass.pdf.

2011 and 2017 despite the continuing increase in herd size as shown in Figure 4. Between 2008 and 2017, the significant conversion to agriculture of an additional 8.2 million hectares in the state can explain this reduction in pastures which had previously occupied those lands (MapBiomas 2019). Such substitution did not occur without leakage to other countries and non-forest regions; however, the recent literature suggests that much soybean expansion was accompanied by cattle intensification (de Waroux 2019; Schielein and Börner 2019).

Farmers are widely adopting practices of low consumption feed supplementation (soy-maize-minerals mixtures) of animals grazing pastures. This strategy is used to overcome pasture shortage during the dry season and to speed animal growth before confinement. It is also reported that smallholders in rural settlements have adopted a strategy of overstocking of pastures to augment the number of animals they may be able to market as a basis for accumulating resources to purchase additional lots.

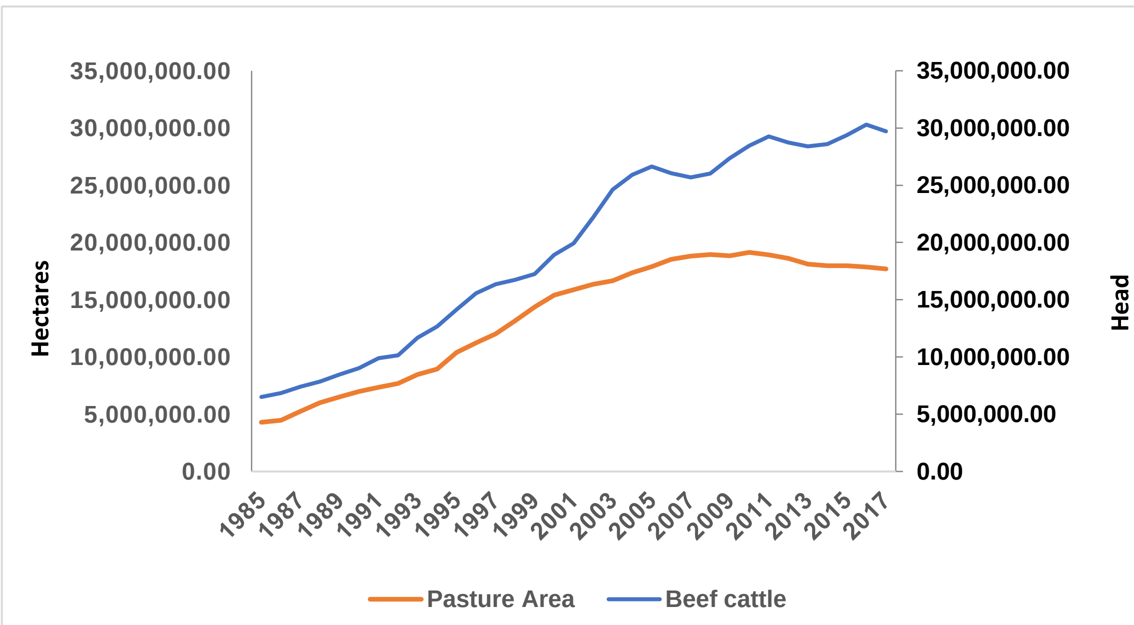

Figure 4: Historical series of planted pasture area (hectares) and beef cattle (head) in Mato Grosso: 1974-2016. (Sources: MapBiomas 2018, IBGE 2018b).

Although stocking rates have not increased significantly in pasture-based cattle operations, as part of an intensification process underway in Brazil, cattle finishing in feedlots (‘*confinamentos’*) has begun to flourish. The increase in feedlot technology to fatten cattle with shorter slaughter time, in the last twenty years in Brazil has grown from 3.9 million to 5.26 million head in intensive systems (IBGE 2018a; Figure 5); estimated at 12.6% of all cattle raised (ABIEC 2019). Most such feedlot operations are combined on the farm with extensive grazing in pastures and are thus more accurately termed ‘*semi-confinamento*’.

Since 2010, this increase was particularly notable in the Legal Amazon, though the growth in feedlots in the Amazon biome was restricted to parts of Mato Grosso, Pará and Rondônia (ASSACON 2018). This process began in the early 2000s in Mato Grosso, expanding only much more recently into neighboring Pará and Rondônia (Vale *et al.* 2019). The state of Mato Grosso now has the largest confined herd in the country, with approximately 1.2 million head (Barbosa *et al.* 2015), and where slaughter of such confined animals accounted for 25% of all animals processed in 2012 (ASSACON 2012). These data may help to explain the relative flattening of the herd and pasture growth curves (Figure 4). Many properties with feedlots also produce their own feed or buy from neighboring farms, so they are also closely linked to expansion in the soy-maize complex (Vale *et al.* 2019).

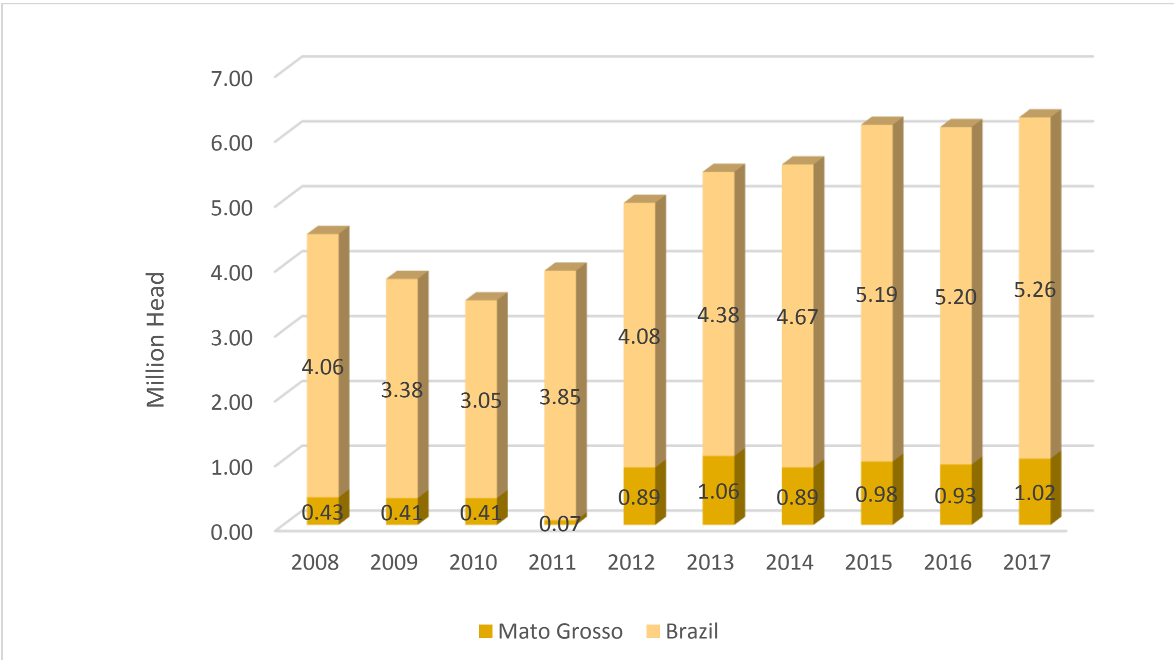

Figure 5: Cattle in feedlots, Brazil and Mato Grosso 2008-2017 (million head). **Source: Athenagro; IBGE, 2017.**

Slaughterhouses and risk of deforestation

The extensive growth in slaughter capacity in the Amazon region has played an important role in stimulating cattle herd growth and consequent expansion of the agricultural frontier. According to surveys by the Instituto do Homem e Meio Ambiente na Amazônia (Imazon) (Barreto *et al.* 2017), of the 157 slaughterhouses registered in the Legal Amazon region, 128 plants operated by 99 companies were active in 2016. Slaughterhouses registered with the federal inspection system (SIF) in Brazil, are permitted to conduct interstate and overseas sales. Those registered under SIE are permitted to sell only within each state but constitute the greatest share of the cattle herd in the region. Based on the average capacity per slaughterhouse (SIF and SIE) of 181 head per day, derived from pastures on an estimated 390 thousand farms with a herd of 79 million head, their demand represents 93% of the total herd of the Legal Amazon.

Slaughterhouses operate in most of the areas in which deforestation has exceeded maximum acceptable levels in the Amazon region, representing 88% of the total areas embargoed by IBAMA for environmental noncompliance.[11] Such areas stand out in the occurrence of deforestation between 2010 and 2017 as posing greater risk of deforestation in coming years (Barreto *et al.*, 2017), thus exposing all actors in the

[11] In accordance with the Term of Adjustment of Conduct (TAC) signed with major slaughterhouses (see Box 1).

value chain to continuing and potential risk (Feitosa 2018). The municipalities that comprise 80% of areas embargoed by Ibama up to April 2018 in the Amazon region were primarily in Mato Grosso.

Despite the risks of expanded agricultural activity and output, deforestation in the southern Amazon declined significantly from 2005-2012, leading many observers to proclaim a "decoupling" of agricultural production growth from deforestation (Macedo et al. 2012). However, this tendency appears to have been attenuated since 2012 (see Figure 6). An additional factor associated with deforestation is the degree to which agricultural and pasture expansion advance at the extensive forest frontier. Despite an increase in required forest protection on private lands in the Amazon from 50% to 80% of each property by area, the Amazon biome as a whole has lost over 20% of its original forest cover, and deforestation is no longer on an abatement trajectory. Further discussion of the issues associated with cattle ranching, slaughterhouse expansion and deforestation may be found in Box 1.

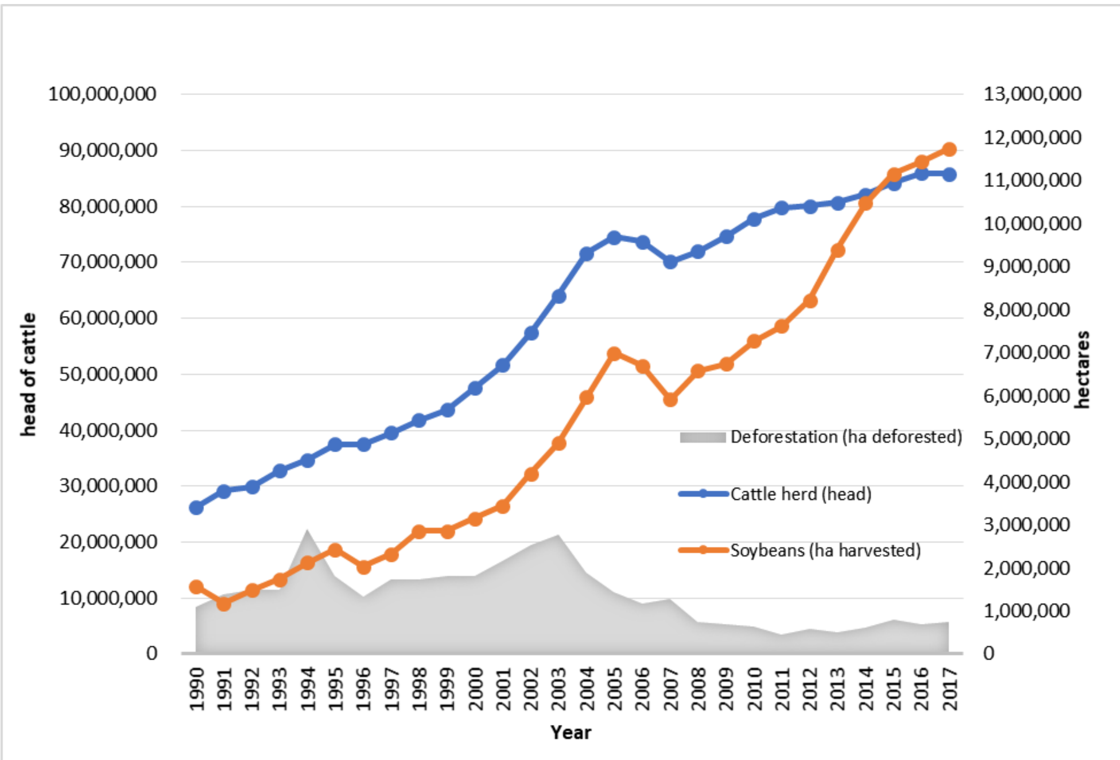

Figure 6: Cattle herd, area of soy harvested and annual deforestation in the Legal Amazon: 1990-2017. Sources: IBGE (Produção Pecuária Municipal; Produção Agrícola Municipal). INPE/PRODES.

Box 1: The 'Slaughtering the Amazon' Campaign and Its aftermath

In 2008-2009, expansion in the livestock industry became a *cause célèbre* as the principal culprit in Amazon deforestation, leading to campaigns by several leading NGOs, including Greenpeace ("*Slaughtering the Amazon*"; Greenpeace 2009) and Amigos da Terra-Amazônia Brasileira ("*The Cattle Realm*" and "*Time to Pay the Bill*"; Smeraldi and May 2008, 2009). These campaigns revealed that significant public credit had been extended to support ranching and slaughterhouse expansion. NGOs discovered that the National Economic and Social Development Bank (BNDES) had provided nearly R$ 6 billion in long term credit to Bertin, JBS/Friboi, Marfrig and several other meatpackers in 2008 alone, that permitted them to buy out overseas competitors. Brazilian corporations through this means acquired controlling interest in several multinational conglomerates in the USA and Australia, and soon dominated global trade in meat and meat products.[12]

These revelations reinforced legal action by the Public Prosecutor's office in the Amazon state of Pará that led to an embargo on beef sales by several major slaughterhouses and supermarkets that purchased cattle and beef from ranches that were not compliant with the national Forest Code, some of which were also accused of labor practices resembling slavery. As part of the Term of Conduct Adjustment (TAC) signed by the slaughterhouses, plants were required to ensure environmental compliance by the cattle producers that supply them over a relatively short period.

In the decade since these 2009 legal actions, only partial success has been observed by slaughterhouses in responding to the TAC and Greenpeace campaigns. Although they brought an immediate drop in deforestation rates, since the largest slaughterhouse groups had committed themselves to restrict purchase of animals to farms that had not deforested new areas after 2009, by 2012 these rates began to rise again. In some cases, this occurred due to leakage: ranchers discovered they could transport their cattle to neighboring properties to continue the process (Barbosa *et al.* 2017). Other difficulties were found associated with indirect purchases of animals from noncompliant farms that sold animals for fattening to other properties.

Frustrated with the limited results, the Public Prosecutor launched a national campaign with consumer groups to press for improvement in production practices. In response to this critical pressure, slaughterhouses and ranchers' associations organized a Working Group on Sustainable Ranching (GTPS) that seeks to establish industry norms for sustainable beef origin.[13]

Some additional initiatives were taken by slaughterhouses themselves to inform the origin of the animals. In 2014 Mafrinorte deployed a site with a traceability tool that indicated the year, month and date of suppliers. Marfrig offers the list of its suppliers,[14] when filling in the SIF number of the plant and the date of slaughter, the name and municipality of the supplier appears. In addition, JBS has two verification mechanisms. The QR code, on the packaging of the brands with the list of suppliers that can be accessed by a smartphone and a website,[15] through which the consumer can access the list indicating the SIF number of the plant and date of slaughter. Grupo Pão de Açúcar's retail chain is using a system to track the origin of beef and promises in the short term to have 100% of its beef tracked, considering animals from birth to slaughter (Barreto *et al.* 2017). Further discussion of beef tracking is provided in the section on supply chain certification.

2. *Soy-maize systems*

Brazilian soy production arose in the 1940s in temperate southern Brazil on small farms in rotation with wheat. Starting in the 1970s with technical support from Japan to EMBRAPA to develop tropical varieties adapted to the savanna, soy began to migrate to the Cerrado biome, which today produces 60% of the national crop. Brazil's soy output topped 116 million tons on 35 million ha in 2018, becoming the largest

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[12] It was recently discovered through the "Carwash" operation by the Public Prosecutor in Paraná that JBS and other meatpackers had colluded with political parties to provide kickbacks to public figures (including then president Temer) in return for such public largesse to fuel their international expansion. JBS has consequently been forced to return billions to the public purse and to sell off a number of its foreign acquisitions to do so. (*The Economist* 2017).

[13] http://gtps.org.br/

[14] https://rastreabilidade.marfrig.com.br/Gado Legal /

[15] http://www.confiançadesdeaorigem-jbs.com.br/

global producer of soy, having passed the US in 2017, with markedly higher levels of productivity and protein composition. Figure 7 shows the current extent of soy production in Brazil, illustrating the growing concentration in the Center-West region.

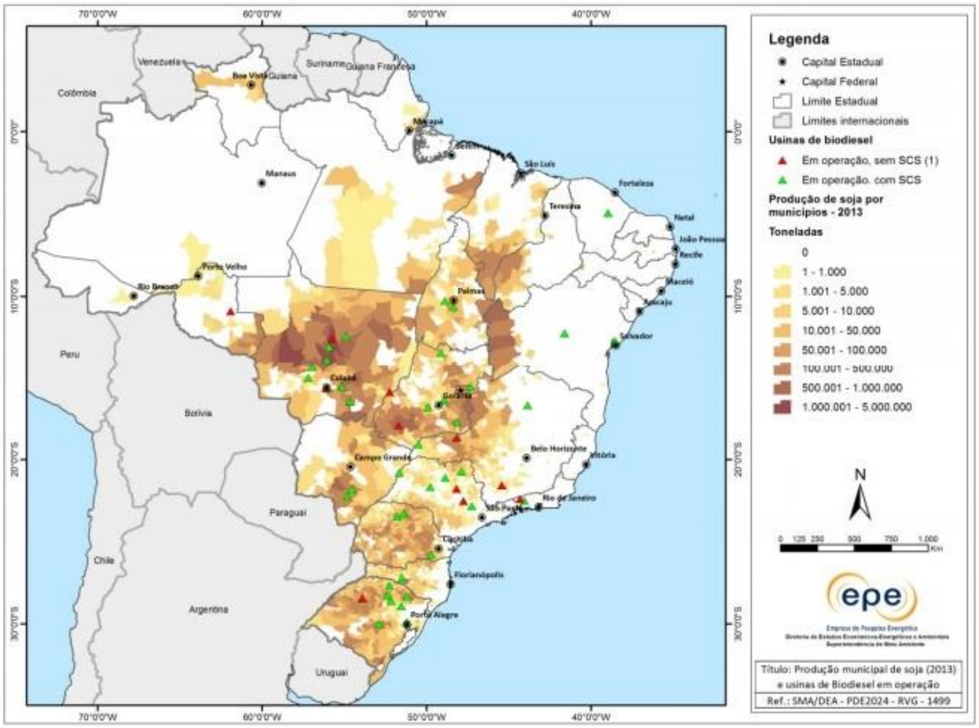

Figure 7: Soy production in Brazil and biodiesel plants in operation in 2013. Source: EPE (Selo Combustível Social), based on IBGE data.

Productivity enhancement was the major source of growth in income in Brazilian grain production, according to MAPA (2017). From 1976 to 2017, soy productivity increased 94% overall (CONAB 2018, Figure 8).

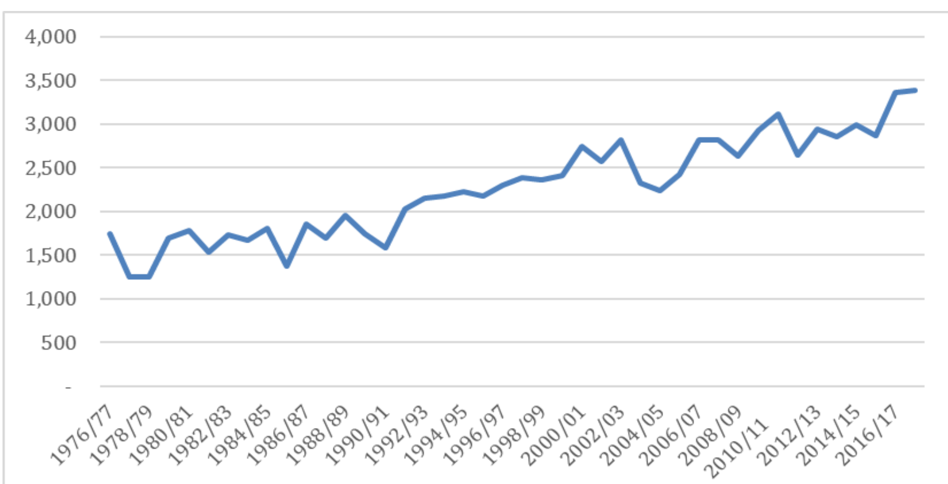

Figure 8: Productivity of soy in Brazil, in kg/ha: 1976-2017. Source: CONAB 2018.

The soy-maize rotation has been practiced since the 1970s in southern Brazil and is now the predominant cropping system in the country, with soy planted during the principal growing season and maize planted in rotation in the "*safrinha*" short growing season immediately post-harvest. The benefits of the safrinha rotation include several factors: increased income from the same crop field, synergetic use of soil nutrients remaining after soy harvest, increased ground cover and organic matter residues for no-till cultivation and reducing plant pathogens and weeding costs (Ferreira 2015). However, with continuous soy-maize rotations beginning to show signs of declining productivity (the additional crop forced farmers to plant ever more precocious varieties and to harvest prior to maturity), agronomists have begun to promote intercrops, diversification, leguminous pasture grasses or cover crop rotations.

Soy-maize systems cultivated in the cerrado areas of the Legal Amazon region are often over 1,000 ha in planted area. According to the 2017 Agricultural Census, the mean area in soy per establishment in Mato Grosso was 1,237 ha, far larger than that of any other soy producing state in Brazil, suggesting high enterprise concentration. Other states in the Amazon also exhibit smaller areas under soy. A 2010 study by the Mato Grosso State Institute of Agricultural Economics (IMEA) found that economies of scale reward large farmers primarily due to discounts in input cost and reduced per hectare administrative costs (IMEA 2010). Mato Grosso, despite being the largest producing state also has the highest costs of inputs in Brazil due to transport logistics. Solutions found for this problem include further industry concentration, use of non-Genetically Modified (GMO) varieties to obtain a price premium and the increased adoption of integrated crop-livestock-forestry (ILPF) systems (Garret *et al.* 2013; Cortner *et al.* 2019).

GMO crop cultivars began to gain in prominence in 1997, when the National Technical Biosafety Commission (CTNBio) authorized field tests for research purposes with transgenic soy. After several judicial procedures and technical discussions, in 2006, commercial GMO soy plantations were officially approved. Since then, planted area in transgenic varieties has grown, from 2.6% of planted soy in 1998, while in the last crop (2017/2018), the value recorded was 97.1% (Céleres 2018, Figure 9). A small and fluctuating part of the Brazilian harvest is non-GMO, which sporadically fetches higher prices in some global markets, suggesting that the promising option initially pursued by segments of Brazil's agroindustry of securing a permanent niche market for non-GMO soy was overwhelmed by market tendencies and inadequate certification infrastructure (Van Wey and Richards, 2014).

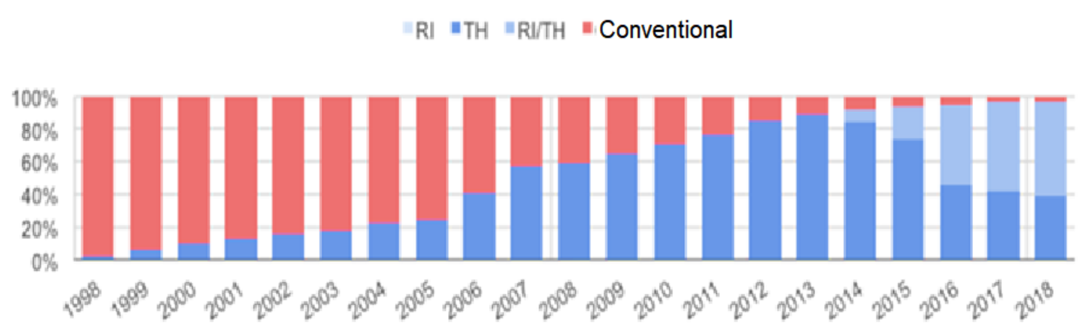

Figure 9: Adoption of biotechnology in soy in Brazil. Source: Céleres 2018.
RI = GMOs designed for resistance to insects; TH = GMOs designed for tolerance to herbicide; RI/TH = GMOs designed for resistance to insects and herbicide tolerant; Conventional = non-GMO

Much of the soy produced in Brazil have been destined for overseas markets as feedmeal after crushing for oil extraction (a co-product serving primarily domestic demand), but increasingly soy is exported as grain for processing overseas, a substantial share of which has been absorbed by China. In the 2016/17 harvest, 56.5% of all soy produced in Brazil were exported as grain (Lemos *et al*. 2017).

According to the 2017 Agricultural Census, soy is grown in Mato Grosso on slightly over 7 thousand establishments, while maize is produced on over 9 thousand properties; as we have seen, the majority of maize is produced in rotation with soy. Both the state's soy and maize output constitute 29% of the total national production of these two crops. The area planted to soy in the state was 8.7 million ha in 2017, as compared to only about half that area (4.8 million ha) in maize, while soy output totaled 29.2 million t, and the maize harvest was 28.5 million t. Soy productivity was on a par with that of the entire Center-West region, at 3.4 tons/ha, while maize yields were over 5.9 t/ha, also at a par with the regional yield rates (IBGE 2018a).

To operate at this scale, soy-maize farmers are fully mechanized. They often employ precision agriculture to optimize returns. They typically finance their crops through the public credit system, though other finance channels are increasingly important, suggesting that measures to enhance production practices to combat external costs could be leveraged by due diligence procedures in place in the finance system.

Deforestation and soy expansion

In order to reduce deforestation rates and meet the demands of the external market actors increasingly concerned that soy was advancing into the Amazon frontier, the Soy Moratorium, an environmental pact initiated in July 2006 has played a significant role. Through this agreement, the Brazilian Association of Vegetable Oils Industries (ABIOVE) and the Brazilian Association of Cereal Exporters (ANEC) committed to avoid the marketing or financing of soy produced in areas that have been deforested in the Amazon biome after this date (ABIOVE 2019; Gibbs *et al*. 2015, see Box 2).

There has been a significant decline in direct soy-related deforestation in areas subject to monitoring. According to the most recent report of the Soy Moratorium (ABIOVE 2019), deforestation underwent a drastic reduction in the 95 municipalities monitored in the Amazon biome (Figure 10). Looking only at the portion of the Amazon in which 97% of soy is grown (89 municipalities with more than 5,000 ha of soy each), only 5.8% of the new soy area during the period in which the Soy Moratorium has been in effect was in lands deforested during this period. It should be alerted, however, that many of these municipalities were included in those embargoed by the Ministry of the Environment as the most severe sources of deforestation in the Amazon region, subject to credit restrictions and fiscal restraints. The partners engaged in the monitoring of the Moratorium contend that the effectiveness of mechanisms to combat deforestation in the Amazon was greater in those municipalities subject to its monitoring than other municipalities subject to similar command and control strategies exerted over this period (ABIOVE 2019: p. 9). Nevertheless, deforestation for soy cultivation in areas in disobedience with the Moratorium has increased over the past several years, representing a cumulative total of 64,300 ha throughout the Amazon biome.

Even with this apparent success in restricting deforestation directly attributable to soy expansion in the biome, it is important to note that, since the beginning of the Moratorium, the area planted with soy in the Amazon biome has more than tripled, from 1.14 million ha (Mha), in the 2006/07 harvest, to 4.7 Mha in the 2017/18 harvest, which corresponds to 13.3% of the 35.1 Mha of national territory occupied with soy (ABIOVE, 2019: 20). Although they are not directly associated with deforestation, soy occupancy in these areas in many cases implies the transfer of their impacts to other areas, taking into account that many areas occupied by soy were previously used for cattle grazing. Herds displaced by soy expansion may be taken to new pastures within the same biome, so contributing to additional deforestation. However, recent econometric studies point to greater intensification as a result of such displacement rather than further deforestation in the Amazon (de Waroux *et al.* 2019).

Part of the horizontal cropland expansion appears to have occurred outside of the Amazon, as much new soy production occurred in the so-called Matopiba region in the Brazilian cerrado. In cerrado areas of Maranhão, Piauí and Tocantins alone, the area planted to soy grew from around 150,000 to 2.2 million ha in the past 20 years (IBGE 2018a). But in the same period, several states in the Amazon biome itself also began to report soy planting where there had been next to none before (Amapá, Roraima, Pará and Rondônia) and Mato Grosso led the national soy expansion with an additional 7 million ha, more than half of which arose after the short-lived "decoupling" wishfully described by Macedo *et al*. (2012).

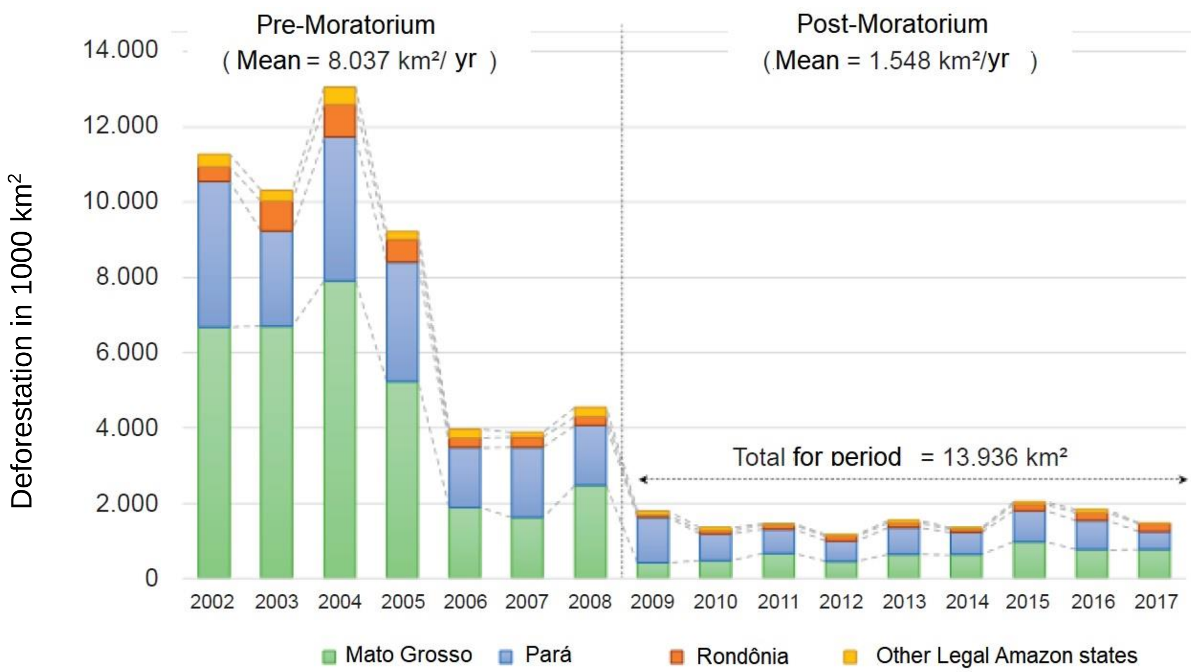

Figure 10: Hypothetical policy impact of Soy Moratorium on deforestation (in 000 km²) in 95 municipalities of the Amazon biome region monitored by the program from 2008-2017. Source: ABIOVE 2019; translated by the author.

3. *Interactions between eco-agri-food systems*

The two eco-agri-food systems under study intersect in land use transition: soy-maize usually follow cattle ranching in opening forest frontiers. In many areas such systems now coexist on the same farms, while soy-maize provides feed to more intensive feedlot and semi-confined livestock production. Integrated Crop-Livestock-Forest (ILPF) systems have recently been promoted to increase productivity and diversify production systems with purported environmental benefits. Estimates are that ILP or ILPF systems have grown dramatically and now occupy over 11.5 million ha in Brazil; in the Amazon, such systems have no forest component, employing pasture-soy rotations alone (Amazonia 2018).[16] Both livestock and soy-maize also produce feedstocks for a burgeoning biofuels industry. The growth in maize production closely linked with soy expansion has permitted the development of maize-based ethanol enterprises in Mato Grosso. Since much of the maize production occurs in rotation during the *safrinha,* this development does not appear to imply more significant pressure for deforestation but will tend to lead toward further substitution of pasture by cropland and tree plantations to provide energy for distilleries.

Box 2: Soy Moratorium and deforestation in the Brazilian Amazon[17]

Soy crops are implicated in deforestation pressures in Brazil (Macedo *et al.* 2012). These pressures were the subject of a major campaign by Greenpeace entitled "*Eating up the Amazon*" (Greenpeace 2006) denouncing the contribution of soy expansion to progression of deforestation. This campaign was widely publicized and targeted the large agri-food companies that controlled the bulk of exports (Cargill, ADM, Bunge and AMaggi) as well as banks (IFC and European banks). They also targeted the main actors of the European meat sector, including fast food chains and traders. The action took place at the end of a period of major agro-industrial expansion in Brazil, at a time when some governmental measures against rampant deforestation had been undertaken (Nepstad *et al.* 2014), but NGOs found these measures insufficient to bring significant reduction in forest degradation. Supporting the narrative was robust scientific evidence from satellite monitoring systems showing large-scale conversion of forest to soy between 2001 and 2006. This evidence was instrumental in recruiting major retailers such as McDonald's to act and sign the first zero-deforestation agreement in the tropics.

As a result of this campaign, and with the help of low prices at that time, the change in the power relationship gave birth to a renewed dialogue between the major stakeholders of the industry (led by the oilseed crushers' association ABIOVE), the government and NGOs (Cooper 2009). This resulted in the first historical example of voluntary industry-wide individual commitments to a "zero deforestation" policy, known as the "soy moratorium". Monitoring systems able to identify violating farms facilitated enforcement of the policy and reported a high compliance level (Kastens *et al.* 2017*,* Rudorff *et al.* 2011).

This wholly voluntary measure is now considered one of the decisive factors in securing broader agricultural sector commitments toward reducing the deforestation of the Amazon. Nevertheless, proposals for termination of the moratorium to pass control to government regulation after ten years were considered premature, due to the need to resist the surge in deforestation that has been associated with the persistent Brazilian economic and political crisis (Gibbs *et al*. 2015).

[16] In 2016 Brazil registered 11.5 million hectares with some integrated system. 83% of this area was in integrated crops and pasture (ILP), 9% also included tree planting (ILPF), 7% in pasture-forest (iPF) and 1% in crop-forest (iLF).
[17] Adapted from TEEBAgriFood (2018), Ch. 9.

Furthermore, the current overall effect of these commitments on the transformation of practices and ultimately on deforestation and working conditions are still uncertain. Recent fieldwork by researchers in Pará have found that soy continues to expand into forested areas around Santarém despite commitments by Cargill and other traders which have invested in port facilities in the area (Nirvia Ravena, personal communication 2018). Other fronts of soy expansion include the BR-136 corridor between Cuiabá and Santarém, the so-called "southern tier" of municipalities in southwest Amazonas and eastern Rondônia.

2. SCOPE OF RESEARCH FOR MATO GROSSO TEEB FRAMEWORK TEST

1. Scope of case study research

This case study is concerned primarily with the prevalence and means to overcome bottlenecks to internalization of environmental values in the beef and soy chains originating in the Legal Amazon, be they caused by price policies of buyers, technical assistance or credit provision, among other factors. Key issues identified during the scoping and literature review for this study include:

1. <u>What factors motivate a conversion from 'conventional' to 'good practices'?</u>

At present no conditionalities are incorporated in public subsidized credit instruments (i.e., Harvest Plan), except those included in the still negligible ABC Plan. The perspective to reach more discriminating markets affected by changing consumer demands is clearly a factor in the decision by some soy producers to return to non-GMO ('conventional') practices. Others are attracted by the promise of improved productivity or profitability, though initial investments are required (e.g., conversion from conventional tillage to NTS soy production, now universally adopted). Rural technical assistance is widely cited as necessary to mobilize small producers in the direction of change, but credit takers are restricted to an approved "package" of inputs and production techniques, as well as being required to put up their land as collateral. Many financing arrangements are conducted via direct contract with traders using either so-called 'barter' schemes to trade inputs for products (Johann *et al*. 2016) or '*cédula de crédito rural*'[18] (rural credit certificate) which also constrain producers within approved input packages. The role of rural land markets, speculation and privatization of closing frontiers should also be identified (Sparovek *et al.* 2019).

2. <u>What externalities are currently internalized by at least some actors in value chains and which remain "invisible"?</u>

In accordance with the Moratorium, soy expansion was to be restricted to areas already deforested, yet soy has expanded rapidly into former pasturelands, thus bringing indirect deforestation. No-till crop production has been touted as reducing soil erosion, sequestering carbon and (in combination with herbicides) improving productivity. However, weeds are becoming resistant to glyphosate, so the efficacy of GMO-based technology may be questionable in the long-term. A small number of ranchers have adopted a set of 'good production practices' (*Boas Práticas Agropecuárias* - BPA) technologies promoted by Embrapa (Valle 2011), incentivized by offers of technical assistance and joint venture investment

[18] http://gestaoeconsultoria.blogspot.com/2012/12/cpr-o-que-e-cedula-de-produto-rural-e.html

(PECSA 2019a) but most resist. Slaughterhouses (partly in response to TACs) and supermarkets (e.g., Carrefour) have also sought methods to trace animals and reward best practices.

3. What change in rural credit terms might incentivize sustainable intensification?

One of the most prominent measures in place in Brazil is the inclusion of the property in and compliance with the requirements that of the Rural Environmental Registry (CAR) that was designated as a precondition for credit concession in 2015,[19] although the trigger to condition credit more extensively on the CAR has been delayed repeatedly since then. This instrument would act in combination with other measures such as the low carbon agriculture plan to incentivize environmentally suitable practices. The scale of such measures is insufficient to mobilize the significant transformation needed, suggesting the need for revamping criteria for the overall public credit system under the *Harvest Plan.* Such financing is deemed necessary to motivate adoption of best practices (Coalizão 2018; Carbon Trust 2015; Financial Times 2018), yet no such credit policy instruments complementary with the new Forest Code have yet come into force. Based on these scoping issues, it was determined to place principal emphasis on overcoming barriers in the financial markets and public credit policy, which may be instrumental in nurturing a transition toward eco-agri-food systems in the chains under analysis.

Box 3: Sustainable intensification of agricultural production practices: land sparing or land sharing?

Over the past decade a debate has arisen in the literature on food production around the relative desirability for nature conservation to promote either a "land sparing" or "land sharing" approach (Phalan *et al.* 2011). A strategy oriented toward land sparing would focus its efforts on increased productivity to avert high rates of land use change and shield endangered species from pressure. Land sharing, in contrast, would investigate land use alternatives that combine agricultural and livestock production with biodiversity conservation on the same piece of land, or in the "productive landscape" (Scherr and McNeely 2008), securing commitments from producers to adopt biodiversity friendly practices. Either strategy would be compatible with concepts of sustainable agricultural intensification advanced by Pretty (2018) and others.

In Brazil, intensification has been heavily promoted in the case of livestock practices as a means to avert deforestation and consequent biodiversity loss (Dias Filho 2011; Latawiec, *et al*. 2014; Silva *et al*. 2017). Despite the potential reduction in deforestation associated with pasture and herd improvement, environmental risks associated with intensification can arise from waste disposal and inattention to animal welfare. Rapid growth in cattle feedlot operations in Mato Grosso, and more recently in Pará and Rondônia, fuel such concerns, while intensification can also provoke expanded demand for feed grain production which may neutralize deforestation avoided through this practice; extensive livestock grazing practices may "leak" to frontier areas once intensification takes hold.

On the other hand, Macedo *et al*. (2012) document an apparent decoupling of soy output from deforestation in the southern Amazon in consequence of intensified production on already cleared properties rather than cropland expansion, spurred by the Soy Moratorium. Yet, an analysis from 1988 to 2017 shows that a doubling in soy yield was accompanied by a three-fold increase in harvested area in Brazil as a whole (Soares-Filho and

[19] http://www.fazenda.gov.br/noticias/2015/junho/cmn-altera-normas-de-credito-rural-e-taxas-de-financiamento-de-fundos-constitucionais

Rajão 2018), suggesting that intensification led to increased competitiveness in a growing global market rather than land sparing.

Recent transformation of over 11 million ha of soy operations in Brazil to so-called Integrated Crop-Livestock-Forestry (ILPF) intercrops or sequences emphasizes land sharing, since the sequencing would promote synergies in nutrient provision, while partial shading of pasture could improve animal welfare as well as enhance milk and beef production. But these systems would also permit both crop and livestock intensification since at least hypothetically, these systems can increase soil micro-organisms, water infiltration, reduce runoff and erosion, and provide greater and more diverse outputs. Nevertheless, since the forest component of the ILPF intercrops underway is restricted to an estimated 17% of the total area under integrated production, and is primarily composed of exotic species, ILPF is unlikely to provide substantial biodiversity benefits, and could even be another source of simplification and native forest substitution. How biodiversity and ecosystems will fare over time under ILPF has not yet been appraised, though some experiences in native forest species plantation have been catalogued as a basis for further dissemination (Batista *et al.* 2017).

In broader landscape-based appraisal in the Cerrado, Pompeu *et al*. (2018, p. 1) found a positive relationship between land sharing and human population, suggesting contexts under which "joint agricultural activities and human presence may favor biodiversity conservation." Such results bespeak the need for a territorially amplified landscape perspective in managing rural resources for a combination of production and protection (Scherr and McNeely, 2008). However, studies such as those by Phalan et al. (2011) noted markedly higher overall rates of biodiversity impoverishment under land sharing case studies in other regions. Such predictions have prompted recommendations on land-sparing through expansion in protected areas and enforcement of the national Forest Code rather than land sharing to conserve biodiversity and ensure provision of ecosystem services (Soares-Filho and Rajão 2018).

1. Agricultural and livestock intensification in the Amazon region

Changes in production systems to promote increased productivity and greater environmental sustainability can be characterized by the movement toward intensification of agricultural production systems (Pretty 2018). In this context, a great opportunity for Brazil is the challenge of expanding agricultural production without promoting the expansion of the area currently used, intensifying land use and increasing productivity (Strassburg *et al*. 2015; See Box 3).

1. Livestock intensification

In Brazil, although cattle ranching is one of the main factors responsible for continuing expansion at the agricultural frontier and also the main source of GHG emissions, it is also the sector with the greatest margin for implementing improvements in its productive system. (Piatto *et al*. 2018). Traditional livestock farming has proved to be both economically and environmentally inefficient. Currently the activity occupies 75% of the deforested area in the Amazon but generated less than 3% of the national GDP in the last decade (Strassburg *et al.* 2015).

Livestock expansion has taken place in all regions of the country, with emphasis in recent years in the Center-West (Cerrado) and North (Amazon) regions. The recent dynamics of occupation of productive areas, however, shows an increase in area under crop production to the detriment of pastures. Considering the annual increase of the bovine herd and the reduction in pasture areas, an increase of productivity in cattle production would be needed to avoid further deforestation at the frontier. In recent years, environmental and market pressures, as well as the increase in the availability of technology (techniques for restoration and management of pastures, launching of more productive cultivars of grasses, genetic improvement of the herd, etc.) have encouraged a change of attitude in the nation's meat and dairy sector (Dias-Filho 2014) leading to increased beef yield from 1.7 to 4.5 @/ha/yr (Figure 11).

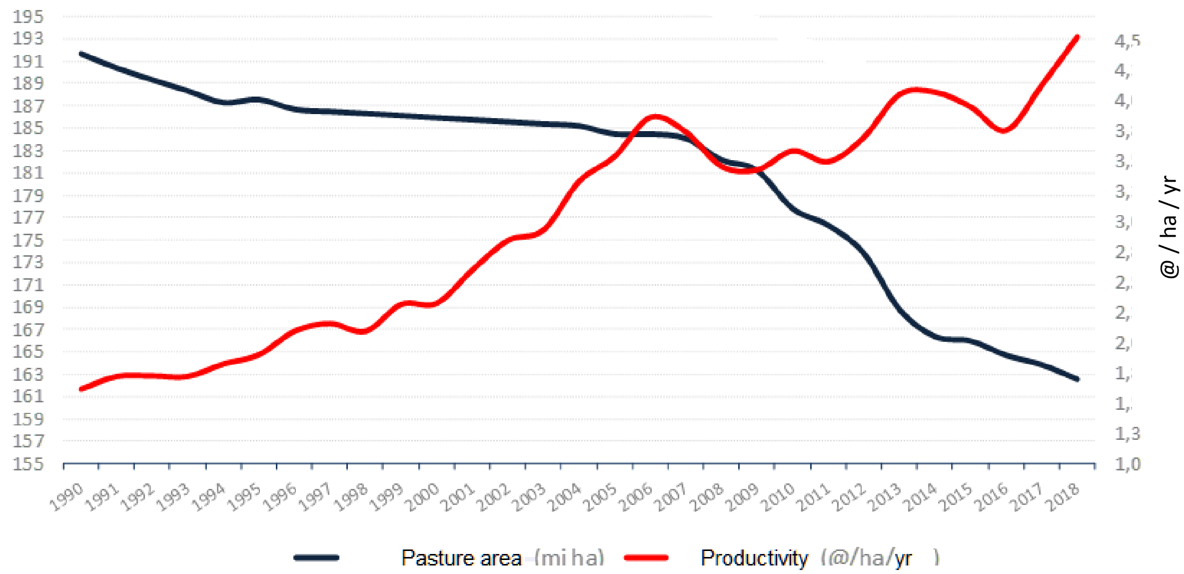

Figure 11: Evolution of pasture area and herd productivity in Brazil: 1990-2018. Source: Nogueira (2019).

The intensification of livestock systems is characterized by a change in the livestock production model. This change begins with the implementation of a set of good production practices (Valle 2011), the restoration of degraded pastures or areas with low capacity of support, the environmental suitability of the systems with the requirements of protection of permanent preservation areas (APP) and in the implantation of systems of pasture rotation in combination with the principles of animal welfare. The intensification aims at increasing productivity, and number of animals grazed per ha, while meeting environmental requirements in accordance with current legislation.

This dynamic denotes socio-cultural changes and brings both environmental and socioeconomic impacts. Socio-cultural impacts are related to labor relations as well as to concerns such as deficient business management; the lack of land use planning, resulting in the choice of areas with low agricultural potential or having environmental constraints; and extreme risk aversion, which leads to the option for extensive cattle raising.

In 2009, with the emergence of the Sustainable Livestock Working Group (GTPS), those involved in the beef cattle value chain launched discussions on the concepts and principles that guide the sustainable livestock model in Brazil, through the dissemination and promotion of good practices and promotion of a Guide of good practices for sustainable livestock ranching (GTPS 2016).

Efforts to promote changes in cattle production systems in the Brazilian Amazon have occurred to date primarily through NGO initiatives, and technical support by EMBRAPA, whose BPA provided technical criteria to guide the shift. Among NGO initiatives, the Novo Campo project in Mato Grosso, executed by the Instituto Centro de Vida (ICV) showed itself effective in converting “conventional and traditional” livestock production practices to sustainable livestock models beginning in 2015. Its results suggest opportunities for achieving positive direct environmental impacts through restoration of degraded areas, respect for APPs, establishment of legal reserve (LR) areas and management of water resources, a fundamental factor for sustainable production. These aspects were documented in Novo Campo field sites on ranches in Mato Grosso centered on the municipality of Alta Floresta (Marcuzzo, 2015) and in the “Sustainable Meat project: from field to table”, carried out under the auspices of The Nature Conservancy (TNC) in municipality of São Felix do Xingu in the state of Pará, as well as in other cases described in considerable depth by Bogaerts *et al.* (2017) and Ermgassen *et al*. (2018).

The increase in livestock productivity is linked to investments in production technology, the diffusion of good production practices and the improvement of livestock indices, such as increased stocking rates and increase of pasture support capacity, animal weight gain, reduction of mortality, increased birth and reproductive rates and reduction of the slaughter age of finished animals. This set of good practices[20] associated with the effort to recover pastures characterizes the current models of intensification of livestock. Strassburg *et al.* (2015; IIS 2015) appraised a set of alternative scenarios affecting the potential for dissemination of such practices in the Amazon biome in Mato Grosso. The current scenario is also characterized by the development of several systems that include the integration of livestock, agricultural and (in some cases) forestry activities. The integration models provide methods for the recovery of degraded areas, mainly pastures, and allow an increase of livestock productivity. This increase would make livestock farming increasingly competitive when compared to isolated agricultural and forestry activities. An increase in per hectare profitability of livestock supports this trend.

The transition from the traditional model to the intensification model

The transition from the traditional model to the intensified and sustainable livestock model considers that the permanent preservation areas (APPs) need to be protected to avoid that cattle watering disturb fragile streambanks, in compliance with the current legislation (Forest Code) and the productive areas need to be transformed toward recovery of pastures in different stages of degradation. The recovery of environmental areas and degraded areas is aimed at the conservation of natural resources (soils, water, plants) by means of soil conservation practices, protection of water resources, plant restoration with native plants, erosion recovery including silting and gullies. The recovery of these areas promotes the preservation of animal and plant biodiversity, through the establishment of ecological corridors and the maintenance of the natural fertility of soils, being fundamental aspects for the production model of an intensive and sustainable livestock.

[20] These included EMBRAPA’s Boa Práticas Agropecuárias da EMBRAPA; BPA Práticas Agropecuárias – Bovinos de Corte (as described in Valle (2011); Protocols of certifiers such as the Instituto de Manejo e Certificação Agrícola e Florestal (IMAFLORA,), IBD, ECOCERT, Certified Humane; and the Guide of Indicators of Sustainable Livestock Management (GIPS) of the Working Group on Sustainable Livestock (GTPS (2016).

Pasture degradation can be defined as the process of loss of vigor, productivity and the natural recovery capacity of the pasture making it unable to sustain the production and quality levels demanded by the animals, as well as to overcome the harmful effects of pests, diseases and invasive plants (Macedo 1995).

According to EMBRAPA and WWF-Brazil (2011), the main causes of degradation include:

1. Areas without aptitude and vocation for pasture formation;
2. Extensive model without pasture division;
3. Fodder species not adapted; forage monocultures;
4. Inadequate soil preparation and planting; lack of soil correction;
5. Use of poor-quality seed of unknown origin;
6. Incorrect management with burning;
7. Stocking above capacity.

The methods of recovery of degraded pastures can be direct or indirect. In direct recovery, renovation of the pastures occurs after mechanized operations, clearing (chemical and/or physical) and replanting. In this method, physical, chemical and microbiological restructuring of the soil is necessary to guarantee the sustainability of the pastures over a long useful life and thus contribute to the reduction of the emissions of greenhouse gases and other environmental impacts generated by the activity.

Indirect methods include renewal through the practice of crop-livestock integration (ILP), using agricultural crops as a rotation in the system, silvopastoral or forest-livestock integration systems, or crop-livestock-forest integration (ILPF). In this alternative the recovery of the degraded areas includes first agricultural land use and later formation of the pasture. Trees may then be planted in Brazil. rows once the pasture is formed to furnish shade and fuelwood.

The vast majority (83%) of the area involved in integrated systems are currently focused on the ILP system, with a total of 17% with some forest component, whether in ILPF, iPF or ILF iLF (Figure 12). The ILPF Network association, a public-private partnership formed by EMBRAPA, Cocamar Cooperative, Bradesco, John Deere, Soesp and Syngenta aims to accelerate a broad adoption of these integration technologies. Initiated in 2012, the network - co-financed by private companies and EMBRAPA - supports 107 Technological Reference units distributed in all Brazilian biomes and involves the participation of 22 EMBRAPA Research Units (EMBRAPA Rede ILPF 2018).

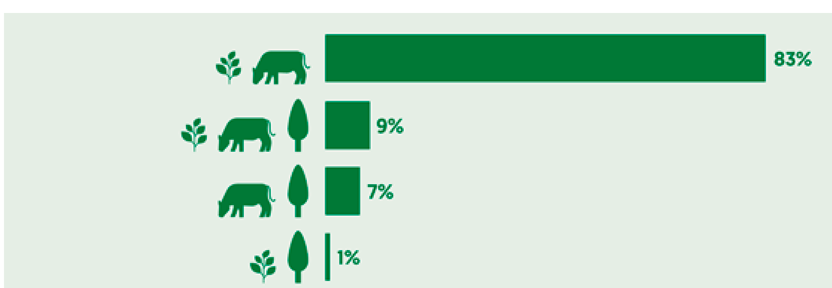

Figure 12: Proportion of areas with integrated systems established: Brazil. Source: Embrapa Rede ILPF (2018).

Environmental and financial results of pilot projects and initiatives

As discussed above, several pilot projects or demonstration units have been developed in the Amazon region over the past decade to evaluate the feasibility of livestock intensification models for more sustainable livestock farming. In addition to pilot projects or demonstration units, several studies, dissertations and theses about livestock production in the Cerrado and Amazon biomes were carried out. These models had in common the recovery of areas of degraded pastures and later implantation of systems of pasture rotation and/or confinement for finishing. Other common points include the evaluation of means to improve the carrying capacity of the pastures to increase stocking rates and the environmental impacts of such intensification, such as greenhouse gas emissions, and effect on water resources (Bogaerts *et al.* 2017; Ermgassen *et al.* 2018). Complementary results have been documented in other countries of Latin America, with emphasis on agrossilvipastoral systems (Acosta *et al.*, 2013).

Initial studies derived from thesis research used simulations to evaluate the effect of increased livestock intensity and feed regimes on GHG emissions. For example, Cardoso (2012), using lifecycle analysis, affirmed that with the adoption of more intensive systems of production, including semi-confinement, there could be a reduction of GHG emissions per unit beef output. This reduction would occur due to the improvement in feed, in the zootechnical indices obtained, in pasture productivity, in the stocking rate and reduction of the average slaughter age. The association between intensification and carbon sequestration by the soil presented an even greater mitigation potential. The use of inputs in the pastures, although they generated greater GHG emissions, were in turn compensated by the sequestration of carbon in the soil (Cardoso, 2012).

In another study (Almeida *et al*. 2010), GHG emissions were estimated in response to improvement of feed quality provided in intensive animal systems. The objective of this study was to economically evaluate the fattening system in confinement in the finishing phases of properties, as well as the changes in emissions derived from the production of animal feed to make cattle for slaughter. The result from calculation of GHG emissions indicated that shortening the age of slaughter of the animals by supplying food with high protein and energy could reduce their emissions by 17% (from 41 kg of CO_2e/kg meat produced to 33 kg of CO_2e/kg meat). Nevertheless, in the economic analysis, the results from confinement suggest the system would be less viable when compared to pasture-based nutritional management of the herd (Almeida *et al*. 2010).

A study conducted by Bogaerts *et al.* (2017) investigated the potential of intensification of livestock production to abate GHG emissions, as well as the economic benefits verified in the field through practices of intensification. Sustainable intensification programs promoting these practices had begun operation to test their application on farm in several states in the Amazon region. The research team was able to survey 40 cattle ranches located in the Amazon biome in five such initiatives to investigate how GHG emissions differed between farms participating in sustainable livestock intensification projects and farms not participating in these programs.

The results of the comparative research by Bogaerts *et al.* (2017) showed that project participants were able to reduce on average 8.3 kg of CO_2e/kg of carcass weight (CW) as compared with non-participating ranches, representing relative emissions reductions of 19%. Farms that had participated in a sustainability program for at least two years showed larger emissions differences: 19.0 kg of CO_2e/kg CW less for participating farms compared to their counterparts, or 35.8% fewer emissions. Key drivers of the total CO_2e/kg CW in all farms were enteric fermentation and manure management. This study concluded that farm-level data support intensification as a possible strategy to reduce GHG emissions per kg of beef produced and suggests that future research efforts should focus on long-term impacts of intensification and expanded metrics for success beyond such emissions. Results compared among pilot schemes surveyed are summarized in Figure 13.

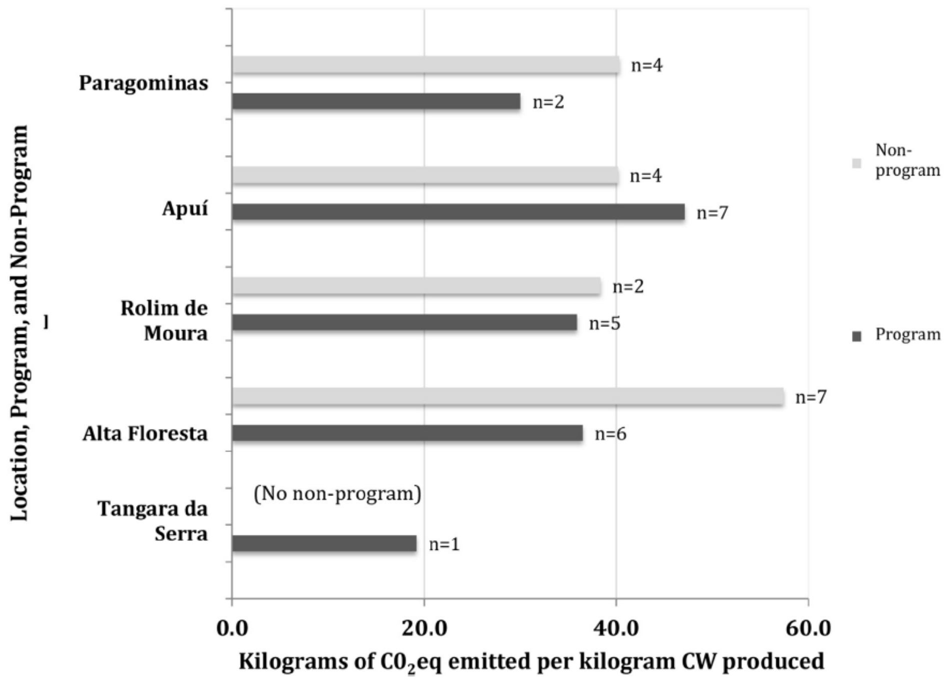

Figure 13: Summary of five livestock sustainability initiatives studied for GHG emissions in the Legal Amazon. **Source: Bogaerts et al (2017).**

One of the earliest of the initiatives surveyed by Bogaerts *et al.* (2017) was the Green Livestock (*Pecuária Verde*) project carried out on six farms in the municipality of **Paragominas**, Pará state, that began in 2011. The project was aimed at increasing the profitability of farms through improved productivity, management skills, animal welfare, safety and well-being of workers, environmental performance (land use planning and restoring illegally deforested areas), and empowering and valuing workers. The properties involved in the project increased their yield from five to 20@ (CW) per hectare-year. This increase in productivity was found to be directly related with improved working conditions compared to farms that were not part of the project in the same municipality (Barreto *et al*. 2013).

The intensification of livestock raising significantly increased farm income in Paragominas compared to low-productivity farms. A farm with the regional average productivity of 5 @/ha resulted in a loss of R$ 38/@ produced or R$ 190 per ha. Farms started to make a profit from a productivity of about 10 @/ha, but with a profit margin of only 4%. Productivity of 15 @/ha would be profitable (R$ 300/ha) but would still be less attractive than renting the land for grain production or for reforestation. Productivity of 20 @/ha would result in an attractive profit of 37%. The yield at around R$ 750/ha would be competitive with other currently available agricultural and reforestation opportunities (Barreto *et al* 2013)

The Novo Campo Program coordinated by ICV in the municipality of **Alta Floresta**, Mato Grosso, from a pilot project from 2012 through 2015, aimed to promote livestock production in the Amazon, improving its economic, social and environmental performance. As a result, it contributed to reduce deforestation, conserve or recover natural resources and strengthen local economies (ICV 2014; Marcuzzo 2015). The interventions promoted by the Novo Campo Program were based on the integrated management of 23 rural properties, with the progressive adoption of Embrapa's BPA for Beef Cattle (Valle, 2011) and the Sustainable Livestock Indicators (GIPS) developed by the Working Group on Sustainable Livestock (GTPS 2016). These are centered on the recovery and intensification of degraded pastures, the adequate supply of feed and mineral supplements, improvement of sanitary and reproductive management of the herd and environmental compliance of the properties. Investments in intensified areas, comprising 10-15% of each property, included pasture reform averaging R$ 1,120/ha (Marcuzzo 2015).

The technical results of the Novo Campo project indicated a perspective to reduce the average slaughter age from 44 to 30 months for males and from 34 to 24 months for females. Animal stocking increased from 1.2 AU per hectare to 1.6 AU/ha overall, and in the intensified areas the stocking rate reached on average 2.7 AU/ha. Productivity increased overall from 4.7 @/ha/yr to 10.8 @/ha/yr, while in the intensified areas the average reached 20.8 @/ha/yr. The economic results indicated an overall increase in profitability from R$ 100/ha/yr to R$ 680/ha/yr (ICV 2016). In addition, the Novo Campo Project promoted an initially estimated 90% reduction in GHG emissions per kg CW produced, 50% in emissions per ha, and increased carbon sequestration in the soil (Ibid). These net GHG emissions reduction estimates from baseline to 2014 were later assessed as between 5% and 60%/ha and between 32% and 86% per kg CW on detailed application of the GHG Protocol Agricultural Tool on five ranches involved in Novo Campo, including emissions from cattle, pastures, urea, liming and application (Piatto and Costa Junior 2016).

Another milestone focused on Alta Floresta was the initiative in 2016 to create the technical assistance company ***Pecuária Sustentável da Amazônia*** **(PECSA)**, as a corporate spinoff of ICV and Novo Campo, with the objective of creating a management model for intensifying livestock production in the region. PECSA enters into management contracts with landowners to conduct technical and economic projects with the mission of implementing animal traceability, ensuring the conservation and recovery of natural resources, reducing GHG emissions, optimizing productivity and quality, and generating positive technical and economic results. Under PECSA management, the productivity of livestock systems in the rearing and fattening stages reached 2.5 to 3.6 head/ha by 2016. Productivity is expected to attain up to 30 @/ha. In 2016 the area under PECSA management included 15,000 ha of legal forest reserve and 355 ha under APP, which were isolated to avoid access by the animals. Altogether the farms involved include an area of 25,000 ha of preserved forests (PECSA 2016).

Measurement of GHG emissions in areas under PECSA management indicated a reduction of 4.8 to 3.0 tons of CO_2e/ha/yr, representing a 40% reduction from the baseline situation. The beef emission intensity was reduced by more than 90%, from 77 kg to 7 kg CO_2e/kg carcass produced (PECSA 2018). After two years of improvements following the BPA for beef cattle, meat production was expected to increase by almost 2.5 times (Piatto *et al*. 2016).

The "Sustainable Meat from Field to Table" (*Do Campo à Mesa*) project on intensification of livestock production, carried out between 2013 and 2016 by TNC on 13 farms on a total area of 40,000 ha in the municipality of **São Felix do Xingú**, Pará. The project incorporated a model for intensification of livestock production that included provision of fences for pasture rotation, placement of water tanks and the recovery of pastures through practices of soil management, nutrient correction, liming and management of pasture rotations. Besides this, the project provided for isolation of 990 ha in APPs to avoid that the animals enter into natural water courses, substituted by the provision of distribution systems to water the animals (Agrosuisse 2016).

The results from the TNC project investment were based on revenues from an estimated 300 kg/ha/yr CW, equivalent to 15 @/ha/yr. The expected internal rate of return on investment was 20% over a 10-year period, including training costs for adoption of best practices. This return is compatible with the 17% found by Maya (2003), for farms in São Paulo, and 19% found by Homma et al (2006) in simulations for similar interventions adapted to conditions in Pará (cited by Silva and Barreto 2014).

Garcia *et a*l. (2017) appraised the transition costs for the intensification of sustainable livestock production the TNC project. The costs of adoption of good practices, recovery of pasture areas and restoration of APPs were included in the analysis. The pasture carrying capacity increased from 1.0 AU/ha to 3.0 AU/ha. The average cost for the transition was US$ 1,335/ha, ranging from US$ 750 to US$ 2,595/ha (TNC 2016; Garcia *et al*. 2017). The internal rate of return and net present value estimates indicated that the proposed intensification approach for sustainable livestock farming was profitable on farms with more than 400 hectares of pasture but not on those whose pasture areas were smaller than 150 hectares (Garcia *et al.* 2017). Projections for the farms involved in the project indicated that after 12 years the emissions generated by increased enteric fermentation and use of fertilizers in the scenario of sustainable intensification would be 1.69 Mt CO_2e which represents twice the emissions generated by a scenario without intensification (0.81 Mt CO_2e). However, these emissions would be offset by avoided deforestation of 5,184 ha in APPs protected by the initiative (over 25% of remaining forest on the properties), which – if converted to pasture –would have generated 1.9 Mt CO_2e in emissions, while the restoration of degraded APPs on 990 ha would lead to sequestration of almost 0.36 Mt CO_2e (Ibid).

This study of sustainable intensification of livestock farming in São Félix de Xingú indicated the potential to mitigate GHG through increased production efficiency associated with higher slaughter weights and lower slaughter age; no tillage; restoration of APPs; and avoided deforestation, but only as a net effect. Other positive results from intensifying sustainable livestock include improving and restoring soils, which can help prevent impacts on water resources. Another important finding of the study is that the adoption of such a strategy with the transition costs estimated by the project would not be financially viable for small-scale farmers with under 150 ha of pasture, including dairy operations (Ibid). Lower cost strategies would be needed to enable such producers to sustainably intensify their production systems, including genetic improvement, technical assistance, privileged market access and establishment of cooperatives.

The costs of transition from traditional livestock to intensive livestock according to the studies analyzed may vary by region. The TNC project reached costs between US$ 750 and US$ 2,590/ha and the reference value of PECSA is US$ 1,041/ha, indicating a large variation. This variation is influenced by the stage of degradation of the areas and the particularities of each region, affecting the relative costs associated with intensification, e.g., transport of lime to remote areas. Moreover, for the same level of investment, profitability can vary greatly depending on the quality of management, training and technical assistance (Dias and Barreto 2013).

In the experiences under study, some of the increase in average stocking rates and increased GHG emissions is due to semi-confinement with finishing in feedlots. Intensification through adoption of animal containment systems requires the development of technologies and mechanisms to reduce the potential environmental impacts that these systems can generate. Their viability is largely dependent on the relative cost of feed rations as compared with pasture and the higher weight gain in feedlots. According to Cerri (2018), the confinement or semi-confinement system allows a gain in fattening efficiency due to increased concentration of supply. At the same time, it generates large GHG emissions (CH_4, N_2O and CO_2) which results in higher concentrations of gases in the atmosphere. The relation of carbon sequestration to emissions is reduced under feedlots since the animals are confined in an area without pasture management, in which carbon is sequestered in the soil.

The productive efficiency and environmental benefits of the feedlot system depend directly on the sources of food to be used and compliance with the principles of animal welfare and environmental legislation on waste treatment issues. These variables should be incorporated into the analysis of results, both in technical and economic indices and in environmental indicators (GHG, waste).

Cerri (2018) indicates that the recovery of degraded areas can bring technical, economic and environmental benefits. The soil-plant-atmosphere flow is directly related to the organic matter content and microbial life of the soil, which fix carbon and promote the avoidance of emissions. In addition, the presence of nitrogen from the use of legumes and biological fixation contribute to the natural fertilization of soils and the increase of productivity in intensive livestock systems (Ibid). The beneficial results for productivity and biological nitrogen fixation of long-term research and diffusion of improved pasture grasses with legumes in Acre has been documented (Ermgassen *et al.* 2018, Shelton *et al.* 2005).

Reduction of pasture area and increase in livestock productivity indicate a broad-based movement toward intensive livestock management. Results have been proven in farms that have already made the transition between traditional livestock toward sustainable intensive livestock. Nevertheless, it is questionable whether the interventions carried out at a pilot level could be upscaled by demonstration alone. According to one study, the environmental and financial advantages of increasing productivity do not guarantee rapid evolution of livestock systems. In fact, the adoption of improved practices livestock farming has progressed slowly, and deforestation continues despite the presence of large deforested areas that are underutilized (Dias and Barreto 2013). The models of intensification of animal husbandry adopted are often locally exclusive; alternatives should be considered in each region according to local opportunities, such as integration with crops and forests and the use of pasture legumes. The profitability found in pilot areas will not necessarily be the same in other regions due to differences in agroclimatic conditions, infrastructure and distance to the market, which influence the productive potential, the need and costs of inputs and revenues.

Figure 14: Integrated livestock and forest (IPF) system. Photo: Embrapa Meio Ambiente

Integrated systems are accredited with increasing grain yield (Behling et al., 2013), and for magnifying productivity by residual fertilization of the crop and, to a lesser extent, the reduction of input use by 10% (Gasparini et al. 2017). Zolin et al. (2016) found a lower correlation between soil and water loss in crop-forest integration system than in conventional plantings. Silva et al. (2016), evaluating ILPF systems with *Eucalyptus urophyla* found that soil porosity, soil organic carbon content was improved, although the ILPF stocked significantly less carbon than the native forest.

As for cattle, integrated systems present higher stocking rates, shorter time to slaughter, higher feed conversion and better animal sanitation, compared to conventional systems (Barbosa et al., 2015; Vilela et al., 2012; Gasparini et al., 2017). Several examples of intensive livestock-to-pasture systems and ILP and ILPF systems have been successfully adopted in the Legal Amazon, although on a limited scale in relation to other biomes (Valentim 2016).

On a similar note, Garrett et. al. (2017) provides a review of what is already regarding ILPF in terms of nutrient flows, crop performance, animals' performance, health and welfare. The study includes not only Brazil, but also other major countries regarding large scale and commercial agricultural systems: Australia, France, New Zealand, and the United States. The positive findings can be summarised as it follows:

1. ILPF can enhance soil organic carbon accumulation, the availability of N and P in soils. It often increases yields per unit of N or P input.

1. Crop performance outcomes is dependent on biophysical context, and to an even greater degree, co-management factors.

2. The use of ILPF can improve meat and milk production per unit of land. Biomass and diversity of soil microbes and macrofauna tend to be greater, while disease and weed tend to be less frequent.

3. ILPF often have lower GHG emissions per unit of land compared to continuous cropping systems and lower GHG emissions per unit of food in comparison to continuous grazing or animal confinement systems.

4. In certain contexts, ILPF provide higher profits than continuous pasture and continuous crop systems, but more generally they provide increased self-sufficiency and resilience to market and climate shocks.

Little is known about nutrient flows and crop performance in integrated tree-crop-livestock systems, and more generally in emergent ecosystem properties. The knowledge gap applies to the net GHG and nutrient emissions per unit of food produced, and tradeoffs between different ecosystem services in ILPF are rarely analyzed.

While available literature tends to focus on agronomic and economic aspects of ILPF, Cortner et. al. (2019) addresses the perceptions of the farmers (and technical assistants) about ILP, concentrating on the reasons why adoption levels are still low despite clear potential economic benefits to farmers. The article deals with ILP, ruling out the crop-livestock-forestry which, albeit being experimented by Embrapa and some large producers, is scarcely adopted.

Examining the degree to which structural factors interact with personal experience to shape behaviour, the research identify as perceived benefits (which tend to be stressed in more detail by adopters): economic benefits, higher competitiveness in light of regulatory (environmental) pressure, elevated productivity (e.g. more harvests), profitability, diversification, income throughout the year, and, for those already worried with climate crisis, being more prepared for such risks.

As for sensed barriers farmers point to: high up-front costs, uncertainty about return, difficulties to access green credit (ABC plan) with much red tape involved, lack of competition allowing large slaughter houses to control prices, perceived insufficient grain storage capacity, low domestic demand for higher quality/environmentally sustainable beef, lack of cooperatives, old generation reluctance. Overall, ILP is more perceived as advantageous by ranchers than by farmers, due to higher soy profitability and, in some cases, cultural aspects such as higher complexity in dealing with two chains of production and keeping a way of life.

1. Soy integrated systems

More recently, Brazilian agricultural research has been searching for alternative solutions to intensify production systems and reduce pressures on natural vegetation and thus reduce GHG emissions. Thus, arose the focus on Integrated production systems, encompassing agriculture, livestock and, in some cases, forestry.

According to Balbino *et al*. (2011), it is possible to divide these integrated systems into four types:

Figure 15: Integrated crop and forest (iLF) system. Photo: Gabriel Faria, Embrapa Agrossilvicultura

1. Crop-livestock integration (ILP) or Agropastoral Systems are arrangements that integrate agricultural species, mostly annual, and livestock, through rotation, succession or consortium, in the same production area and in the same crop period for one or more years;
2. Livestock-forest integration (iPF) or Silvipastoral systems (Figure 14): integration as a consortium between forest species and non-forest components (pasture and animals);
3. Crop-forest integration (iLF) or Silvicultural systems (Figure 15): integrates the agricultural and forestry components into an agroforestry system; and
4. Crop-livestock-forest integration or Agrosilvipastoral System (ILPF): it is the most complex system among the four presented that integrates components of agriculture, livestock and forest, in rotation, combination or succession.

Gonçalves and Franchini (2007) define the crop-livestock integration as being a mixed system of utilization of crops and livestock. According to Cortner et. al. (2019), ILP are "agricultural systems that integrate crops, livestock and/or trees in combination or in a rotation on the same area".

Among the important advantages of the method is the fact that the soil is economically exploited throughout the year, or at least a large part of it, contributing to the increase in the supply of grains, meat and milk due to the synergism between the crop and pasture. In this system, soy is initially grown, being replaced later by pasture, resulting in synergy of nutrients. It should be noted that the increasing integration of maize as a rotational crop after soy harvest in the *safrinha*, may then permit seeding with pasture after harvest, thus further integrating animals with crops.

The ILPF system can be seen as a system that improves land use, whose main objectives are: to recover degraded pastures; reduce soil erosion and end the monoculture cycle; to generate grass, fodder and grains for animal feed in the dry season, as well as wood from tree harvesting and straw for NTP; minimize dependence on external inputs; expand the income stability of the producer and minimize the costs of agricultural and livestock activities (Martins *et al.* 2011). This system begins with degraded pasture areas, where soy is planted, and subsequent to the crop, replaces this with pasture grass, interplanting rows of economically useful trees (mainly eucalyptus), leaving this consortium as a posterior land use.

There has been an expansion of ILP/F systems since their beginning in 2006 to almost 11.5 million ha in Brazil, up to 2016, particularly in the states of Rio Grande do Sul (1.5 million ha), Mato Grosso do Sul (2 million) and Mato Grosso (1.5 million) (EMBRAPA Rede ILPF 2018). Among such mixed farming systems, the most used in the State of Mato Grosso is the ILP (Behling *et al*. 2013). Among the approximately 500,000 hectares used in integrated systems in the state by 2014, 89% are in the ILP modality (Ibid), which implies planting annual crops in the summer and grazing in the winter months. Although the nomenclature refers to integration of forests, such systems do not amount to more than 17% of the total (Cerri 2018, Cortner *et. al*. 2019).

5. CHARACTERISTICS OF THE SUPPLY CHAINS TO THE FINAL DEMAND SEGMENTS AND THEIR RESPECTIVE EXTERNALITIES

The ensuing analysis refers to the impacts of the two chains under consideration from an integrated perspective. The central axis of the eco-agri-food value chain represents the main segments and characterizes the mission of each segment in the development of the sector. Regardless of the region and its stage of development, the segments of this central axis determine the development model of the productive and agroindustrial value chain, as detailed in the following sections.

Research and technology

Defines the scientific basis and technological standards of the chain;

Inputs and services

Supply of general inputs. In the case of livestock, equipment for infrastructure such as fencing and corrals, vaccines and medicines; in soy: acidity correction and fertilizer, farm machinery, implements and drying equipment. In addition, credit and extension services can be applied in both livestock and soy. Access to transgenic seed versus conventional varieties also creates differentials in the cropping systems.

Production

Segment responsible for production, involves all factors of production, such as land, pasture, animals, inputs, services, labor and technology.

Industry

Segment responsible for industrialization, handling of the raw material that comes from the production segment, meat, milk and by-product processing in livestock, with grain, oil and feedmeal in soy-maize. Both chains produce feedstock for biofuels (biodiesel from tallow and vegetal oils, and maize ethanol).

Marketing, logistics and distribution

Assures the disposal of products and providing access to consumers; and

Consumption

Performs the evaluation of the final product, including acquisition of final products from the livestock and soy value chains, and their nutritional and health characteristics and residuals disposal.

1. Inputs and services

1. Livestock

The sector of inputs and services in the livestock value chain is represented by the participation of the following segments directly or indirectly involved with the sector: veterinary, agronomy, machinery and equipment, fertilizers, seeds, chemical pesticides, animal nutrition including feed and supplements, animal reproduction (artificial insemination and embryo transfer), and marketing (fairs, auctions, animal exhibitions). The financial sector also has an important role to play in this chain, discussed in Chapter 6.

The animal health products industry closed 2017 with revenues of US$ 34 billion worldwide, a result 6% higher than 2016, reflecting the global growth of the sector. The forecast for 2020 is US$ 40 billion, with Brazil accounting for approximately 4% of this total, despite its significance in global production and commerce of animal products. The Brazilian livestock market channeled pharmaceutical goods valued at BRL 5.34 billion in 2017, according to a survey by the National Union of Animal Products Industries (SINDAN), whose members command more than 90% of production and marketing in the country.

In 2017, animal production industries faced challenges such as the "Weak Flesh" operation by the federal police investigating corruption connected with permits granted for exports of tainted meat, accompanied by the suspension of beef exports to the United States of America and Russia (SINDAN 2018).

The Brazilian market presented a 36% growth in the industrial sector's billing for animal health products between 2013 and 2017, climbing from US$ 3.9 billion to US$ 5.3 billion, with cattle raising accounting for 55.3% of this market.[21]

SINDAN and MAPA are partners in the vaccination program against foot-and-mouth disease, the main threat to the health of Brazilian cattle herds. According to the executive vice president of SINDAN, the sector mobilized 300 million doses of the vaccine nationwide in 2017.

In the cattle market, approximately 57% is represented by traditional products such as antibiotics and antiparasitics. According to the Vetnosis consultancy,[22] this segment reduced its relative participation since it accounted for 62% of that market in 2013. The segment of biological medicines (vaccines) increased its share to 26.7 in 2017 from a prior 23.3%, and supplements in 2011 accounted for 12% and in 2017 had risen to 14%. In summary we find that there is a dynamic in the quantities offered and available in the market, though the overall tendency in absolute terms is one of consistent growth.

The forage seed industry, represented by the Association for the Promotion of Research and Improvement of Tropical Forages (UNIPASTO), accounts for 60% of national pasture seed production. UNIPASTO has a cooperation agreement with Embrapa in which it finances part of the research and is granted a five-year exclusivity in commercialization of new forages grasses and legume cultivars released in the market upon payment of royalties (Jank *et al*. 2013) The area of seed production is 126 thousand hectares with an annual output of 27 thousand tons. The real demand of the market is 44 thousand tons, that is, there is a deficit of supply of seeds, according to MAPA data, from the registered production fields. The deficit is

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[21] http://www.sindan.org.br/mercado-brasil-2017/ Accessed on October 8, 2018.

[22] https://www.vetnosis.com/index.php?p=content&id=59

made up from seed produced locally, but this may not exhibit quality parameters acceptable to the industry.

According to MAPA Normative Instruction 30, regarding the criterion for the quality of fodder seed, it requires a Cultural Value (VC)[23], minimum of 48%. Should a producer choose to buy seeds with VC of 36% or less, the purchase is treated as an irregularity, for both the merchant and seed producer.

According to data from the Brazilian Association of Artificial Insemination (ASBIA) the industry of animal reproduction services, a growth of 5% was registered from 13.1 to 13.8 million doses of semen marketed from 2016-17, of which 8 million were for beef cattle and 4 million for dairy cattle.[24] Of all beef cattle semen marketed, 35% was destined for Legal Amazon states, principally Mato Grosso and Pará. Species preferences were nearly equally divided between Aberdeen Angus and Nelore breeds in the two states.[25]

2. Soy-maize

As a basis for evaluating alternative soy-maize production systems, this study investigated the direct and indirect costs of their respective inputs and production practices in the cases of no-till, conventional planting, GMO and non-GMO, and integrated versus monocrop systems.

With respect to soy production practices, significant changes in soil preparation have arisen in the past few decades. No-tillage planting (NTP) has gradually replaced conventional tillage (plowing with each harvest cycle) with herbicide application followed by furrow opening operations for the deposition of seeds and fertilizers.). According to Heckler (2006), the use of NTP began in the mid-1970s in southern Brazil. Because it was a practice that demanded new management techniques and planting equipment, this practice did not materialize immediately. However, by the 1990s, NTP experienced rapid growth, becoming the main production system and was rapidly disseminated in the Cerrado with lower production costs than that of the conventional method (Landers 2001).

Ferreira *et al.* (2015) concluded that the operational cost of soy production in NTP in the municipality of São Gabriel do Oeste in Mato Grosso do Sul state was R$ 1,251.35/ha, with inputs (fertilizers, seeds, agricultural pesticides) being the most onerous factor. According to the authors, the direct operational costs of NTP production were distributed as shown by Table 2.

[23] An index of seed viability.

[24] There are no records of semen marketed for other species of animals by this source.

[25] http://www.asbia.org.br/wp-content/uploads/2018/10/INDEX-ASBIA-2017_completo.pdf

Table 2: ***Costs of NTP operations in São Gabriel do Oeste***[26]

Cost component	Cost in R$/ha	%
Inputs and Sowing	993.35	79.4
Mechanized operations	237.00	18.9
Technical Assistance	21.00	1.7
Total	1,251.35	100.0

Source: Ferreira et al. (2015)

The NTP system was not proven to be more attractive financially than the conventional planting system, which presented an effective operating cost only 2% higher in comparative studies reviewed, despite similar levels of soy output, indicating the competitiveness of NTP (Ibid). However, the NTP system has as a disadvantage the need to invest in a direct drill planting equipment as a cost of transition, though fixed costs are amortized over time in mechanized operations. On the positive side, NTP provides soil and water conservation benefits, though requires greater use of agrochemicals to yield the same output.

This practice also was soon adopted in the Amazon, in areas of recent grain production expansion. Alves, *et al*. (2014), evaluating properties of different sizes in the municipality of Paragominas, Pará in the eastern Amazon, concluded that for both maize and soy, NTP was more advantageous, presenting lower costs and higher net revenue when compared to the conventional system. Mean production costs for the two crops are exhibited in Table 3. Revenues were roughly equivalent, due to proximate yields.

Table 3: **Production cost of soy and maize in Paragominas, Pará**

Crop	**Production Costs (R$/ha)**	
	Conventional tillage	*No-till planting (NTP)*
Soy	1,570	1,548
Maize	1,896	1,803

Source: Alves et al. (2014)

Despite the predominance of transgenic crop varieties in all parts of Brazil, this seed preference does not appear to imply reduced cost. In comparing production costs between conventional soy and transgenic soy, Richetti (2017) compared the economic viability of these varieties in four soy production systems in São Paulo, three of which were cultivated in the rainfed regime and one under irrigated conditions. The crops were differentiated by the technological characteristics of the cultivars used, being one with non-genetically modified soy (conventional); another with soy genetically modified with Roundup Ready technology, denominated soy RR1; the third with Bt + Roundup Ready (INTACTA RR2 PRO) technology called RR2 soy; and the fourth with RR1 irrigated soy. In the 2016/2017 harvest, the RR2 soy production

[26] The principal inputs in the system evaluated per ha at planting were the herbicides glyphosate (4 L) and 2,4-D (0.7 L); fungicides (carboxin and thiran at 0.11 L); fipronil insecticide (0.08 L); PK fertilizer (400 kg); GMO seed and associated royalties (55 kg); micronutrients (0.15 L). During the growing cycle, the following additional chemical inputs were applied: a second dose of glyphosate (4 L), the insecticides fipronil (0.1 L), methomyl (1.4 L), metamidofos (2.8 L in two applications), and the fungicides azoxystrobin and cyproconazole (3 applications of 0.9 L). Mechanical operations required for planting, cultural treatments and harvesting totaled 2.4 machine-hours/ha with costs differentiated by the type of equipment required for soil preparation and planting, agrochemical applications and harvesting (Ferreira *et al*. 2015).

cost was the highest of the three systems cultivated under rainfed conditions, despite the reduction in the number of agrochemical applications in control of crop pests. The high cost is mainly due to the price of the seed, which incorporates the value of the technology adopted (Richetti 2017).

Furthermore, weed resistance to glyphosate applications has further affected the discourse regarding cost differentials. Since 1993, the occurrence of native herbicide-resistant weeds in crop fields has grown to 22 different species and 8 forms of activity (Adegas *et al.* 2017). Resistance grew in two phases, prior to and following introduction of glyphosate-based herbicide (primarily Roundup) and its packaged transgenic seed (Roundup Ready-RR). Prior control costs had reached an average of R$ 285/ha, while Roundup initially permitted a reduction in control costs to an average of R$ 92/ha, which may in part explain its rapid uptake. However, the emergence of Roundup resistant weed mutations began to occur by the mid-2000s, having eliminated much of the cost differential.

Growers now apply a range of growth-inhibiting herbicides to counter glyphosate resistance. Analyzing data obtained from areas under soy crops infested with such herbicide resistant weeds in South and Center-West Brazil (including Mato Grosso), the control costs tripled in relation to the area without resistance problems from R$ 120 to R$ 386/ha (Adegas *et al*. 2017), seriously cutting into producer margins. (Further details on the continuing controversies over glyphosate are referred to below.)

2. Downstream infrastructure and processing

1. Livestock processing

Beef processing for market occurs in slaughterhouses within a radius of 100 km from ranches to reduce transport costs and weight loss. However, many of the ranches in the Amazon are located on dirt roads that are impassable in the rainy season, imposing significant additional costs and emissions to get the animals to market. The expansion in slaughterhouses in both numbers and scale was a principal spur to expansion in pastures in frontier areas (Figure 16). According to the 2017 Agricultural Census, nearly half of Brazil's beef cattle slaughter came from ranches in the Legal Amazon (IBGE 2018).

Slaughterhouses process the meat for transport to supermarkets and export. Supermarkets have only recently become sensitive to the origin of the beef they offer to consumers.[27] The top 10 fresh beef importers from Brazil in 2017 were Hong Kong (entrepôt), China, Iran, Egypt, Russia, Chile, Saudi Arabia, Italy, Netherlands and the United Arab Emirates (ABIEC 2018). Live cattle have been increasingly shipped directly from the Amazon to the Near East, where they are slaughtered in accordance with religious norms. The states from which most beef is exported is in line with slaughter rates, though bans have been periodically imposed on exports from some Amazon states due to hoof-and-mouth barriers. More recently, reports of tainted meat by major meatpackers in Brazil led to import bans by many countries.[28]

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[27] Further discussion of certification of beef origin is provided in Chapter 6.

[28] The federal police operation "Carne Fraca" led to indictment of many meatpacking executives in Brazil in 2017, and the cancellation of orders from most major meat importers, not only of beef but also of chickens and pork.

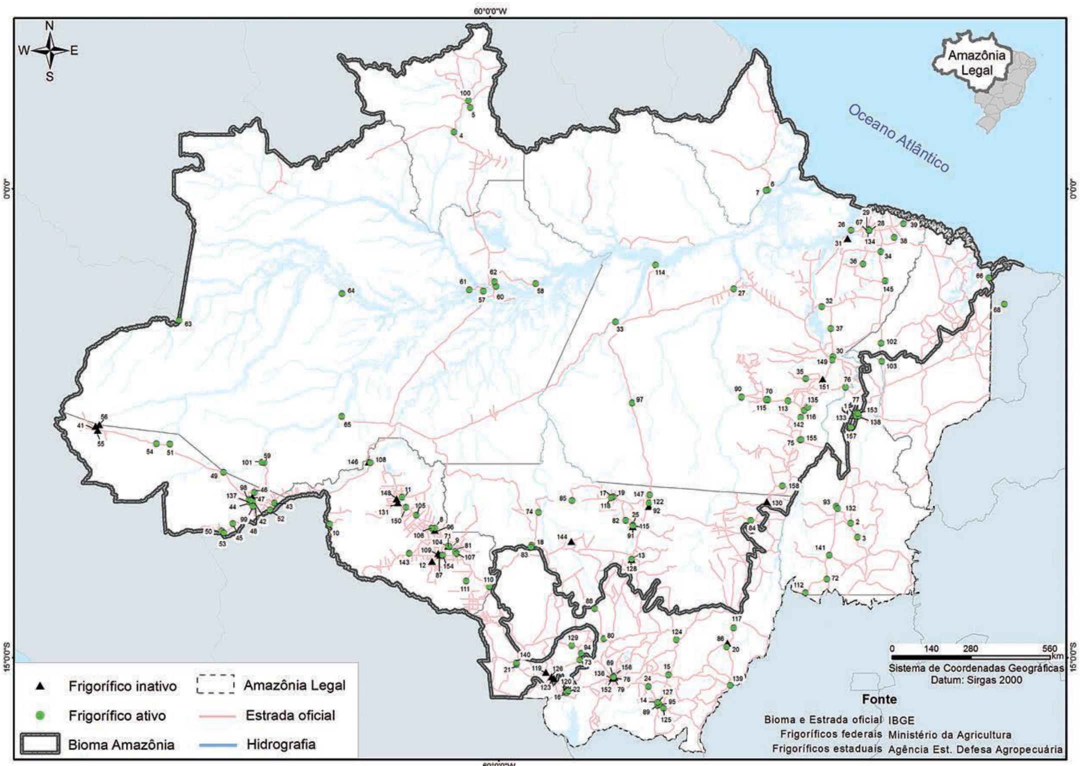

Figure 16: Active (green) and inactive (black) slaughterhouses in the Brazilian Legal Amazon region registered by State or Federal authorities (SIE/SIF), 2016. Source: Barreto et al. 2017.

Most (79.1% in 2017) of beef produced is also consumed in Brazil; that originating in the Amazon is also primarily sold to domestic consumers (ABIEC 2018).[29]

Figure 17 describes in a simplified way the beef value chain in Brazil, as it appeared at the beginning of the 2000s.

[29] This calculation was based on apparent consumption derived from total beef slaughter (39.2 million animals at an average carcass weight of 247.7 kg and beef yield of 52.3%) and total exports (2.032 million tons of beef at carcass weight equivalent) in 2017. It does not register live animal exports, estimated at 407,365 head in 2017.

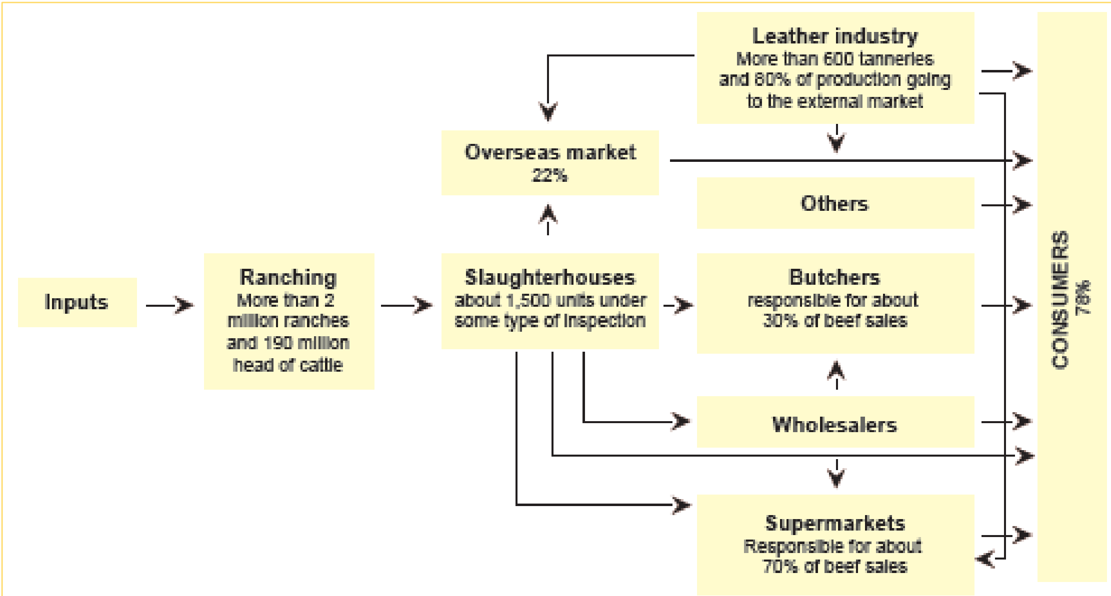

Figure 17: The beef value chain in Brazil. Source: Smeraldi and May (2009) based on Rocha et al. (2001).

2. Grain storage and transport infrastructure

While soy production has advanced in the interior of the country, investments in production alternatives have not been sufficient on their own. Currently, the roads are mostly in precarious condition, especially in the regions bordering cropland, where there is a lack of connections between transport modes, with a predominance of trucking, making transportation difficult and resulting in losses and reducing competitiveness of Brazilian soy (Zemolin 2013).

The lack of investments is historic in this sector. The most significant infrastructure investments occurred during the 1970s, benefiting from the "Brazilian Miracle" that seriously indebted the nation. From 1980 to 1990, government investment in transport infrastructure dropped substantially: about 0.2% of annual GDP, while in other countries such as China, the average is 3.5% of GDP. The lack of investments during this period affected logistics costs, which were estimated at around R$ 350 billion in 2012, having doubled from that registered ten years prior to this date (PBLOG, 2013). In general, railways and waterways are inadequate, making roadways the main form of production flow, weighing on costs due to high freight rates. Such rates are even higher for producers in the Amazon basin, where roads are more precarious, although the average trucking freight costs from Mato Grosso at about R$ 220/t are somewhat lower than the average for Brazil as a whole (R$ 260/t). Because of this scenario, the Brazilian producer suffers an average income loss of 25% with transport expenses, whereas for the North American producer this expense is less than 10% (Oliveira *et al.* 2016). According to Frischtak and Mourão (2017), the overall national stock of transport infrastructure suffered a substantial depreciation and disinvestment since the early 1980s, when it constituted 21% of GDP, having reached a low of 10% in 2012.

According to current data the state of Mato Grosso presents a historical deficit in grain storage capacity, especially that for soy. In the year 2016/2017 the static storage capacity was 29.6 million tons, but with an equivalent production of 47.7 million t. These data demonstrate that the total state storage capacity deficit borders on -37.9%, demonstrating a critical risk for grain storage (Oliveira *et al*. 2016). These data demonstrate that the structures of the static bulk warehouses are insufficient to meet both the current production and the potential growth of soy output in Mato Grosso.

6. EXTERNALITIES EVALUATED ON APPLYING THE TEEBAGRIFOOD FRAMEWORK

1. Results of prior TEEB studies on soy and cattle ranching in Brazil

The present study intends to advance in the application of the TEEBAgriFood Framework to the value chains under study, with reference to the available literature[30] and stakeholder responses. This sub-section describes the results of prior TEEB studies in Brazil regarding the natural capital costs associated with soy and beef cattle production practices, similar to the systems studied in the current study, though lacking a focus on the Amazon region, or of the full value chain perspective of the TEEBAgriFood Framework.

A study conducted by TRUCOST on behalf of the Brazilian TEEB for Business project (Conservation International 2014), involved soy production systems in the Brazilian Cerrado (using a farm in the west of Bahia as a test case). The study, which was based on data provided in part by Monsanto technicians, compared two production options, one with and one without maintenance of legally required Cerrado vegetation reserves of 20% of total area. No production practice changes in soy operations were modelled, assumed to be based on use of GMO seed with Roundup under NTP cultivation.[31] The results showed a total net environmental service benefit (including regulation of CO_2 emissions, soil erosion and water availability, and direct agricultural environmental impacts) of R$ 138/ha in favor of the "with Cerrado" option. This net social benefit more than outweighed R$66 in output foregone due to dedicating land to native vegetation (of which part was offset by net revenues from native *pequi* tree fruit sales, although soy producers are not readily engaged in activities involving sale of native tree products). Given that the crucial maintenance of Cerrado vegetation was not considered to represent "business as usual" (despite federal law to the contrary), its offsite benefits could conceivably be compensated by payments for environmental services (Conservation International, 2014).

Scientists based at Wageningen University entered into a consortium with TRUCOST to undertake a series of valuation studies of the natural capital impacts of global livestock production systems as part of its contribution to the TEEBAgriFood Feeder Study series (Baltussen *et al*. 2016). In its initial "top-down" comparison of production system impacts among major beef producers, Brazil was found to have the highest natural capital intensity of the five principal countries assessed, even when semi-confinement is used as a parameter, due primarily to land use change in tropical forests (Figure 18). When pasture management is improved, however, there is assumed to be a reduction in demand for deforestation and thus lower emissions. Supply chain impacts are restricted to upstream provision of feedgrain, estimated at a mean 20% of natural capital costs for the five beef systems under study from the top-down.

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[30] In efforts to refer to the principal research on the two value chains focusing on the Brazilian Amazon, the authors have undoubtedly neglected to cite part of the growing international literature on the subject, as suggested by reviewers.

[31] Soil erosion was assumed to have been reduced from non-NTP levels of 12 to 3 t/ha/yr, while for the gray water footprint from nitrate leaching, a metric of 130 m3/ha/yr was used for soy, while no such leaching was anticipated to soils under native vegetation.

This was illustrated in the "snapshot" study of Brazil in which a "bottom-up" analysis was concerned with modeling the natural capital impacts of cattle intensification in Brazil from a BAU of extensive grazing through semi-intensive pasture improvement, and finally semi-confinement for finishing. These systems are compared among typical ranches in Mato Grosso, categorized as cow/calf, stocker and feedlot operations. The cow/calf system illustrates extensive non-rotational grazing at 1 AU/ha, while both stocker and feedlot operations exhibit pasture rotations and fertilization. All systems adopt artificial insemination. In feedlots, animals are finished chiefly with soy and feed grains produced on-farm or nearby. A tracking system for tracing beef origin had been implemented. Antibiotics are used in feedlots.

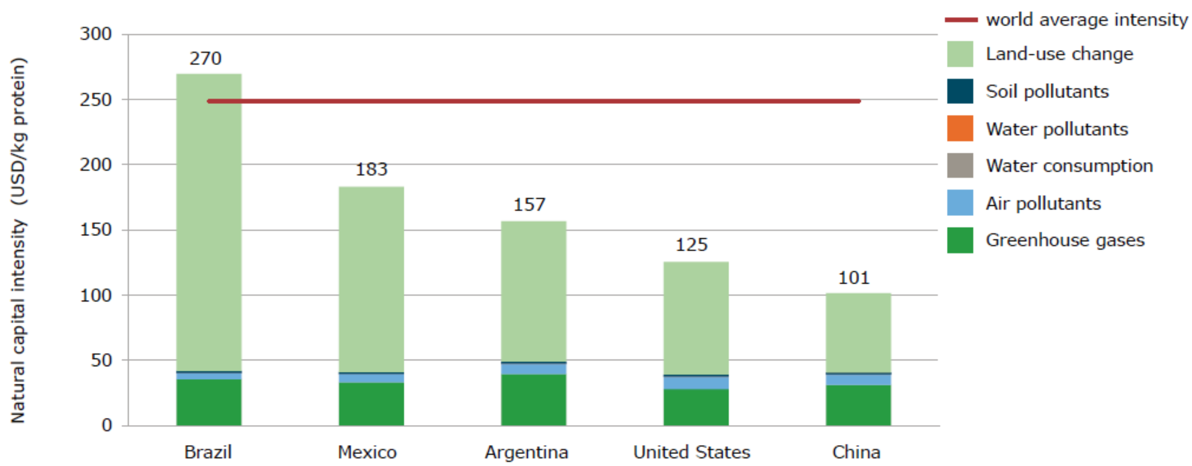

Figure 18: Natural capital intensity of beef production in top five beef producing nations (US$/kg protein). Source: Baltussen et al. 2016.

Comparing the four beef production models analyzed (increased to show semi-confinement with and without improved pasture), the estimated natural capital costs varied in intensity when measured in $/kg. While improved pasture management reduces water pollution, finishing in feedlots results in greater problems of waste disposal, generally issued to streams. Emissions of GHG were reduced 20% by feedlot finishing, however (Figure 19), primarily due to reductions in enteric fermentation and N_2O from organic fertilizer.[32] Furthermore, regarding biodiversity impacts, the study found that mean species abundance (MSA) is inversely related to the degree of intensification, with highest land use change footprint registered for the extensive cow/calf operation, and the least for semi-confinement. Overall, the study found that beef cattle production represents the greatest of all livestock sources of animal protein surveyed in terms of natural capital cost, that such costs should be internalized in market prices, but that higher protein productivity can be obtained without adding to natural capital costs through intensification. On the other hand, intensification is not without environmental and social risk (Baltussen *et al*. 2016).

[32] However, it should be noted that the study did not incorporate natural capital costs associated with feed provision from outside the immediate production system.

The two prior studies undertaken under the auspices of TEEB have thus identified some of the principal natural capital concerns that have emerged from the current report but failed to detail measures through which their externalities might be effectively mitigated.

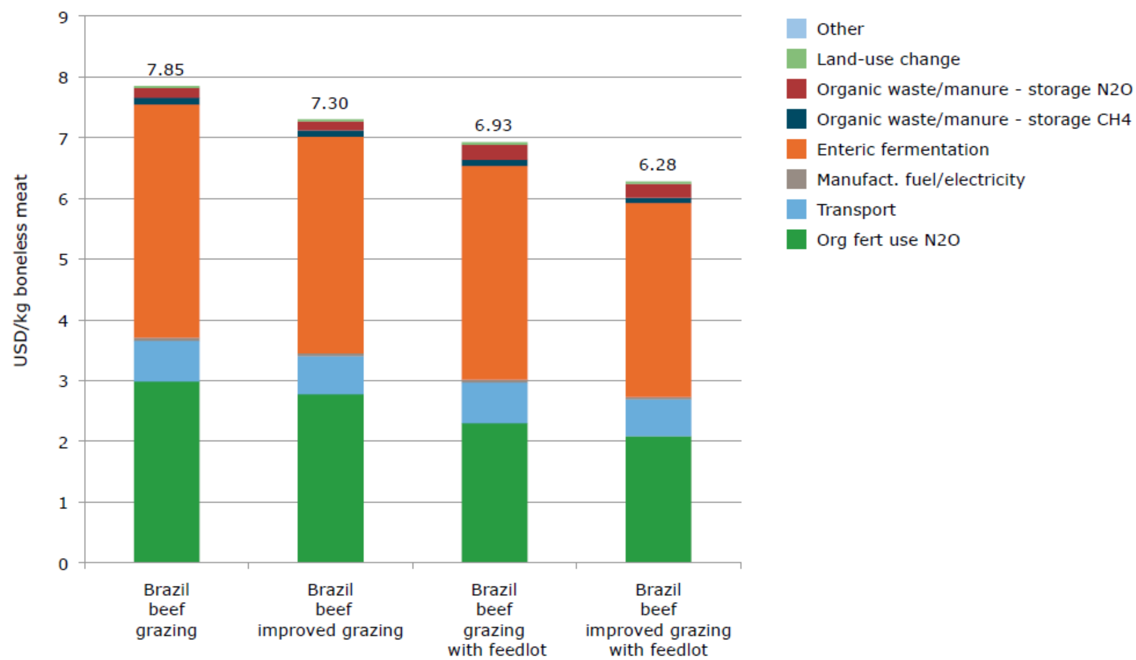

Figure 19: Greenhouse gas intensity (US$/kg boneless meat) in alternative beef production systems identified in Mato Grosso. Source: Baltussen et al. 2016.

2. Soil and water impacts of production systems

1. Erosion and land degradation

Among the several factors that affect agricultural productivity, water erosion is considered one of the most critical, accelerating soil degradation and increasing nutrient loss (Carvalho *et al.* 2007). Erosion, compaction and loss of organic matter, among others, reach almost a third of the world's land. A study involving 600 researchers from 60 countries showed that more than 30% of the world's soils are degraded (FAO 2015).

Annual losses of crops caused by erosion were estimated at 0.3% of production. If the problem continues at this rate, a total reduction of more than 10% could occur by 2050. Erosion in agricultural and intensive pastureland ranges from 100 to 1,000 times the natural erosion rate and the annual cost of fertilizers to replace nutrients lost to erosion amounts to US $ 150 billion (FAO 2015). Another problem that threatens the soil is its compaction, which can reduce global incomes of agricultural crops by up to 60%. In the world, compaction has degraded an estimated area of 680,000 km^2, or about 4% of the total arable land area. Damage caused by soil compaction is long lasting or even permanent. A compaction that happens today can lead to reduced crop productivity up to 12 years later. Soil biodiversity is also threatened by intensified land use and the use of chemical fertilizers, pesticides and herbicides (Ibid).

In the case of Brazil, Embrapa Soils estimates that soil losses valued at US$ 5 billion per year in foregone productivity is lost through surface erosion alone, due to improper land uses (EMBRAPA 2018a). Water and soil losses due to surface runoff depend on rainfall, topography, vegetation cover and conservation practices used in production systems (Guadagnin *et al.* 2005). Among these factors, plant cover and conservation practices can be adjusted and contribute to the reduction of water erosion in agricultural systems. Vegetation cover plays an important role in soil protection by reducing the impact of rain drops (Martins *et al.* 2003; Candido *et al.* 2014). In addition, the increased soil organic matter and the root system contribute to the improvement of soil physical attributes related to water infiltration and aggregation and, consequently, to the reduction of soil erodibility (Wohlenberg *et al.* 2004; Conte et al., 2011). Crop residues, in turn, dissipate the kinetic energy of the rain drops, by avoiding or minimizing the initial soil disintegration, and serves as a physical barrier to the shear and transport effects of the runoff (Guadagnin *et* al. 2005; Amaral *et al*. 2008).

1. Conservation practices in the soy chain

In the past few decades several practices and techniques have been incorporated into Brazilian soy production systems to minimize the effects of soil erosion, such as livestock and crop integration (ILP and ILPF), NTP and biological nitrogen fixation. According to Machado, Balbino and Ceccon (2011), ILPF, when established on solid bases, increases agricultural and livestock productivity, without the need to introduce new areas to the productive system. Such conservation practices can contain projected soil losses, by restraining agricultural expansion particularly in degraded sites in the cerrado and Amazon regions (Merten and Minella 2013).

Among the main results observed in recent research with these systems, what has been observed is the increase of grain yield in integrated systems compared to non-integrated, using the same production technologies (Behling et al., 2014). In addition, a significant increase in pasture productivity by the use of residual fertilization of the crop and, to a lesser extent, the reduction of input use (by 10%) in agricultural production (Gasparini *et al*. 2017).

According to researchers from EMBRAPA (2010), the factors that ensure soy productivity growth in NTP are associated with physical, chemical and biological soil improvement. In this system, greater availability of water and nutrients, less extreme soil temperatures, higher organic matter content, better soil structure conditions (greater water infiltration and better aeration, fundamental to meet the higher respiratory demand of plants with development), and biological diversity (greater diversity and biological activity, including natural enemies, organisms that decompose toxic substances, amino acid producers, vitamins and antibiotics beneficial to soy), aspects that influence crop development and productivity (EMBRAPA 2010).

In a study carried out in the municipality of Sinop-MT to evaluate soy-maize integration systems, Zolin *et al.* (2016) observed that soil losses due to water erosion are influenced by managements, but both in forest-land integration and in succession with soy-maize crops, values were below the tolerance limits for Red Yellow Latosol, in the Cerrado / Amazonia transition region. In addition, this system presented the lowest water and soil losses, consistently throughout the evaluated period, showing a high potential in minimizing soil water erosion. Soil loss showed a positive correlation with water loss, but this interrelationship is lower in the crop-forest integration system than when compared to conventional systems (Zolin *et al,* 2016).

Other production practices that have been used to minimize the impacts caused by soil erosive processes have been through adoption of NTP. The supply of adapted agricultural machinery and pesticides for these systems increased the adoption of this system, together with the benefits provided by this technique, such as improved organic matter, nutrient cycling and soil conservation.

In a study carried out in Mato Grosso to evaluate the impact of the machines in conventional production systems, it was observed that the traffic of such machines resulted in soil compaction, significantly increasing the density, soil resistance to penetration, and reducing macroporosity and total porosity of the soil, the depth of this layer being defined by the intensity of traffic (Valadão 2015).

In order to evaluate the effect of cover crops in succession / rotation for NTP on soy yield in Mato Grosso, they concluded that the *Urochloa ruziziensis* species alone or in association with fallow is recommended for NTP in the Cerrado, in the state, because it promotes significant increases in phytomass production, soil cover and nutrient cycling, increasing the yield of soy planted in succession (Miguel *et al.* 2018). Likewise, there was an increase in nitrogen and potassium accumulated in the aerial part, being released in a larger amount in the soil, mainly with the use *Crotalaria spectabilis*, compared to *U. ruziziensis*, directly influencing the soy yield due to the synchronization between nitrogen release and uptake by soy cultivation (*Ibid.*).

In order to evaluate soil physical attributes in the 0-0.40 m layers and the grain yield of the soy crop, Teixeira *et al.* (2016) compared different production systems: conventional tillage, minimum tillage and NTP, using as cover species millet, crotalaria and also fallow practice. It was concluded that the different farming systems did not influence physical attributes: soil density, total porosity, macro and microporosity in the layers of 0.0 to 0.20 m in the first year of adoption of the systems. In the 0,20-0,30 m layer, pearl millet promoted better soil density, macro and microporosity compared to fallow, as well as lower resistance to penetration (Teixeira *et al.* 2016). Long-term studies in other regions of Brazil, have confirmed the positive effects of these systems on soil parameters (Betioli Junior *et al*. 2012; Tavares Filho and Tessier 2010)

Almeida *et al.* (2016) carried out research to evaluate the effect of vegetation cover on water erosion in different cropping systems (soy under conventional tillage, soy under NTP, pasture established without animal trampling, and exposed soils). The authors concluded that the reduction of soil erosion under soy cultivation is associated with the adoption of cropping systems that do not till the soil and that retain high vegetation cover.

In a study carried out by Meneses (2013) in Mato Grosso to analyze cross-sowing, the types of preparation were evaluated: conventional, reduced tillage and no-tillage. The sowing of the soy was done in a conventional way, with parallel lines, and crosswise, where the sowing machine passed twice in the same area in perpendicular directions. Considering all the costs demanded, there was an expenditure of US$ 749.95 for conventional sowing and $ 1,372.99 for the crosswise method, resulting in an increase of 83%, with a 90% increase in average productivity, in sowing, respectively. The cross-sowing of soy showed higher plant height at flowering, maturation and insertion of the first pod, grain yield in the no-tillage system and higher fuel consumption and energy demand (Meneses 2013).

1. Valuation of soil erosion and sedimentation costs

Studies accomplished to compare the relative benefits of adopting NTP versus conventional planting methods in soy and maize in the Cerrado were published by Rodrigues and colleagues (2009; 2011), based on case studies in two municipalities in Tocantins and Goiás. Both studies applied the methodology of valuation of replacement cost, referring to soil and nutrient loss due to erosion, and stream sedimentation and required investments in water treatment for downstream usage. Rodrigues found that although NTP ensured better soil retention, and long-term productivity in soy and maize, their economic benefits did not vary significantly from those derived from conventional tillage, in terms of output. Their environmental effects, when valued in economic terms, showed a net reduction from R$ 5.58 to 6.59/ha/yr in costs when both soil nutrient loss and water quality were valued for soy alone. Such costs signified less than 2% of overall production costs. Adoption of NTP techniques was therefore more a function of producer perception of long-term benefits than of differential productivity. In the long-term, however, further studies have found greater economic benefits on soil retention and water quality from NTP adoption.

2. Nitrogen fixation in soy cultivation

Another technology that has brought advances in terms of sustainability in the use and conservation of soils has been the use of Biological Nitrogen Fixation (BNF). Brazil has developed a very successful BNF program with soy since the 1970s, so that plant breeding in the absence of N fertilizers and selection of efficient strains allows the plant to obtain all the N necessary to meet its demands (Hungria *et al*. 2005).

According to EMBRAPA (2017), the BNF process can supply all the nitrogen needed for soy to attain high yields and increase productivity. BNF is a natural process in which bacteria establish a symbiosis with legume roots, such as soy and convert nitrogen from the atmosphere into nutrient for the plant. Thanks to the advancement of Brazilian technology, this process is accomplished in soy with the inoculation of *Bradyrhizobium* bacteria. More recently, EMBRAPA has perfected inoculation with *Azospirillum brasilense* bacteria to promote nitrogen fixation in maize, wheat and forage grasses (EMBRAPA 2019).

Estimates indicate that with BNF technology, Brazil will save about 13 billion dollars annually in nitrogen fertilizer. In addition to reducing production costs, this contributes to less damage to the environment and to the reduction of greenhouse gas emissions (EMBRAPA 2018). In the last harvest, more than 40 million doses of inoculants were commercialized, mainly for the soy crop (EMBRAPA 2018b).

By the year 2010, estimates indicated that BNF's technology is present in about 11 million hectares, with ABC Plan targets to enable and increase BNF's membership of 5.5 million hectares of agricultural crops by 2020. With this a potential reduction of GHG emissions of up to 10 million tCO2e is estimated due to a decrease in the use of synthetic nitrogen fertilizers, with a calculation basis of 1.83 Mg of CO2 and ha-1.an-1 (SEEG 2016).

If BNF were to meet the need for nitrogen from maize plantations in Brazil, the emission of 4.3 million tCO2e per year could be reduced, i.e., 14% of GHG emissions from the application of synthetic nitrogen fertilizers in Brazil (considering conservative fertilization of only 50 kg of that fertilizer per hectare of planted maize) (SEEG 2016).

In a study by Salvagiotti *et al.* (2008), where the results of 637 studies published in scientific journals from 1966 to 2006 with BNF in the soy crop were evaluated, it was observed that the technology was able to supply, on average, 50 to 60% of the N demand of the crop. Proportion of plant N derived from fixation decreases with increased nitrogen fertilizer inputs. In most situations, the amount of N fixed was not sufficient to replace N field exportation in harvested seeds. The partial N balance (N fixed in the aerial biomass X N in seeds) was negative in 80% of all data sets, with a net average of 40 kg of N.ha-1. (Salvagiotti *et al.* 2008).

3. Soil and water impacts of cattle ranching in the Amazon

A great part of the cattle ranching in Brazil, and especially in the Amazon region, is carried out in an extensive system (Ferraz and Felício 2010), with low stocking rate and little adoption of pasture rotation practices and soil conservation management, as extensively detailed in previous sections of this study.

This type of system has one of the lowest costs in the world, estimated at 60% and 50% of costs in Australia and the United States, respectively. For this same reason, the degradation of the pastures has been a great problem for the sector, causing economic and environmental damages (Nogueira 2013). The causes vary with the specific situation of each biome and may be related to: inadequate pasture and management practices, establishment failures, pests, diseases, excess or lack of rainfall, low fertility and insufficient soil drainage. As a critical resource for livestock productivity, water provision can be measured in terms of the water footprint metric, which has estimated that for each kg of beef produced in Brazil on pasture or semi-confined systems, 20-25,000 liters of water are necessary (Gerbens-Leens *et al.* 2013).

The integrated systems presented a higher stocking rate in all farms, lower slaughter time, higher feed conversion and better animal sanitation, compared to conventional systems previously practiced, confirming that the use of integrated systems increases the productivity of livestock (Barbosa *et al*. 2015, Vilela *et al.* 2012, Gasparini *et al*. 2017).

In the same way, pastures, when properly managed, provide a high coverage to the soil, favoring a greater aggregation of their particles and, consequently, reducing the soil susceptibility to the erosive process. In areas under conventional tillage and low vegetation cover, soil disintegration and erosion occur with the same intensity as in areas with exposed soil (Almeida *et al.* 2016).

Also, in 2004, forage peanut (*Arachis pintoi*) had been adopted by approximately 1,000 properties on 65,000 hectares of intercropped pastures, generating economic benefits estimated on the order of US$ 33 million to producers in Acre (Valentim *et al.* 2005b). In 2015, this legume was being used in 137,600 ha of grasses in such intercrops, generating economic benefits of R$ 201 million to cattle producers in the state (Valentim 2016), with net profits from this practice estimated between R$296 and 381/ha/yr (Ermgassen *et al*. 2018). According to Andrade *et al*. (2015) planting the grass *Cynodon nlemfuesis* with forage peanuts, with a stocking rate of 2.55 AU/ha during the dry period and 4.06 AU/ha during the rainy season, provided daily animal weight gain of 761 g and 682 g, respectively. This provided an additional yield of 35.3% of carcass wt/ha over a period of 315 days. Additional benefits of leguminous pasture intercrops include reduced emissions of N_2O from nitrogen-based fertilizers, as well as a decline in methane from enteric digestion due to reduced slaughter ages and increased carbon sequestration in soils (Ermgassen *et al*. 2018).

Although feedlot finishing in the beef cattle chain is generally considered to reduce GHG emissions, its impact on water quality can be problematic. While improved pasture management reduces water pollution, finishing in feedlots results in greater problems of waste disposal (Figure 20), generally issued to streams (Baltussen *et al*. 2016). On the other hand, Raupp *et al*. (2014) concluded that fattening of cattle in confinement is advantageous for several reasons. Confinement demands a considerably smaller area, its turnover cycle is half that of fattening in pastures, and climate vulnerability is considerably lower than is reliance on pasture growth with increasing rainfall uncertainty due to climate change.

However, it should be noted that only a small proportion of cattle enterprises in the Amazon are able to shoulder the investment cost associated with feedlot operations; measures are required to improve the productivity of cattle operations at different scales and technological levels, requiring distinct interventions.

Figure 20: Confinement in Mato Grosso showing unsanitary conditions. **Photo: Orcival Guimarães.**

3. Loss of biodiversity

Multi-taxa data collected at regional and local scales in the northern Amazon demonstrate reduced species richness with increasing anthropogenic disturbance and considerably more biotic homogenization in arable croplands and cattle pastures than in disturbed, regenerating and primary forest (Solar *et al.* 2015). It may thus be contradictory for biodiversity conservation to promote greater agricultural intensification.

Due to the economic relevance of the sector and the ability to convert areas with native vegetation into anthropic areas, it is incumbent upon the competent bodies to supervise compliance with current environmental legislation (Law 12.651/12), mainly in the regularization of APPs and LR in private properties. Nevertheless, recent studies suggest that there is a divide between large and medium sized producers and small-scale family farms in terms of their relative ability to comply with regulatory strictures and their associated opportunity costs (Börner *et al.* 2014). The lenience of the revised forest code with respect to the liabilities of smaller landowners was meant to compensate for this divide. Yet current weakening of environmental regulation has undermined the protection of biodiversity on farmlands as well as the relative protection afforded to smallholders and traditional peoples.

The recovery of environmental areas and degraded areas is aimed at the conservation of natural resources (soils, water, plants) by means of soil conservation practices, protection of water resources, plant restoration with native plants, erosion, silting and gullying reduction. Promoting the preservation of animal and plant biodiversity, the establishment of ecological corridors and the maintenance of the natural fertility of soils, all being fundamental aspects for the production model of sustainable soy and livestock production in the Amazon region.

The concept adopted for the recovery of APPs is summarized in the practice of adapting the degraded areas of pasture to the requirements of the legislation, by the method of natural regeneration, considered, in this study, by means of demarcation of the APPs, and their enclosure to promote the restoration of native vegetation. Protection of water courses and springs can thereby ensure water provision to supply both livestock and human requirements.

According to data from IMAFLORA (2018) when the deficits of APP and RL in each biome in small, medium and large properties are evaluated, it is possible to observe that there are significant differences between the different profiles.

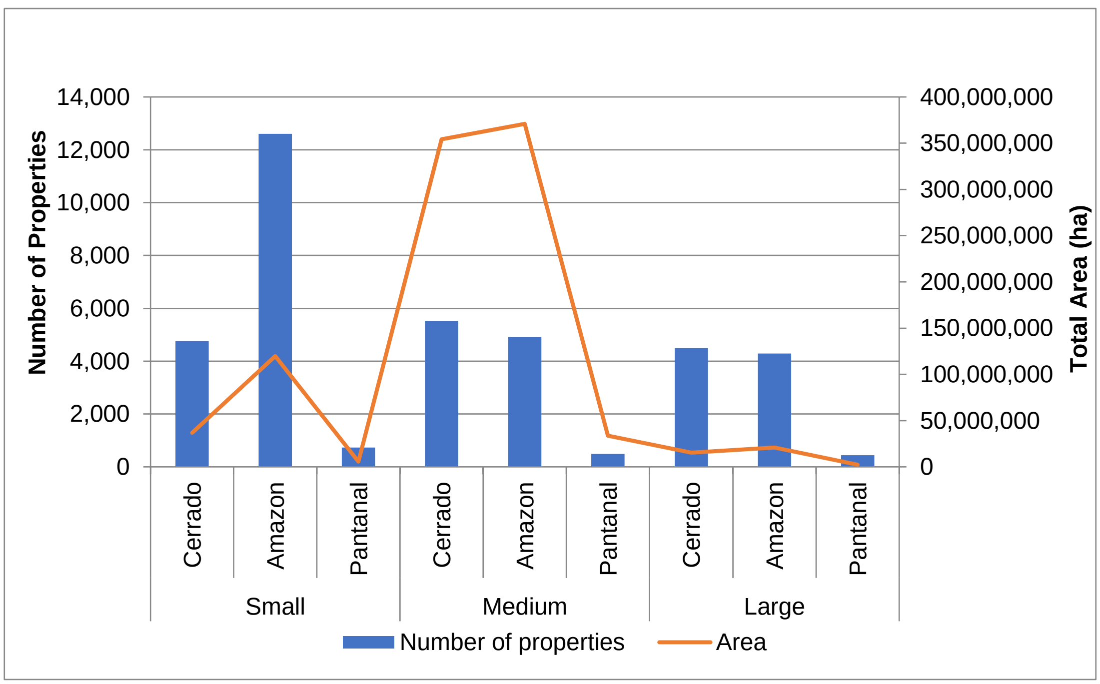

Figure 21: APP and RL deficits in small, medium and large properties in the Cerrado, Amazon and Pantanal biomes. Source: IMAFLORA 2018.

In relation to small producers, it is possible to observe that there are a large number of properties in the Amazon biome with APP and LR deficits, but with lower values for the Cerrado and Pantanal biomes. Despite this, these data indicate there are a large number of families whose ability to comply with conservation requirements is lower than that associated with medium and large properties, whose deficits are proportionately larger as can be seen in Figure 21.

For the medium holdings, the number of properties is significantly lower, but with total area above the other categories for the three biomes. This category is the one with the greatest deficits in the environmental area, evidencing the need for regularization and greater commitment to inspection for compliance.

Finally, the data show that the large properties fall into the category that presents smaller deficits of environmental areas, both in number and area, making it possible to conclude that these are the most recurrent targets of land regularization and control.

These data demonstrate that one of the main impacts of the sector related to biodiversity loss is correlated with deforestation and non-compliance with environmental legislation. These deficits are evidenced even more by registering the properties in the CAR system, thus enabling better enforcement and application of measures by the inspection bodies.

To prioritize forest areas by their relative biodiversity characteristics, studies conducted by Strand *et al.* (2018) as part of a broader valuation of the Amazon forest interpolate into map representation six biodiversity dimensions for the Brazilian Amazon: (1) phylogenetic and (2) species compositions, (3) species richness and (4) endemism, (5) areas of endemism, and (6) phylogenetic endemism. Species and phylogenetic compositions were used to classify biogeographic regions with unique combinations of species and lineages. Next, for each biogeographic unit, the model sums the quantitative biodiversity variables (species richness, species endemism, areas of endemism and phylogenetic endemism) on a scale from 0 to 1. Finally, the model generates a final set of classes that combine biological relevance, sampling density and regional vegetation coverage (Figure 22). No monetary valuation was performed. These priority areas were then overlaid with spatially explicit valuation of ecosystem service benefits to attach biodiversity relevant information to those values without adjusting their monetary values.

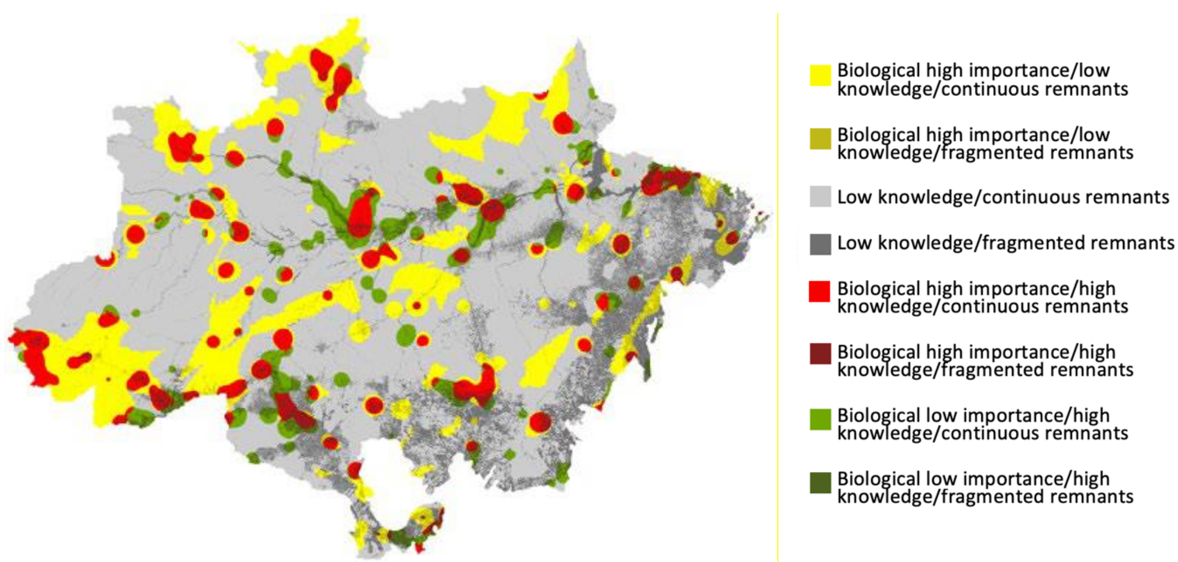

Figure 22: Spatially explicit model of the Amazon biome of Brazil for biodiversity conservation. Strand, et al. 2018.

4. Greenhouse gas emissions

Global warming is caused by increased concentrations of greenhouse gases (GHGs) in the atmosphere, with emphasis on carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O), in part due to anthropogenic activities such as deforestation, fires and agricultural activities (IPCC 2007).

Data from SEEG (2018) show that in 2016, Brazil emitted a total of 2.27 billion tons of greenhouse gases (GHG), measured in carbon dioxide equivalent (CO_2e). This represented a growth of 9% in relation to the previous year and 32% in relation to 1990. Of this total, 51% arose from deforestation, especially in the Amazon and in the Cerrado. In 2016, the rate of deforestation in the Amazon was 7,893 km^2, double the amount needed to meet the original target for 2020 of 3,900 km^2 defined in the national plan for climate mitigation. Deforestation rates have persisted in the last two years, having increased still further in 2019 (INPE 2019).

In a recent study conducted by IMAFLORA and the Climate Observatory (2018), it was concluded that agriculture accounted for approximately 30% of GHG emissions in 2016, while land use change and deforestation contributed an additional 39%. Direct emissions from the agricultural sector totaled 499.3 million tons of CO_2e, an increase of 1.7% over 2015.

The amount of GHG emitted only by the beef cattle sector represents 65% of the emissions of the agricultural sector and 15% of overall national emissions (SEEG 2018). Emissions from agriculture and livestock have grown 163% since 1970, but over the last four years measured have remained relatively stable, at 478 million to nearly 500 million tCO_2e. The variations between 2011 and 2014 were on the order of 1%. In 2016 there was an increase of 2% in relation to 2015, which can be explained by the decrease in the slaughter of animals and consequent increase in the cattle herd. A slight decline was registered in 2017, the last year measured by SEEG.

The main gases contributing to emissions by the sector are methane (CH_4) emitted by enteric fermentation in livestock and the management of animal wastes and nitrous oxide (N_2O) resulting from the use of nitrogen fertilizers, which has the highest growth rate. Between 1970 and 2016 emissions from fertilizer use increased 15 times. Only between 2000 and 2016, the increase in the consumption of synthetic fertilizers, which grew in proportion to emissions, was more than 158%, accompanying the growth of grain production driven by the increase in their productivity. Between 2015 and 2016, the consumption of nitrogen fertilizers took an unprecedented 23% jump. If the emissions are divided between the subsectors of agriculture and livestock, 86% of them come from animal production (79% of beef cattle and milk), approximately 6% from vegetal production, 6% from the application of fertilizers and the remaining 7% from other sources. Livestock production predominates in methane emissions from enteric fermentation and deposition of manure on pasture.

A study coordinated by Gurgel (2017), shows that in relation to the goals of the Brazilian NDC, to be reached in 2020 (Brazil 2015), based on emissions in 2010, the restructuring of agricultural production and land use with the adoption of low-carbon practices would enable a 5% increase in the cattle herd without the need to open new areas, from 205 million head in 2009 to 216 million head in 2020, after the implementation of pasture recovery and implantation of ILPF. The adoption of the ABC Plan goals would also increase the supply of grains (soy and maize) with the adoption of integrated systems in degraded areas and the expansion of the forest area and natural vegetation in the South and Southeast regions.

Agriculture is directly related to the concentration of greenhouse gases in the planet, through the basic processes that occur in the soil-plant system, contributing with approximately 24% of the total emissions (IPCC 2014). Agricultural soils may act as a source or sink for GHG, depending on the management practices used (Johnson *et al.* 2005).

In recent years, climate change has raised concerns in several sectors of the economy, especially in agriculture and livestock production. In the case of Brazil, two of the main crops for the national economy, soy and maize, have attracted special attention from researchers and scientists.

Within the practices that can reduce GHG emissions in agricultural systems, the timing and method of soil preparation have been evaluated as an important mechanism to reduce emissions. Vieira *et al.* (2014) in a study of lowland areas, or planosols, found that early soil preparation during the off-season reduces methane and nitrous oxide emissions during soy cultivation, compared to an NTS crop. Regardless of the management of the soil in the off-season, the cultivation of soy in the lowlands provides low methane emissions, representing a promising alternative for the mitigation of GHG emissions. Nitrous oxide is the main component of the partial global warming potential of plananosol cultivated with soy.

Gusso et al. (2014) in a study to evaluate the impact of climate change on soy production, has observed that increases in the frequency of extreme events, such as the occurrence of high temperatures, are likely to produce severe effects on summer crop yields, especially soy and corn. Studies of adaptation of Brazilian agricultural systems to climate change suggest that soy production may lose up to 40% of productivity with losses valued as high as US$ 7.6 billion/yr. by 2070 in the worst-case scenario (Assad and Pinto 2008). In this work, it is proposed that temperature fluctuations around the optimum level in the canopy of the crop can cause favorable effects on the soy yield. The overall results showed that increases in canopy temperature during flowering/grain filling periods, are related to higher soy productivity.

Forest fire risk has become increasingly serious in the Amazon basin due to climate change, and drought has become as familiar as flooding in many parts of the region. Although valuation studies have tended to focus on losses associated with potential timber extraction revenues in forests affected by fires (Strand *et al*. 2018), losses of cattle and both pasture and crop productivity can also result from excessive burning.

5. Impacts on health of burning and spraying of aerial agrochemicals

The conversion of crops into pastures produced a significant increase in the consumption of agrochemicals in the state of Mato Grosso. As the environment has been transformed, hazards, threats and risks have been modified. This variation conditioned, among other factors, the transition from a higher prevalence of infectious diseases to an increase in the number of cases of chronic-degenerative diseases (Weihs and Sayago 2017).

Deforestation and environmental degradation were also important for the prevalence of respiratory diseases. Among its main causes was the smoke released by the burning of pastures or forests, which release into the atmosphere a series of chemical compounds and organic wastes with highly toxic characteristics (Gonçalves *et al.* 2012).

Among the different compounds, the most harmful to health are known as particulate matter. The origin, chemical composition and size of these particles define their effects on human health. The most damaging particles are PM2.5 (Particulate Matter), so named because of their physical dimension (Ribeiro and Asunción 2002).

In the north of Mato Grosso, these particles were mainly produced during the dry season, between July and October (Artaxo *et al.* 2005). They accounted for more than 60% of all particulate matter emitted by fires and increased hospitalization among the most sensitive groups, such as children and the elderly, between 13% and 20% (Ignotti *et al*. 2010).

In general, it is observed that the main chronic health problems of the current phase of the frontier are mainly caused by exposure to environmental contaminants. From this perspective, we may include the risks produced by exposure to agrochemicals in the Amazon biome of Mato Grosso.

As for neurological diseases, Alzheimer's disease and Parkinson's disease appear among the most relevant in the current phase of the agricultural frontier. The causes of these diseases are multiple, including exposure to pesticides and some heavy metals (De Lau and Breteler 2006).

According to Ascherio *et al.* (2006), farmers, family members, and neighbors have a 70% higher risk of developing Parkinson's disease. In patients' brains, much higher levels of chlorine molecules have been found than in the brains of healthy people (Fleming *et al.,* 1994). They are derived from acute and/or prolonged exposure to organochlorine insecticides, such as DDT, BHC, Aldrin, Endrin and Endosulfan, widely used in the Amazon agricultural frontier (Carneiro *et al.* 2012).

In addition to this, strong evidence has been found of morbidity associated with exposure to 2,4-D herbicides and paraquat (De Lau and Breteler 2006; Tanner *et al*. 2011).

In a study carried out by Belo *et al.* (2015) on the perception of workers living in soy farms in the municipality of Lucas do Rio Verde – MT, they point out that the residents and participants recognize in their daily routine different situations of risks to the environment and human health. In some situations, pesticides, used intensively in the production of soy which is the main economic activity of the municipality, were identified by these individuals as a risk, and in other situations this risk was minimized, ignored or denied. The main environmental problems highlighted by rural dwellers were those arising from sanitation conditions, while in the urban center the most important environmental problem was attributed to aerial spraying by pesticides and their effects on the environment. Studies carried out by the Ministry of Health between 2014 and 2017 throughout Brazil identified water supply contamination by all 27 agrochemicals tested for in all municipalities for which data was obtained in Mato Grosso and Tocantins in the Amazon region; toxic concentrations were found to be superior to both national and European standards in many areas. However, regulatory standards in Brazil aim to regulate each substance individually, rather than the combinations that were found to exist in a "toxic cocktail" (Aranha and Rocha 2019).

In another study carried out in Campo Novo dos Parecis, Mato Grosso, by Soares *et al.* (2017), the region presents a real risk of environmental contamination by pesticide residues, since 45.6% of the agrochemicals commonly used in local agriculture are classified as extremely toxic or highly toxic. In addition, several of these additive ingredients, about 22%, have already been detected in different environmental compartments in other regions of the state. It is also concluded that 26.1% of the active ingredients listed in the region represent some risk of groundwater contamination, considering the criteria of the USEPA groundwater vulnerability index (GUS).

6. Labor analogous to slavery in production systems

In 2018 throughout Brazil, 1,723 workers were officially found living in conditions analogous to those of slave labor, almost three times that recorded in 2017, which reached 645 cases. Cattle ranching topped the business statistics related to the "dirty list", repeating what has been happening throughout the historical series since 1995. Next comes the coffee production sector, closely followed by the forest production sector (native and planted forests) and for support activities for agriculture and soy cultivation, among others. The states which topped the list of notified infractions were Pará and Mato Grosso in the Legal Amazon region.[33]

7. Loss of pollination and biological control services

Soy is not dependent on insect pollinators for its pollination since it is an autogamous or self-pollinating plant species (Gazonni 2017; Giannini 2016). However, according to recent research, soy may exhibit a pollination deficit should insect pollinators not be present, which may result in a reduction in productivity with implications for national income and export revenues (Giannini, *et al.* 2015).

Pollination effects of pesticide use in soy and maize does represent a source of declines in insect pollinators important for other crops and ecosystems. Declines in bee populations due to colony collapse disorder have been documented worldwide, traced primarily to excessive and continuous application of specific insecticides, constituting one of the most onerous anthropic causes of biodiversity loss (IPBES 2016). Estimates in yield loss range from 10–40% (Klein *et al*. 2007, Gallai *et al*. 2009), and up to US$ 490/ha (Lautenbach *et al*. 2012).

In Brazil, declines in pollinator species have also occurred due to deforestation, and loss or fragmentation of insect habitat (Novais *et al.* 2016). An experimental study in Paraná found a 38% productivity difference in conventional and GMO (RR) soy when access to pollinators was removed (Chiari *et al.* 2008). In the Brazilian Amazon, soy producers interviewed for this study do not report a perceptible decline in pollination services. This may in part be traced to the moratorium on deforestation in areas of soy expansion.

Proximity of habitat for native pest predators is also important for pasture productivity. In the Amazon region, ranchers have succumbed in many cases to decimation of pastures caused by the prevalence of spittlebugs (named for the saliva they produce to host their offspring in pastures), of the genus

[33] https://projetocolabora.com.br/ods1/aumentam-flagrantes-de-trabalho-escravo-no-brasil/; https://sit.trabalho.gov.br/radar/

Homoptera, family *Cercopidae*. In Northwest Mato Grosso, studies by Del Arco *et al.* (2018) showed how the proximity of forest reserves reduced spittlebug infestation due to the presence of natural predators, resulting in net benefits of US$ 113.28 to $233.76/ha/yr as compared to pastures without forests nearby. The loss of such forest proximity due to deforestation would conversely impact pasture productivity.

8. Impacts of confinement, beef packing and related externalities

The slaughterhouses that buy livestock from the Amazon have been pressured by environmental campaigns and legal processes to combat deforestation by farmers. The pressure to deforest, whether legal or illegal, is increasing. This is the most polluting activity in the country if we consider the emission of forest-burning gases that contribute to global warming. In light of these data, it can be inferred that by charging the 110 meatpacking companies – which are the doors to the market – to comply with the law or commit to zero deforestation, seems to be a more promising way to reduce deforestation than to individually monitor the 390 thousand farmers whose cattle ranching contributes to deforestation (Barreto *et al.* 2017). Nevertheless, efforts to improve the purchase policies of these enterprises to address the environmental compliance of their sources are unable to reach the far more numerous local slaughterhouses which are rarely subject to sanitary inspection.

However, the focus nearly exclusively on deforestation associated with beef cattle enterprise in the Amazon does not take into account the impacts associated with intensification via finishing of cattle in feedlots which affect animal wellbeing and by extension the quality of the final product, as well as additional demand for feed grain whose impacts are described above.

It also does not take into account the impacts associated with slaughterhouse operations themselves, whose refrigeration energy requirements and waste disposal associated with the slaughter of an average of 708 animals/day in each of 110 slaughterhouses responsible for 93% of all animals slaughtered in the Legal Amazon (Barreto et al., 2017) can be considerable. For example, the liquid effluent generated by beef slaughterhouses in Brazil has been estimated at 4.8-6.7 m^3/t liveweight processed (Rocca 1993), though subsequent improvement has been obtained in industrial facilities to treat effluents.

The processing operations in a typical slaughterhouse operation include the demand for electric power, water, cleaning products and waste treatment, as well as the channels for disposal and byproduct markets for offal, bones, heads, hooves and hides such as leather manufacture, as well as tallow and grease for biodiesel. In Brazilian slaughterhouses the principal residues include 23 kg of offal and 18 kg of blood and other residues, for each animal slaughtered (Pacheco 2008).

9. Labor conditions in slaughterhouses

Meat preparation workers are faced with a series of health-damaging situations, such as constant exposure to sharp instruments, which results in accidents and may cause mutilations. Another problem is Repetitive Strain Injury (RSI). Workers face exhausting hours, often more than 10 hours a day, exceeding the 8-hour workday established by Brazil's national consolidated Labor Law, and often are required to work on Saturdays. This shortens the life of these workers, who spend 5 to 10 years in the meat industry and then become unable to undertake other manual labor activities, leading to reporting of disability.

Statistical data from what is reported to the government show that cattle slaughter workers have 3 times more abdomen, shoulder and arm trauma than other workers and 2.5 more spine problems (Aguiar and Tura 2016).

The psychological pressure to cope with the rapid pace of production is intense. These workers are charged with a high level of productivity. To keep the production line moving, they are unable to stop to go to the bathroom, look sideways or talk. There are layoffs of people considered less productive. The environment is also suffocating and cold, aggravating the health of workers (Ibid.).

10. Food losses and logistics impacts along the value chain

Loss of soy production occurs at different stages and scales, concentrating mainly during the production process and grain transport. Most of the losses in the production process are caused by technical problems in equipment and implements. Assessing the levels of these losses is critical to reducing the risks associated with different stages of production, especially harvesting.

In order to investigate the efficiency of harvesters used in soy farms, Zandonadi *et al*. (2015) concluded that approximately 69% of harvesters evaluated had an acceptable level of losses (up to 60 kg/ha). Considering the harvesters which were in adequate working condition, the average total loss was 57 kg/ha. In some cases, harvesters with losses of less than 40 kg ha-1 (25% of the fleet) and even losses of less than 20 kg/ha were found, indicating that the level of losses in the region can still be reduced.

Transport logistics is a preponderant factor for the development of Brazilian agriculture. Here we focus on the logistics involved with soybean exports, as one of the principal factors that affects the competitiveness of Brazilian soy. The three main means used to transport grains in Brazil are road, rail and waterway. According to data from the vegetal oil association ABIOVE compiled by the National Transportation Confederation (CNT 2018), the road modal most represents the soy transport sector, corresponding to 65% of the soy transported, while rail transport represents only 26% and lastly by the waterway modal (9%). Although Argentina's logistics situation is similarly skewed, that of the US is dominated by waterways and railroads, with only 20% being transported by highway, with commensurately lower costs despite similar average distance to market (1,000 km).

Figure 23 shows the flow of grain transport logistics, showing which modalities are used in each stage of the production flow to the final destination. The main export port of soy from Mato Grosso is Santos in São Paulo, which accounted for 50.7% in 2014, followed by the port of Paranaguá (10.5%) and Vitória (9.8%) (CNT, 2015). All of these ports are situated at least 2,000 km from the point of origin of soy produced in Mato Grosso. Transport costs for soy may reach 25% of the value of the product, while coffee costs, for example, are 2% and orange juice costs 1% (Filho 1996). The average freight rates practiced in 2015 on the Lucas do Rio Verde route to the port of Santos, through the road route exclusively, were around R$ 258.00 per ton, according to data compiled by CNT (2018). Prices vary according to the time of the year, the modalities involved and the distance between the production and the final destination. When there is integration between modes, the cost of freight can decrease by up to 94%.

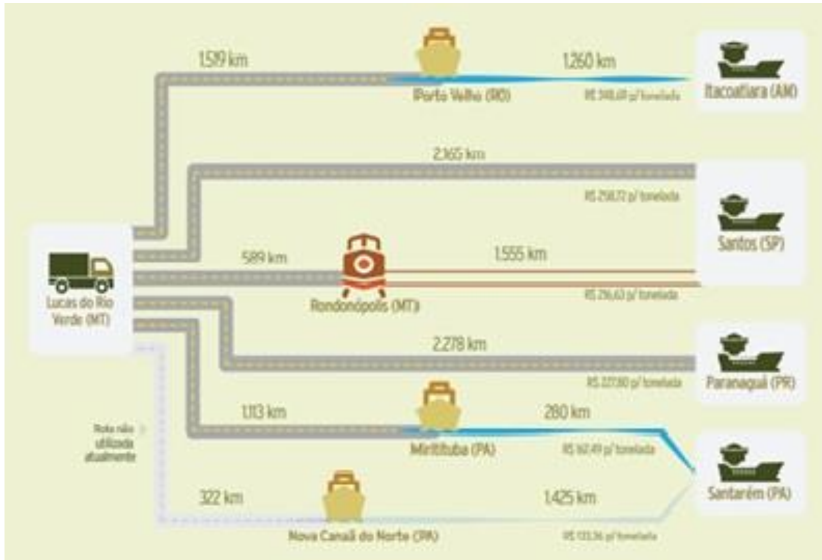

Figure 23: Logistics barriers to soy and maize distribution. Source: CNT 2015.

The ports located in the North and Northeast of Brazil make up the export corridor known as Arco Norte, which is comprised of the following ports (Figure 24): Porto Velho (in Rondônia), Manaus (in Amazonas), Mirititiba (in Pará), Santarém (in Pará), Barcarena (in Pará), São Luis (in Maranhão) and Salvador (in Bahia).

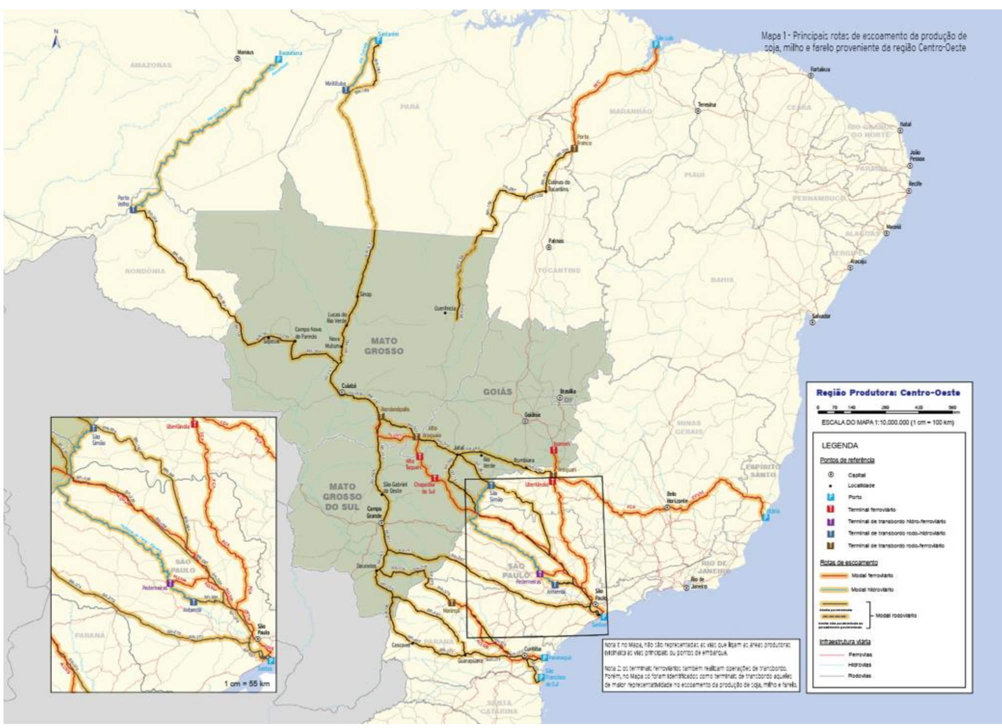

Figure 24: Principal logistics channels for soy and maize export. Source: CNT 2015.

The flow to these ports tends to grow because the transportation of grains is often carried out through the waterway and road modalities, contributing significantly to reduce logistics costs (Vettorazzi, *et al* 2017). The sector that accounts for the largest share of total CO_2 emissions from fuel combustion is that of transportation, according to the International Energy Agency (2015).

The waterways and railways are better suited for the transport of low value-added long-distance cargo (soy for example), in view of the capacity to increase fuel consumption efficiency per ton transported (Correa 2010). It is noteworthy that the predominance of the road modal is due to the difficulty that other modalities encounter in order to efficiently meet the demand increases in more isolated areas of the country, which do not provide infrastructure for railways or waterways (Ojima 2003). The study carried out by the CNT (2013), shows that the road transport system consumes four times more fuel than the railroad and five times more fuel than the waterway modal.

A study carried out by Silva (2015) regarding CO_2 emissions in the soy outflow chain from the Center-West to the Port of Santos, shows that the emissions total 354,596 tons of CO_2 when carried out exclusively by road transport. When transport is carried out intermodally (road and rail), there is an average reduction potential of 37%, while even greater reductions may be obtained by waterway.

Transportation of cattle from the point of origin to slaughter, and that of refrigerated beef from slaughterhouses to market likewise involves a complex and lengthy logistics network. The need to transport dressed meat in refrigerated containers also adds to the fuel cost and associated GHG emissions involved (Bustamante *et al.* 2012).[34]

Food waste at the conclusion of the value chain is significant. According to a recent survey, 41.6 kg of food is wasted per person each year on average, which gives an alarming total of 128.8 kg of food per household that are no longer consumed and will end up in garbage containers. In addition, the study found that rice (22%), beef (20%), beans (16%) and chicken (15%) are the foods that are most frequently wasted (Porpino *et al.* 2018). Although there is little income effect on the volume of food waste, higher income households tend to discard a higher volume of vegetables than lower income groups. Consumers in general regard it important to consume fresh foods, and to dislike leftovers.

11. Consumer health and well-being

Meat consumption in Brazil is among the highest per-capita levels in the world, at 42 kg/yr (ABIEC 2019). Meat consumption elasticities to income and educational level are evident, both influencing the propensity of consumers to purchase "noble" meats (e.g., filet, *picanha*, ribs). With declining incomes in times of economic crisis, many families substituted beef with chicken or pork. Although health professionals tend to discourage red meat consumption, consumers when dissuaded from buying red meat often substitute pork or sausage, which is not likely to engender health benefits (Travassos and Coelho 2017).

[34] Estimates of the respective emissions rates for refrigerated trucking were not identified for this study.

Given the precarious sanitary conditions found in local informal slaughterhouses throughout Brazil, health risks are also prevalent in beef consumption from these sources, despite their being closer to the point of origin.[35]

Although Brazilian beef has improved in quality over the years, a recent scandal involving some of the major meatpackers in accusations of having bribed officials to license tainted meat resulted in exports being banned, as well as fines levied on the offending companies. Periodic outbreaks of foot and mouth disease (FMD) has also led some Amazon states to be barred from exporting. Consumer confidence in widely commercialized brands such as JBS Friboi has thus been shaken.

Nevertheless, the World Organization for Animal Health (OIE) declared Brazil free of FMD with vaccination in May 2018 (other beef exporters enjoy such certification even without vaccination, which only the state of Santa Caterina has earned in Brazil).[36] Thus, Brazil's current position as the principal global beef exporter has been reinforced.

Concerns for the sustainable origin of beef produced in Brazil has not been nearly as significant as it has been among Northern consumers. Since most beef is derived from grazed pasture systems, this concern on the part of those concerned with animal welfare is largely unfounded, though the increasing importance of feedlot confinement may justify such preoccupations in the future.

Brazilian consumers favor soy oil for cooking, having been lured away from animal and palm oil-based shortenings since the 1970s. Soy oil marketed by Cargill under the label Liza won over its substitutes by allowing fried cooking without fumes or smoke.[37]

Recent campaigns to recycle spent cooking oil as a biodiesel feedstock under the Social Carbon program have been somewhat successful in overcoming problems of disposal, though the logistics of its collection have stymied the growth of such initiatives.

12. Valuation of global / regional externalities

The losses associated with precipitation patterns affected by accumulated deforestation and potential loss of productivity in downstream production areas has been assessed by Strand *et al*. (2018). Spatially explicit modelling of the impact of deforestation on Amazon ecosystem service provision shows that at levels over 10% of additional deforestation significant losses of beef and soy output could occur due to climate impacts.[38]

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[35] https://www1.folha.uol.com.br/mercado/2017/03/1869822-abate-informal-de-animais-aumenta-no-pais.shtml

[36] https://www.reuters.com/article/us-brazil-beef-disease/oie-declares-brazil-free-of-foot-and-mouth-with-vaccination-idUSKCN1IP2CD

[37] https://www1.folha.uol.com.br/o-melhor-de-sao-paulo/restaurantes-bares-e-cozinha/2016/06/1784570-com-promessa-de-acabar-com-fumace-nos-anos-1970-oleo-liza-dominou-mercado.shtml

[38] The impacts of changes in land use on climate of South America were projected at a spatial resolution of 300 × 300 km^2. Changes in rainfall are used to estimate the impacts of deforestation on production and net returns of soy production (for Argentina, Uruguay, Bolivia, Paraguay and Brazil), beef production (Brazil only) and hydroelectricity generation from four Brazilian facilities, using the Integrated Model of Land Surface Processes (INLAND), an evolution of the Agro–IBIS model. Reverse calculations are made whereby economic losses, at stipulated (current) output prices, can be traced back to the individual (large) Amazon forest cells from which forest is lost. Loss magnitudes in US$ ha−1 yr−1 are calculated for each cell output (Strand *et al.* 2018).

Such losses would not be restricted to the Amazon itself, but would extend into Brazil, Argentina, Bolivia and Paraguay, whose rainfall is also regulated by the Amazon forest ecosystem.

Overall, regions that are both upwind and close to pasture and soy production areas are those that have benefited most from climate regulation functions of the standing forest. For soy and beef production, reductions in productivity and rents due to diminishing climate regulation functions from deforestation average US$1.81 and 5.43 ha/yr, respectively, but can be as high as US$9 ha/yr (that is 30% of total rents). Such reductions are mostly concentrated on the fringes of the Amazon forest, particularly in downwind production areas in northern Mato Grosso (soy), Rondônia and eastern and southern Pará (livestock). Since most deforestation is caused by the expansion of livestock and soy production (despite self-regulation under the soy moratorium), this effect implies negative environmental service provision by the sector on itself.

The study also estimated the direct opportunity costs in terms of timber and non-timber forest production potential foregone based on loss in estimated net rents from Reduced Impact Logging and from rubber and Brazil nut extraction, due to both deforestation and risk of forest fires, affected by forest fragmentation and drought. Such values varied considerably in geographic terms, given the variation in density and quality of products (Figure 25).

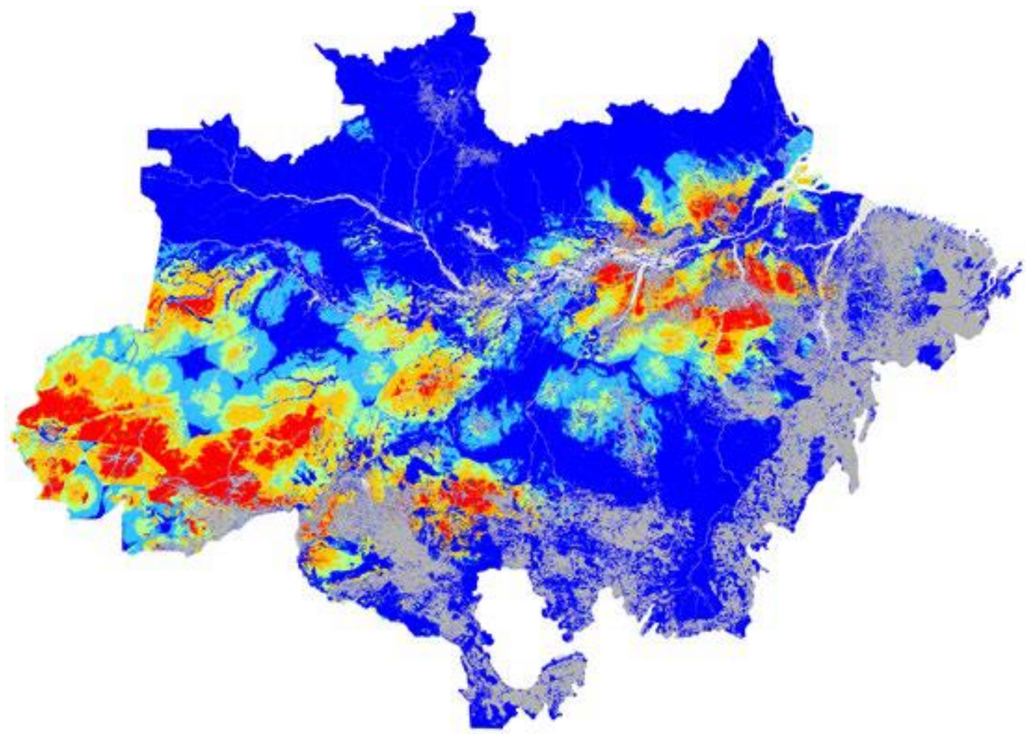

Figure 25: Timber values in the Amazon biome. Source: Strand et al. 2018.

Similarly, deforestation-induced climate change potentially reduces the useful life and power generation potential of hydroelectric facilities. Strand *et al*. (2018) valued the probability of loss in generating potential of two major recent hydroelectric investments (Belo Monte and São Francisco) due to climate change-induced rainfall patterns. Changes in hydroelectricity generation potential are estimated at US$0.32/yr per hectare deforested on average, although economic losses may reach up to US$1.84/ha/yr depending on the extent of deforestation. These changes are mostly concentrated in the wet-to-dry and dry-to-wet season transition months.

In the same study, potential global impacts on CO_2 emissions associated with continued deforestation and burning in the Brazilian Amazon region were valued, based upon current global agreements for performance-based payments (i.e., REDD+ and bilateral accords such as the Amazon Fund) (Strand *et al*., 2018). Reductions of CO_2 emissions are valued only in areas under threat of deforestation along the deforestation frontier from the southwestern to the eastern Amazon as well as western Pará and the eastern Amazon. In these regions, global payments could generate up to US$48 ± 9 billion for Brazil by 2025 if emissions reduction targets in place in 2018 were met.[39] Monetary values could reach up to US$100 ± 20/ha/yr, particularly in the eastern Amazon, northwestern Mato Grosso, near Manaus and along the region's major roads.

A more recent study by scientists participating in the IPBES assessments criticizes proposed revisions to the national Forest Code that would abolish the requirement for Legal Reserves, quantifying potential losses to natural capital that would arise due to blanket permission for deforestation (Metzgar *et al.* 2019). The study "synthesizes the principal benefits of Legal Reserves, including health and economic benefits, and emphasize the importance of these reserves for water, energy, food, and climate securities, in addition to their primary function of assisting in the maintenance of biodiversity in agricultural landscapes" (Ibid.).

13. Summary of externalities identified according to the TEEBAgriFood Framework

Table 4 summarizes in an integrated fashion the principal impacts and dependencies of the two value chains studied for this report, classifying the externalities according to their effects on natural capital stocks and flows respectively. Reference is made to details found in the full text with no pretense to being exhaustive.

[39] The current administration's general repudiation of Brazil's co-responsibility for global climate regulation could seriously undermine efforts to safeguard the Amazon forest under the Paris Accords.

Table 4: Summary of externalities in the TEEBAgriFood Framework		**Soy-Maize and Beef Cattle Value chains**			
		Agricultural production	***Manufacturing & processing***	***Distribution & marketing***	***Household consumption***
STOCKS					
Natural capital	**Water**	Sedimentation of waterways due to insufficient streambank protection, pasture degradation and deforestation Agrochemicals contaminate water supplies in "toxic cocktails" Water footprint from beef and soy production depletes regional water resource stocks	Pollution of waterways from slaughterhouse and tanning waste (controlled with settling ponds in larger operations)		Water quality affected by disposal of residuals from cattle feedlots, slaughterhouses and agroindustrial facilities; Water export in form of soy and beef shipped overseas
	Soil	Soil erosion and nutrient export from degraded pastures and exposed agricultural soils, partially abated by use of no-till practices valued at net R$4.46/ha/yr			Nutrient export in form of grains and meat shipped overseas for consumption and processing
	Air	Atmospheric GHG and particulate matter concentrations increased due to forest fires from deforestation and pasture burning, and by aerial spraying of agrochemicals	Ambient air quality and atmospheric GHG concentrations increased by power use in slaughterhouses and fuelwood for crop drying	Ambient air quality and atmospheric GHG concentrations increased by agricultural product and beef transport, primarily trucking (diesel)	High per capita beef consumption increases GHG emissions
	Vegetation cover and habitat	Carbon stock loss due to deforestation: valued at up to US$100 ± 20/ha/yr	Legal conditions (TACs) on slaughterhouses to ensure suppliers obey forest code provisions on forest cover		
	Biodiversity	Irreplaceable loss of endemic diversity and reduced species richness due to deforestation; Threats of GMO and pesticide dependence to agrobiological diversity		Rudimentary transport corridors without adequate land use governance threaten remaining Amazon biodiversity	Loss of food diversity due to concentration on a limited number of crops and animal products

Table 4: Summary of externalities in the TEEBAgriFood Framework		**Soy-Maize and Beef Cattle Value chains**			
		Agricultural production	***Manufacturing & processing***	***Distribution & marketing***	***Household consumption***
	Buildings			Transport infrastructure stocks are declining in value relative to GDP, due to disinvestment and depreciation	
Material capital	**Machinery and equipment**	Economies of scale in grain production imply need for greater investment capacity			
	Infrastructure	Sedimentation of waterways and deforestation-induced climate change reduces useful life and power potential of hydroelectric facilities; fencing of APP enables regeneration of native vegetation		Rudimentary transport corridors on dirt roadways increase costs and facilitate access to remote areas to open agropastoral frontiers, increasing deforestation	Reliance on long commercial circuits for urban food supply increases costs and impacts
	Research and development	Research innovates in providing best practice information (BPA) and systemic integration (ILPF)		Deforestation monitoring involving multi-stakeholder group	
	Finance	Banking system unsupportive of low-carbon production options in Amazonia. Purchase price premiums for conventional (non-GMO) soy and quality beef	Profits from improvements in production systems are captured by slaughterhouses and supermarkets	Financial sector dominated by multi-national traders dictate input supply and product channeling as a condition of credit	
Human capital	**Education / skills**	Principal deficit of training and organizational capacity among smallholder ranchers			Consumer education needed to reduce food waste
	Health / Age	Agrochemicals and particulate matter increase local respiratory and mental morbidity rates			
	Working conditions (decent work)	Informal labor markets predominate in North region, reducing average wages; labor conditions analogous to slavery persist in Amazon ranching and timber extraction	Unhealthy and dangerous working conditions in slaughterhouses due to exposure to cutting blades and freezing temperatures		

Table 4: Summary of externalities in the TEEBAgriFood Framework		**Soy-Maize and Beef Cattle Value chains**			
		Agricultural production	***Manufacturing & processing***	***Distribution & marketing***	***Household consumption***
Social capital	**Land access/tenure (private, public and communal)**	Extensive cattle land use results in loss of land access by smallholders and reconcentration in land reform areas			
	Food security (access, distribution)	Growing use of non-GMO soy responds to price premium of US$ 3/60 kg sack, 65cience. 15% of market	Prosecution of slaughterhouses that do not ensure sustainable sourcing	Inspectors' failure to condemn tainted beef from major meat packers led to export embargoes, reputation loss.	Concentration in beef market affects price competitiveness and consumer costs
	Opportunities for empowerment (gender and minority)	Conflicts between indigenous populations and agribusiness stimulate protest movements			
	Social cooperation and networks/unions	Cooperation of producer associations in multistakeholder roundtables	Agribusiness participation in multi-stakeholder roundtables		Consumer movement to condition beef sale by sustainable origin
	Institutional strength	Rural lobby victorious in reducing environmental restrictions (Forest Code)			
	Laws and regulation (e.g. child labor)	Monitoring and legal safeguards against child labor and slavery conditions	Terms of environmental adjustment condition cattle purchase by meatpackers on sustainable farm origin	Terms of environmental adjustment condition beef purchase by supermarkets on sustainable farm origin	
FLOWS					
Outputs	**Agricultural and food production**	Soy productivity mean 3.35 t/ha; Maize productivity mean 5.5 t/ha (Mato Grosso, 2017) Cattle 1 AU/ha in extensive pastures; Feedlot finishing can increase productivity up to 9 AU/ha	Agricultural by-product markets (ethanol, biodiesel, hides, etc.) generate additional revenues	Complex and outmoded logistics for raw material supply; inadequate storage facilities	
	Income / operating surplus	Net returns to producers in beef chain are constrained by monopsony		45% of beef exports are to Chinese ports; processed meats go to Europe and USA	

Table 4: Summary of externalities in the TEEBAgriFood Framework		**Soy-Maize and Beef Cattle Value chains**			
		Agricultural production	***Manufacturing & processing***	***Distribution & marketing***	***Household consumption***
	Labour	Housing, training and health care provided to formally employed farm workers; but most labor is informal in Amazon region	Risk of mutilation and overwork stresses in slaughterhouses		
	Intermediate inputs (fuel, fertilizer, etc)	Increased costs of chemical weed control in soy due to herbicide resistance (R$ 120 to R$ 386/ha)		Increased logistics costs (25%) and CO_2 emissions due to road modal for 2/3 of grain transport	
Ecosystem services	**Provisioning (e.g. biomass growth, water)**	Non-compliance with legal reserve and permanent protection areas threatens water resource provision for on-farm needs and regional consumption			
	Regulating (e.g. pollination)	Pollination deficit may reduce soy and ecosystem productivity due to excessive pesticide use and deforestation			
	Cultural				
Residual flows	**Food waste**	In-field crop losses are low due to harvest efficiency; animal health and welfare are problematic in feedlots			Mean 128 kg / household/yr of food waste, 20% of which is beef
	Pollution and emissions (excess N & P, GHG emissions, etc.)	- Water supply costs due to sedimentation by soy-maize erosion valued at R$ 2.13/ha/yr. - Feedlot finishing reduces GHG emissions by 20% and land use change by 37% but increases water pollution discharges. - Respiratory health costs due to smoke inhalation from forest fires and pasture burning	Respiratory health costs due to smoke inhalation from crop drying	Air pollutants and GHG emissions due to use of diesel trucking for most grain and animal transport	

7. ECO-AGRI-FOOD SYSTEM GOVERNANCE

In this chapter, we consider the implications of the findings from the Framework test for actors in the two supply chains and their relevant policy interfaces. We also explore the potential response to modifications in credit terms and related technical support as a basis for dissemination of more sustainable production, processing and transport practices.

1. Stakeholder roles, current and potential alliances and governance of change

The principal institutional drivers of change in agricultural and livestock production systems underway in the Brazilian Amazon has been led by non-governmental organizations[40] in alliance with research institutes, traders, supermarkets and processors. EMBRAPA (in particular the beef cattle research center in Mato Grosso do Sul and Embrapa-Acre) was an important force for change in pasture systems and is at the forefront of the move toward ILPF systems. There was also a strong role taken by the federal Public Prosecutor in the case of the slaughterhouse embargoes and ensuing adjustment terms (TACs) imposed beginning in 2009. Two commodity oriented multi-stakeholder roundtables established in the 2000s (RTRS and GTPS) have assumed important roles as conveners and definers of certification norms.

Tactics have evolved from boycotts in the 2000s to a more collegial approach in the current decade. Nevertheless, defections have occurred, and in a political climate rife with charges of corruption, the principal beefpackers have been targeted. While they benefited from national development capital largesse in the 2000s, permitting them to accumulate global assets, they suffered financial losses in the 2010s, leading to some industrial breakups. The major soy conglomerates and traders, primarily multinational, have rarely suffered such public exposure. One of the leading national soy producers (Blairo Maggi, largest soy producer in Mato Grosso) was named minister of agriculture.

Public policies to combat deforestation recognize how important the promotion of sustainable productive arrangements can be to offer alternative sources of income to counter illegal logging and land speculation, asserting that the promotion of food chains must be conditioned on sustainability standards (MMA 2016). MMA recognized the convening power of working groups and negotiating tables underway in Brazil, such as the WG on Sustainable Livestock (GTPS), Round Table on Responsible Soy (RTRS-Brazil), and the Soy Moratorium, while creating corresponding WGs within the government in 2018.[41] Furthermore,

[40] The principal NGOs involved were Greenpeace, WWF-Brazil, the Amazon Research Institute (IPAM), Imazon, Imaflora, Amigos da Terra-Amazônia Brasileira, TNC and ICV.

[41] Two working groups (WGs), the Sustainable Livestock WG and the Soy WG were created by the MMA Department of Forests and Combating Deforestation in early 2018. These WGs were set up to promote discussion and the search for solutions, strategies and dissemination of practices to control deforestation stemming from the soy production chain and the livestock sector. Most multistakeholder WGs have since been disbanded.

responding to actors committed to the low carbon agriculture agenda, the Brazilian Climate, Forests and Agriculture Coalition[42] has created a specific WG to discuss the limitations of ABC credit.[43]

In a break with the adversarial tactics that have shaped the debate over the Brazilian Forest Code, environmental NGOs have thus increasingly taken on the role of fomenters of improved practice through on-farm demonstration trials together with ranchers. While they have been successful in a few cases of converting degraded pastures and enhancing livestock husbandry, the number of adopters has been limited and few are convinced enough by the results to put up their own resources for investment in such improvements. The principal challenge therefore is one of going beyond demonstration to achieve at scale what has been accomplished with ILPF, now well over 11 million ha (though limited in the Amazon biome).

The following subsections describe the principal objectives of best production practices and the regulatory framework which supports them. The remainder of the section is devoted to the potential to revamp credit offerings in the direction of more sustainable food systems in the Amazon.

2. Improved production systems and associated regulatory instruments

The principal objectives sought by movement toward crop and livestock intensification and the adoption of best practices, include the following central measures:

1. Maintenance of forest reserves and the restoration/protection of streambank and hilltop forests;
2. Conversion to no-till crop production in soy and maize;
3. Forest integration with crops and/or pasture (ILPF);
4. Reduced agrochemical and GMO use, biological control of pests and weeds and inoculation with nitrogen fixing rhizobia;
5. Reduced use of fire in pastures, and in forest clearing for crops and pastures;
6. Improved labor conditions (formal employment according to federal labor laws, including provision of housing, food basket, sanitary facilities and health care);
7. Waste treatment and energy efficiency in crop drying, beef slaughter and tanneries;
8. Logistics improvements to reduce dependency on trucking and extension of unpaved roadways;
9. Reduced waste along supply chains and in final consumption segments;

Such practices, whose characteristics and potential impact on reduction in externalities are explored in Section 5, are supported by a policymix that relies on the following specific instruments:

[42] Participating in the Coalition are several stakeholders, such as the Brazilian Agribusiness Association (ABAG), Cargill, Carrefour, Grupo Boticário, Imazon, Imaflora, Sugarcane Industry Union (UNICA), Sociedade Rural Brasileira (SRB), Bolsa de Valores Verde (BvRio), to name a few. In total 190 organizations participate in the Coalition. See: http://www.coalizaobr.com.br/home/

[43] The Coalition recommended in its position paper presented at COP24 in Poland: "The Harvest Plan, one of the main sources of credit for the Brazilian rural producer, will have its portfolio fully tied to low-carbon practices, as does the ABC Program. Other sources of credit for activities that impact land use and its carbon emissions will follow the same pattern" (Coalition Brazil, Climate Forests and Agriculture 2018: 16).

1. Forest Code land use strictures (principally the requirement that, in the Amazon biome, Legal Reserves and Permanent Protection Areas total at least 80% of each property; in Cerrado areas of the Legal Amazon, this proportion drops to 35%, and the revisions in the Forest Code in 2012 permitted that consolidated land uses in protected areas as of July 2008 be permitted to remain under their current use);
2. Property rights regularization (as part of a commitment to legalize land occupation and thus permit access to credit and other supports as well as legal deforestation where permitted, there has recently been an acceleration in land titling, not rigorously linked to environmental compliance);
3. Deforestation permissions (state governments have assumed authorization power to permit legal deforestation in areas not subject to Forest Code constraints; the majority of deforestation underway is however illegal and if detected and served, results in criminal punishment under the national Environmental Crime law);
4. Agrochemical restriction (currently under fire from rural lobbies to liberalize market access to pesticides and agrochemicals even if they have been banned in other countries; since the current administration took office over 800 previously restricted agrochemicals were permitted to be marketed and applied in Brazil);
5. Labor and gender relations (although the national consolidated labor laws are rigorous, only a relatively small proportion of rural workers are employed with "*carteira assinada*" (signed employment card), guaranteeing retirement benefits, paid vacations and a 13th month wage; gender inequality is generalized in wages and benefits.

1. Credit incentives for improvement in production practices

Rural credit as an institutionalized policy was born in 1965 in Brazil, with the enactment of Law 4,829/1965, whose objectives were to stimulate the increase of rural investments, to favor timely and adequate funding, to enable the economic strengthening of small and medium-sized rural producers, and encourage the introduction of rational production methods for increased productivity, improved living standards of rural populations, and adequate soil protection. Since its inception, defining vectors of this credit policy are to assist credit beneficiary producers (portrayed in the law as an "adequate costing" objective), productivity increase, and "improving quality of life "in the countryside, prioritization of small and medium producers, as well as soil protection.

According to Sayad (1984), at the time that many economists had pointed to the need for a more stable and greater supply of financial resources as a factor limiting better performance of the agricultural sector. Although it can be argued that rural credit tended in certain periods, such as during the "painful modernization" of the military regime (Silva 1982), to give preferential treatment to large producers rather than to social concerns, all the vectors mentioned were present in the discussion since their conception.

Rural credit remains, as a rule, indifferent to different productive models (and different impacts), in the sense that the producers and the forms of production that are more environmentally desirable are not prioritized in the context of scarce resources: credit is no easier for them to take on, nor is their cost cheaper. Incentives are not currently calibrated for transition.

It is a fairly recent idea to take into account the positive and negative externalities, which are usually neglected or even unknown, to look at the value chain as a whole, and to adapt the credit instrument in order to reflect: i) social and environmental risk; or ii) the desirability of the current mode of production-distribution-consumption, taking into account externalities and environmental and ecological losses in the process, consistent with the TEEBAgriFood initiative.

Environmental credit lines are more an exception rather than a rule, and in the notorious case of the ABC Plan (see below), they are said to be more labor-intensive (which also discourages such options economically due to the loss of time involved to plan the intervention and the need to hire a specialist), difficult to achieve, nor are they attractive to the main financial agent of rural credit, the Bank of Brazil, besides being little accessible to other financial agents.

There is nevertheless a growing concern in the agricultural sector with the need to secure financing for sustainable productive activities that value the maintenance of the standing forest in the Amazon and Cerrado biomes. Consequently, production of beef and soy is being increasingly encouraged and/or regulated to be based on sustainable production technologies (intensification, ILPF, no-till, pasture recovery, etc.). Such technologies are purported to enhance productivity while adopting conservationist agricultural practices, thus averting the need to open new production frontiers via deforestation.

1. Evolution of environmental conditions on agricultural credit in Brazil

Agricultural credit constitutes the main public policy instrument to support agribusiness in Brazil, mobilizing an annual volume of resources on the order of R$ 197 billion according to the Agricultural and Livestock Plan launched in June 2018, in the annual instrument known as “Harvest Plan” the volume of resources that the country provides for the agricultural sector in the form of credit. According to information from the Central Bank, which refers to the effective contracting of credit in the last agricultural year, “in the period from July 2017 to June 2018, the amount of rural credit contracted was R $ 171.4 billion, 6% higher than the same period in the previous agricultural year” (BACEN 2018).

Regarding the rural credit portfolio of the overall National Financial System – SFN,[44] in August, 2018, the amount available for rural credit represented 10% of the overall total of the SFN loan portfolio. “Every

[44] The portfolio criterion considers the debit balance of all agricultural credit accounts of all banks and financial institutions (credit unions for example), while the Harvest Plan refers to the volume announced for the year, i.e., a programming of credit concessions in the year. Thus, the Harvest Plan is a goal, which may or may not be fulfilled in its entirety or even exceeded. An investment credit of R$ 3 million will count (with the respective balance due) for five years, since it will be the asset of the financial institution for the same period, while a one-year credit against expenditures will not affect the balances in subsequent years (except for bad debts). The amount actually contracted during the agricultural year is a third measure but is also referenced in the credit granted in the year. In the Harvest Plan for the 2017/2018 crop cycle, R$ 200.25 billion were announced, but the execution in the period, as indicated, was R$ 171.4 billion.

year, the amount of credit available corresponds to about 40% of the value of agricultural production, making it an important source of financing for agribusiness" (Ibid.).

We here highlight several positive experiences that point to credit as an incentive and signaling tool both for the transition to a mode of production with greater conciliation with the preservation of the Amazon biome and for the consideration of socio-environmental risk in credit analysis. The role of credit, although important, must be seen as complementary to purchasing policies and mechanisms for internalization of socio-environmental externalities via prices or taxes.[45] The following initiatives are some examples in this sense and involve public policies, actions of financial institutions operating in the country, and activities of service providers that facilitate geographic and environmental risk analysis, and an international reference document edited by the Financial Standard Setting Body:

1. Issuance of Resolution 3.545/2008 by the National Monetary Council, which required land and environmental regularity as a prerequisite for credit concession – whose impact is addressed in Box 4;
2. Issuance of Resolution 4327/2014, which establishes guidelines and requires the implementation of a Social-Environmental Responsibility Policy (PRSA) by financial institutions;
3. Recent CMN resolutions 4667 and 4668 that changed rules that established a differential for ABC credit, such as a ceiling per borrower of R$ 5 million, and an interest rate of 5.25%/yr, lower than other rural credit lines, and therefore serving as an incentive to its use; it also established the possibility of forest restoration, up to 10% of the credit taken to defray costs;
4. Lines of credit aimed at or incorporating the environmental/ecological component for the family farmer, notably:

    1. Pronaf Agroecology, for investment in agroecological or organic production systems;

    2. Pronaf Forest, for agroforestry systems, extractive exploitation ecologically sustainable, restoration and maintenance of APP, recovery of degraded areas, compliance with environmental legislation or enrichment of forest cover;

    3. Pronaf Semi-Arid, for investment in means for coexistence with semi-arid conditions, prioritizing water infrastructure;

    4. Pronaf ECO, for investment in hydropower plants; renewable energy technologies; environmental technologies; environmental adequacy projects; adaptation or regularization of environmental legislation; implementation of nursery seedlings of certified forest and fruit trees and forestry;

    5. Oriented Productive Microcredit, which allows investment in technological innovation; implementation of infrastructure for abstraction, storage and distribution of water and

[45] We focus here on elements that are more directly related to the credit relationship, leaving out actors like NGOs although the activities of several of these have focused on improving the technical aspect of finances in regard to environmental issues, and other actors such as large retail chains, whose purchasing policy may be a central element in terms of their potential to migrate toward a more appropriate performance within an Eco-Agri-Food chain.

> irrigated agriculture; agro-ecological or organic production systems; restoration and maintenance of degraded area preservation or recovery areas.[46]

Regarding the above Pronaf credit lines, Godoi *et al* (2016) shows that although sustainability elements were incorporated in some lines, these continued to offer a marginal share of overall credit offered to family farming and agrarian reform beneficiaries who are the principal clients of Pronaf. Financing agents prefer lines that encourage the use of conventional credit. The incorporation of sustainability has not as yet generated significant operational changes within the financial institutions operating in the field.

Changes in credit policy, Godoi points out, may be more effective if they take into account the worldview of the different actors involved and the managerial conduct of the financial institutions. It is noteworthy that in cases where there is use of credit to support migration to sustainable practices, other intervening factors have enabled this transition, such as support to short marketing circuits, sales to institutional markets, technical assistance commitment to agroecology, and social organizations that understand that sustainability is important for the future of family farming. Thus, the improvement for a socio-environmental credit policy should occur in conjunction with public policies that involve the above elements, "providing greater coherence to the multidimensional character of sustainability" (Ibid.).

Credit policy, even in the case of family farming, has contributed to the concentration of contracts, especially those for investment purposes, in states with more consolidated family agriculture, and where it was possible to observe an increase in average contract value. The data on the lines themselves show that they tend to provide credit focused on the "product" and investment focused on the "item or equipment", thus reproducing traditional financing models, while the most effective models at a small scale would follow a systems perspective focused on the entire farmstead in a landscape context.

Technical personnel interviewed by this study stated that lower interest rates for sustainable techniques would have greater impact, in terms of encouraging adoption, than line-specific ones. They also criticize the complexity and proliferation of rules.

The social leaders interviewed pointed out the ease of access to credit without planning, the use of simplified "boilerplate" for obligatory projects, sometimes without verifying the farmer's or the property's aptitude for the production system in question. Rather, the interests of the intermediary institution and the technician may prevail, which might be suboptimal for the farmer.

Cultural aspects are also important in aiding transition. Many of those who decide to make the transition to organic techniques, for example, had already learned from their parents and peers that "agrochemicals do no good". This factor facilitates the transition. Even among conventional agricultural producers, many grow crops without agrochemicals for their own household consumption, suggesting they are well aware of the dangers involved in their consumption. Opportunities for dialogue through training and other contexts are also important.

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[46] It should be noted that many of the bottlenecks described in detail with respect to the ABC plan in this section also are applicable to the PRONAF lines with socio-environmental objectives in terms of access, uptake and knowledge on the part of banking agency managers.

Table 5 shows data tabulated by the Central Bank, specifically from the National Rural Credit System, regarding all Pronaf contracts in Brazil in 2018. It can be seen that the program's "sustainability" lines account for only 6.05% of total credit volume. Resources contracted with the remaining 94% went primarily to Pronaf's general credit offerings or specific public lines (e.g., young farmer credit). Almost 80% of total Pronaf credit was concentrated in the lines of General Cost or "*custeio"* and "More Food" ("*Mais Alimentos*"), which is also a generic and flexible line (Godoi, 2016). When the criterion of quantity of contracts entered into is used, the representativeness of sustainable lines is even smaller, with 3.1% of the total number of contracts (87% of which refer to the semiarid line, which is not applicable to the Amazon biome).

Compared to the amount applied nationally for each Pronaf line, the states of the Legal Amazon together have a low participation in the Agroecology line (1.1% of the national value, when the average participation of the same states in the overall Pronaf volume is generally about 12%). The Forest line is primarily directed to the Amazon, securing 94% of the volume applied nationally (83% of total contracts). The Eco line applies 35% of the volume of resources in the states in the Amazon, a more than proportional application, but that does not remain under the perspective of the amount of financing.

Table 5: Pronaf Credit Lines: 2018

Credit Line	Brazil - Value (R$)	% of credit line	Amazon Value (R$)	Amazon % of Line	Contracts – Amazon	Value per Contract
'More food' (investment)	8,621,599,617	32.8%	1,803,298,359	46.0%	40,805	44,193
Annual credit	12,126,593,126	46.1%	831,958,333	21.2%	28,655	29,033
Youth	532,306,374	2.0%	480,681,013	12.3%	390	1,232,515
Forest	350,361,402	1.3%	323,070,343	8.2%	1,747	184,929
Microcredit	1,702,663,828	6.5%	192,708,200	4.9%	47,818	4,030
Women	458,796,703	1.7%	13,845,1957	3.5%	1,624	85,254
Agroindustry (investment)	298,080,505	1.1%	46,657,708	1.2%	8	5,832,214
Eco	114,338,400	0.4%	39,768,681	1.0%	146	272,388
Agrarian reform	190,490,756	0.7%	28,772,144	0.7%	4,355	6,607
Agroindustry	799,588,159	3.0%	16,050,656	0.4%	6	2,675,109
Agroecology	962,392,172	3.7%	10,172,404	0.3%	11	924,764
Semiarid	166,303,668	0.6%	5,999,934	0.2%	16	374,996
Total	26,323,514,710		3,917,589,732		125,581	31,196

Source: Authors' analysis based on SNCR-Bacen data.

Box 4. Effect of conditioning credit on reduced deforestation

The study of Assunção *et al.* (2016) uses a quasi-experiment technique, set up to measure the causality of the demands brought by Resolution 3,545/2008 to reduce deforestation. This standard conditioned the granting of rural credit for agricultural activities in the Amazon biome, on proving compliance by borrowers with the requirements of legal title and observance of environmental regulations (chiefly rural environmental licensing).

The empirical strategy, aimed at controlling the effects of observable and unobservable factors, used the methodology of differences in differences from a database of 179 municipalities that are inside or outside the Amazon biome, but inserted within 100 km from the border of the Legal Amazon region. The database did not include municipalities cut by the border, since they are neither totally outside nor within the defined area.

Estimates indicate that the total deforested area observed from 2009 to 2011 was between 52.9% and 58.4% lower than it would have been in the absence of regulatory change with credit constraints (Figure 26). All specifications used include fixed effects of municipality and year. The impact of 52.9% reduction was also measured by controlling for agricultural prices, environmental policies such as municipal territory under environmental protection, whether or not it is a priority municipality to combat deforestation, in addition to the annual number of environmental fines applied in the previous year, as well as the share of areas embargoed by the policy.

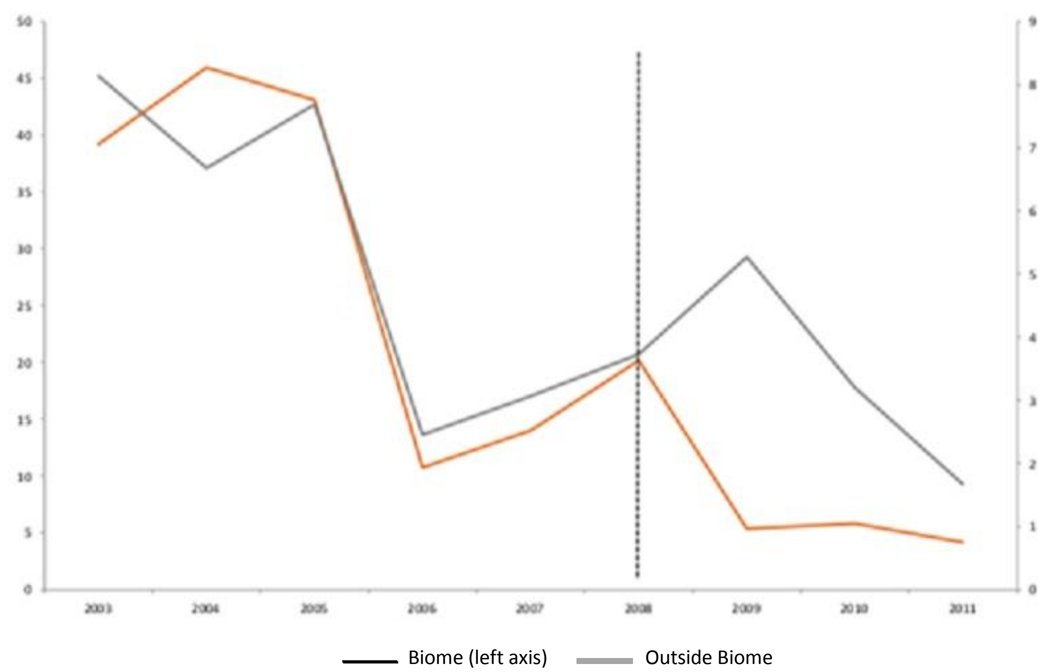

Figure 26: Municipal level deforestation data before and after Monetary Council resolution (vertical line: 2008), comparing municipalities within the Amazon (treatment) and outside biome (counterfactual). Source: Assunção et al. 2016.

After presenting the percentage of deforestation reduction obtained, the study concludes that "conditioning of rural credit is an effective policy to combat illegal deforestation". "Yet, differential effects across sectors and regions suggest that it should complement, rather than substitute, other conservation efforts…. Our finding (was) that credit reduction came mostly from a reduction in cattle loans rather than crop loans." "Implementation details also matter — less stringent requirements and exemptions for small producers determined that medium and large producers were more affected than small-scale ones" (Assunção *et al.* 2016, p.21). The authors also note that "Our results also support the view that the Amazon biome is used to expand production at the extensive margin (through the clearing of forest areas for agricultural conversion), and not at the intensive margin (through increased productivity). The predominance of cattle ranching in the region and the correlation between this activity and extensive land use in the Amazon is consistent with these results" (Assunção *et al.* 2016, p.20).

Private Financial Institutions (FIs) such as Rabobank and Santander are pointed out by actors as examples that, in their socio-environmental risk management policies, started to differentiate rates according to different risk levels.

As one of the actors interviewed, a responsible soy certifier pointed out, "there already are advantages for certified producers. These producers have less socio-environmental risk and thus achieve lower interest rates."

Service providers: a series of services have emerged as a way to enable the agricultural chain to be in environmentally compliant, whether monitored or having its socio-environmental risks assessed. This is the case of services such as Terras®, SafeTrace® and Agrotools®.[47]

Standard Setting Bodies: The Financial Stability Board (FSB) is an international body created to promote stability in the international financial system, based in Basel, Switzerland, that monitors and makes recommendations on the global financial system.[48] FSB launched recommendations on how to measure and publicize risks related to climate change in June 2017 (FSB 2017). Since then, the organization has been working to foster the adoption and integration of this universe into traditional financial statements.[49]

In the following sections, we consider suggestions for considering improvement in rural credit as a whole (Harvest Plan) and secondarily, specific to the ABC Plan, regarding the issues of incentives and ease of access. In the final section, we cite preliminary data regarding the transition cost, noting that ideally there should be an incentive, whether or not through credit offerings, sufficient to justify the effort required to reorient production to reduce socio-environmental impacts.

[47] Several private service providers offer solutions in this sense, with different characteristics and breadth of scope:, see, for example: TERRAS (https://www.terras.agr.br/), SafeTrace (http://www.safetrace.com.br/st2010/Pagina.do?idIdioma=2), and Agrotools (https://www.agrotools.com.br/en-us/).

[48] The FSB, in addition to assessing the vulnerabilities affecting the global financial system, as well as identifying and reviewing, in a timely and continuous manner, from a macroprudential perspective, the regulatory, supervisory and related actions necessary to address such risks, works for the cooperation of supervision and regulation of financial systems, as well as for the creation and implementation of intentional standards (FSB 2018).

[49] Although financial disclosure on climate change is still in its early stages, between the launch in June 2017 and September 2018, the number of companies and entities that have committed to the adoption of the FSB document has jumped from around 100 to over 500, accounting for a total capitalization of US$ 7 trillion. Of the nearly 500 firms, 287 are from the financial sector and manage assets of around US$ 100 trillion. It is the sector of greatest or more rapid adhesion to such concerns. The FSB's view on the subject is "Through widespread adoption, climate-related risks and opportunities will become a natural part of companies' risk management and strategic planning processes" and that "long-term investors need adequate information on how companies are preparing for a lower-carbon economy; and those companies that meet this need may have a competitive advantage over others" (FSB 2018, p.iv).

1. Restructuring rural credit with socio-environmental priorities

To restructure rural credit from an Eco-Agri-Food perspective, it is essential to ensure that incentives are present and meaningful to encourage environmentally desirable production vis à vis Business as Usual. Such incentives should simultaneously ensure i) greater ease and less bureaucracy for access (differentiated simplification of access conditions); ii) lower interest rates; iii) creditors who already produce in an environmentally superior way or who wish to transition to a more balanced model; and iv) that incentives should not only be significant but persistent over time.

Agricultural producers interviewed point out as primary factors that would favor the transition toward more sustainable systems, a lower interest rate compared to other credit lines and less bureaucracy compared to other rural credit options. The inclusion of longer repayment term limits was also mentioned, but less decisive compared to the cost of credit and ease of access (which also would imply a less costly dedication of time needed to obtain financing and/or hiring specialists).

These findings are in agreement with the results of an evaluation of the PPCDAm program to control deforestation (IPEA 2011), which pointed to the need that support systems avoid favoring conventional practices and, specifically with regard to credit, that their provision should demand less rather than greater requirements be satisfied to stimulate sustainable production.

As for prioritization, in the context of scarce resources for the bulk of the country's agricultural producers, the treatment as priority borrowers those properties linked to production practices with more positive externalities, such as compliance with the Forest Code, is a criterion defended by the Climate Policy Initiative among other actors.

At the same time, one of the interviewees argued that public resources, such as rural credit under favorable conditions, should be directed towards the promotion of the public good, practices associated with conservation of the environment: "Public resources for public goods. A subsidy only makes sense if it is to reconcile with the environment or implement a technological change in production. Subsidizing to 'keep moving' should no longer exist" (Producer interview, Mato Grosso 2018).

Inclusion of environmental agents and big data in decision making

The governance and modus operandi of the Harvest Plan can be better balanced with involvement of a body whose environmental mission can weigh the decision-making process, whether in the design or in the adjustment of policies. There is currently no participation of environmental entities in the main discussions that determine the structuring of the rules of the Harvest Plan. Rule changes are discussed and decided upon solely with the bodies responsible for production within MAPA.

One of the interviewees pointed out that "In the Harvest Plan the environmental issue is not an 'item'. Today, not even ABC Plan rule changes are discussed with MMA, but only directly with the area responsible within MAPA" (Certifier interview, Mato Grosso 2018).

Such governance, while reflecting the path dependence of rural credit structuring, tends to make it difficult for the environmental component to receive balanced attention in its composition with the hegemonic productive vector.

To more adequately integrate environmental concerns, there should be an adequate assessment of the environmental aspects for credit concession, adopting a geographical perspective on the whole property; environmental checks from available databanks ("environmental Serasa", see below) and input by specialized third parties. Not only should financial institutions move towards geospatial analysis of deforestation using SICAR and other public databases, but also rely on third parties to provide specialized screening on the subject.

According to one interviewee with extensive experience in the financial system, "only large financial institutions could carry out environmental checks via big data, but even for the largest institutions the evaluation of the socio-environmental issue is, at least for now, far from the core business of the bank". The interviewee added that "In the bank, in terms of system with lines that have to be filled, the question is whether it adheres to the policy of the Forest Code? The commercial manager, who does not even know what it is, guesses 'YES'. And do you adhere to the National Waste Policy? The manager says 'YES!'". (Trader interview, Mato Grosso 2018).

Third party screening plays an important role, to facilitate the management of socio-environmental risk, point out conformities, monitor the changes in vegetation cover with satellite images from SICAR,[50] bringing informational quality in relation to environmental risk, at the same time favoring greater speed in the credit concession processes and documentation needed for the producer interested in the financing. Credit policies can also rely on this type of solution to promote differentiated simplification (larger for models with more positive and less negative externalities). There may be a reduction in procedures or bureaucracy for credit request and analysis, with documentation being reviewed by screening, which tends to be even more effective in assessing the environmental risk involved.

In addition to solutions already available, an environmental database such as the SPC/Serasa system[51] should be conceived, as suggested by one of the actors interviewed, and endorsed by this study. Such a system should be built with broad discussion, participation by the national federation of bankers (Febraban), in dialogue with the Central Bank and other regulators. An environmental SPC would be good for all actors, except those who intend to produce without observing the minimum environmental rules (and still aim to access subsidized resources in the process). Such an "Environmental SPC/Serasa" could have a positive registry identifying, for example, producers and properties who do not have forest reserve deficits, and a negative side, for example, indicating actors subject to legal proceedings. This would result in credit being automatically declined. As the interviewee affirmed: "To be developed, you have to have things that you do not negotiate with, you have to have legal reserves, period, you cannot have slave labor, period" (Interviewee, Mato Grosso 2018). This informational content should not only influence

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[50] Such data is now publicly available through the statewide SICAR registries which include information on rural properties' compliance with land use requirements of the national Forest Code. See http://www.florestalbrasil.com/search/label/SICAR?&max-results=8

[51] The SPC/Serasa system is a national credit rating and vendor protection service, offering rapid response. See https://www.spcbrasil.org.br/home

whether or not financing should be conceded, but also would influence the interest rate, since good practices reduce the risk to the borrower and improve the externalities.

An additional approach to credit conditioning using such data sources would involve the integration of SICAR with the BACEN database on Rural Credit Operations and Rural Insurance (Proagro). Such an approach has been advocated by the INPUT Land Use Initiative.[52]

Strengthen technical support and accompaniment of credit operations

There is an evident need to strengthen the technical follow-up of credit operations, where investment operations involve change or improvement in production practices. Such technical assistance requirements for credit concession, when directed toward large producers, should also involve technical supervision, as a part of the credit operation. The technical agent responsible would have to file a periodic report directly to the lending bank regarding the status of the production system. Should something go amiss, the producer would have to explain and/or adjust and, if necessary, have loan maturity called in and to return the funds provided on credit. The percentage of the loan dedicated to technical assistance should be sufficient to monitor the operation and should be calibrated according, to the scope of change in planned production practices.

It is consensual that there is no way to achieve a transition in production practices with lower externalities without technical monitoring of the operation. Livestock producers, however, do not recognize this need, tending to invest primarily in livestock to the detriment of soil, pasture and environmental issues (preservation or restoration of natural vegetation), even in view of proven benefits to the productive process (such as available water, less need for movement of cattle, shade, higher productivity, higher rate of return, etc.). Even producers participating in projects with improved production practices, such as the Novo Campo with support from the ICV and the São Felix do Xingu project supported by the TNC (see Section 3), show cultural resistance to the adoption of better farming practices and, once the support is finalized, tend to regress to their prior form of production.

According to one of the actors interviewed, this fundamental point motivated the main change of approach between the initiatives of Novo Campo and creation of PECSA, that is, the incorporation of corporate responsibility for the productive side: “We came to the conclusion on PECSA because of this. In the ICV pilot we also had this. When the ICV resources were withdrawn, and it came to the producer to do something ... ‘Oh I do not have cash to do this’. Let’s buy fertilizer when the rains come, ‘Oh, I do not have any money.’ You stay hostage.” (Interview with technical assistance agent, Mato Grosso 2018).

Of course, it is not up to the bank to take responsibility for the operation. It should be up to the responsible technical agent to certify that the investment was made, and that production occurs according to the indicated transition. Thus, in order to improve both technology and improvement in environmental externalities, credit for large producers should be considered elements cited as mandatory for technical monitoring; direct reporting to the bank, with a calibrated value for this monitoring and for the planned

[52] The INPUT initiative, a joint venture between the Climate Policy Initiative and AGROÍCONE, monitors low-carbon credit and land use impacts in Brazil. See: https://www.inputbrasil.org/?lang=en

operational change. In this sense, 2% of the amount of credit (as required by the ABC Plan) can be too much to prepare the project and make two visits, but very little to follow the operation, to guide the new practices in implementation, and to be technically responsible, besides reporting on progress, aspects essential to break the business-as-usual logic. One of the issues portrayed in the qualitative research is that there is an underestimation of the degree of difficulty of managing a farm, considered tacitly as easy. However, farm management involves adjustment and knowledge of chemistry, biology, financial structuring, etc.

Another issue to point out is that as of July 2018, Rural Credit for current expenditures (*custeio*) could no longer incorporate 2% of the total amount to be allocated to technical assistance within the operation itself. Although we are particularly concerned here with investment (a point also addressed in the next recommendation), it would be worth reassessing whether the policy is not moving in the opposite direction. Unlike other countries, in Brazil, credit was chosen as a central part of the agricultural subsidy. Not incorporating measures that favor the technical transition, makes the model perpetuate BAU.

More advanced initiatives or projects, such as those carried out by PECSA-Novo Campo, São Felix do Xingu and Paragominas, operate at a reduced scale in relation to the universe of producers. Public policies need to incorporate the evidence produced, improving, and applying better public resources, with prioritization and obtaining better private and social results. In that sense, notes one of those responsible for PECSA: “The most advanced initiatives are a small thing, what is 30 thousand head over the 8 million that there are here?” (Interview with technical agent, Mato Grosso 2018).

In addition, it should be noted that initiatives such as PECSA, are focused on large properties, or are economically viable for larger properties, such as the trials in São Felix do Xingu, while 80% of the region’s producers operate properties of less than 300 ha, with pasture areas below 150 ha, considered small for this context of a productive jump along the molds implemented.

Regarding smallholders, Garcia *et al*. (2017, p.13) point out that “other approaches should be considered, including improved breeding and genetic stock, better technical assistance and market access, and establishment of cooperatives and other associations with enhanced collective negotiating power” (...) “Undoubtedly, public policies should prioritize lasting supporting programs to boost sustainable alternative activities tailored to small producers in the region, taking into account market demands, access limitations, lack of technical assistance, farms size, and capital constraints”.

Favor credit for investment rather than current expenditure

For a long-term view, investment resources should be given priority over annual credit, with rate stability and simplification of rural credit rules. These points are important to increase productivity, to favor investment since there is significant market risk in financing using a fixed rate in a context where rates change throughout the year, which has a disincentive effect on long-term investment. It is also important to simplify the rules, which are currently quite fragmented, as explained by Assunção and Souza (2018, p.3):

"For the agricultural year 2016-2017, rural credit was comprised of 20 funding sources and 13 programs (...) There were also dozens of sub-programs. For example, PRONAF had 16 subprograms (...) This multiplicity of credit lines makes it hard for both the producer and the local credit lender to pin down what resource best fits current needs".

Not only are there many programs and many sources (sometimes the applicable rule comes from the source and sometimes from the program), but there are also underlying outdated definitions, such as those regarding property size. These are based on the criteria of "fiscal modules" using calculations of productive land from the 1960s, making contiguous areas subject to significantly different classifications, and to producer revenue. In this last aspect, for the purposes of the Constitutional funds: an annual income above R$ 500 thousand was sufficient to be classified as a "large producer"; this figure then jumped to R$ 90 million (if adjusted by the IPCA index of inflation this amount would give a value in 2016 of around R$ 1.36 million). The study highlights that in a particularly abrupt year of change, from 2010 to 2011, "a producer with R$ 2 million in revenues applying for resources from the Central-West Constitutional Fund would be classified as 'large' in 2010 and 'small' in 2011." According to the study, "These facts suggest that eligibility criteria for rural credit programs can be used as a policy tool, favoring specific groups. Therefore, the political game can widen the distortions in access to rural credit" (Assunção and Souza 2018, p.24).

Also highlighting difficulties stemming from the complexity of the tangle of rules, one of the actors interviewed, linked to the financial system, points out that "whenever the Central Bank releases an update of the Rural Credit Handbook, one month is lost to analyze it and train one's workforce." Noting that there are "a lot of rules, and a lot of rule changes. By the time that a producer understands that a given line is no longer active, it loses continuity" (Trader Interview, Mato Grosso 2018).

Despite the clear need for a long-term vision and simplification of rules, which is also demanded by producers, it is worth noting that a long-term view, with rate stability, but without incorporating other recommendations regarding prioritization of environmental investment would not necessarily lead to the incentive needed to achieve an Eco-Agri-Food transition. While credit on its own represents an important element to support transition to low-carbon, sustainable agriculture and livestock, overcoming obstacles to intensify the transition implies the need for a holistic assessment of public policies complementary to credit. Two policy areas stand out as most strategic: i) promotion of technical assistance for the creation of productive capacity in the new technologies and ii) public support toward structuring a "chain of low-carbon farming", including insurance against risk.

2. ABC Credit (Low-Carbon Agriculture)

The perceived important role of credit in disseminating good agricultural practices fostered the development of the ABC credit facility to finance rural producers as part of the national Climate Change policy.[53] In this subsection we address aspects that emerged in the field research, consistent with the data

[53] Commitments include the restoration of 15 million hectares of degraded pastures and an increase of 5 million hectares of crop-livestock-forest integration (ILPF) systems by 2030. These targets are even more audacious than those previously defined by the National Policy on Climate Change (PNMC).

and the specialized literature, and that concern only the ABC Plan, its bottlenecks and possibilities of overcoming them as a model for a broader scaling up of sustainable finance in the Brazilian agricultural sector. Our overall recommendation is that the Harvest Plan as a whole be revamped to offer priority to sustainability as a central criterion, rather than this concern be relegated to a specific marginal credit line.

Despite scientific research showing the benefits and economic opportunities of low-carbon good agricultural practices (e.g. Gurgel 2017), the ABC credit scenario is complex: demand is actually lower than the total government-allocated resources offered to farmers (Figures 27a and b). In the 2016/17 harvest, R$ 2.9 billion were allocated to the ABC Program, compared to R$ 3 billion in the previous period. Of the amount allocated, rural producers only contracted R$ 1.81 billion. In the 2012/13 cropping season, in contrast, the ABC Program had achieved 90% execution (Monzoni 2017; See Box 5).

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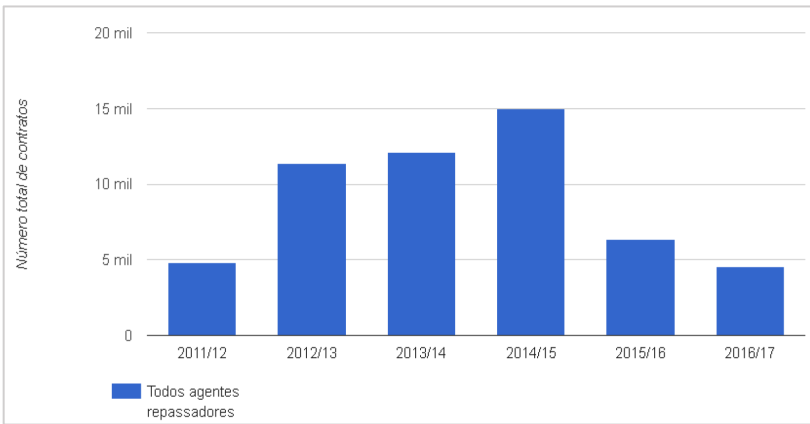

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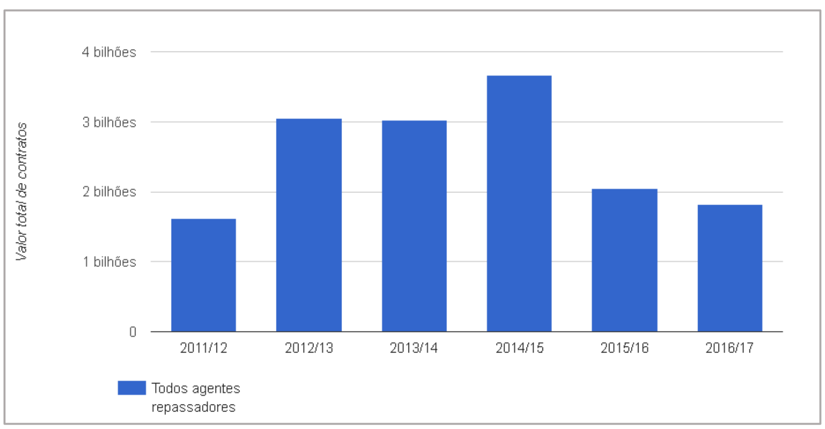

Figure 27: Historical evolution of (a) contracts and (b) disbursements of ABC credit in Brazil. **Source: Observatório do ABC 2019.**

Among the states that most contracted ABC credit, and despite its preeminence in national soy and beef production, Mato Grosso appears in 6th place, behind Minas Gerais (MG), Tocantins (TO), Goiás (GO), São Paulo (SP) and Mato Grosso do Sul (MS) (ABC Observatory 2019; Monzoni 2017; Figure 28 and Box 5). In the 2016/17 season, producers in Mato Grosso contracted 218 ABC credits, totaling R$ 154 million in loan operations. In part, this relatively poor loan performance may be explained by the limited role of state government in the diffusion of credit and low-carbon farming practices, as discussed in detail in the next subsection.

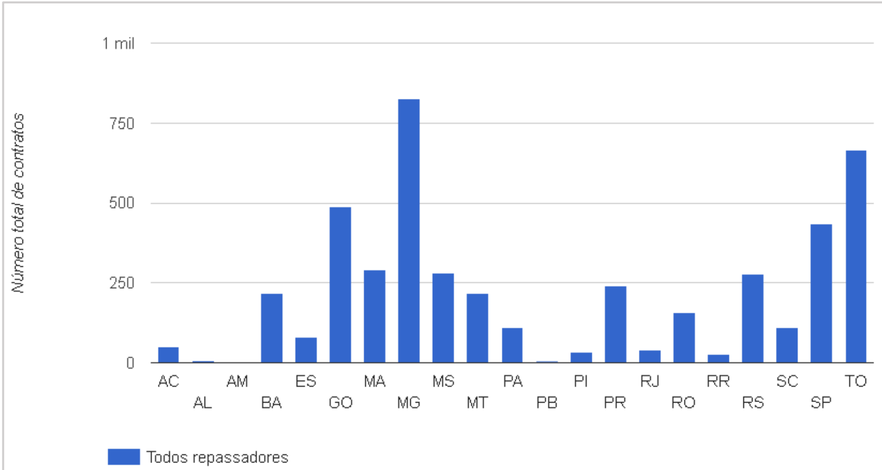

Figure 28: Number of ABC loans contracted in 2016/17 cycle by state. Source: Observatório do ABC, 2019.

Although BACEN and the Getúlio Vargas Foundation (FGV) have cooperated in generating data registering the progress of the ABC Plan, the poor monitoring of both plan and credit are deficiencies in its implementation, reducing transparency. While public subsidies are applied to the reduced interest rates, there is little information available about the program's impact, or indeed its relative efficiency in terms of reduced emissions.[54] On the other hand, trials of best livestock practices underway with other investments (see Piatto *et al*. 2018), and a carbon emissions modelling tool entitled GHG Protocol developed by the World Resources Institute and Embrapa Informatics[55] would permit the estimation of net emissions reductions, were the practices implemented through ABC well enough documented.

Box 5: ABC Disbursement Performance Results

To achieve its goals, the ABC Plan was to provide R$ 179 billion to finance the ABC Program from its inception in 2010 through the Harvest Plan by 2020 (MAPA 2012). Of this amount, R$ 27.15 billion was to be included in the national budget plan (PPA), while the remainder would come from other sources. The Plan also provided for the application of R$ 30.6 billion through the National Program for Strengthening Family Agriculture (PRONAF). From the 2010/11 crop until the 2016/17 harvest, however, the ABC Program disbursed a total of R$ 15.64 billion, of a total available of R$ 23.45 billion in the same period (execution of 66.7%) (Monzoni et al., 2017). In the 2017/2018 harvest, the total executed fell abruptly: of the R$ 2.13 billion made available, only R$ 146.4 million (only 6.9% execution) were contracted (MAPA, 2017). This drop was due to a general unwillingness of the previous administration to support environmental initiatives even when demanded by productive sectors.

[54] The ABC Plan provides a set of monitoring actions to be implemented by 2020: i) creation of a Multi-institutional System of Climate Change and Agriculture; ii) system maintenance; iii) preparation of micro-regional technical studies to quantify and qualify biogas projects, aimed at monitoring an ABC related Animal Waste Treatment Program. Budgetary and management limitations delayed the execution of these activities. The monitoring of GHG reduction in Brazilian agriculture and dynamics of soil carbon stocks when implementing low carbon technologies, only began to be drawn up in 2016 (Brazil 2012: 167; Embrapa 2016).

[55] See: https://ghg-protocol.precision.farm/

Another relevant issue is the distribution of these resources by investment objective. The majority is destined to the recovery of pastures and no-tillage (61% and 23%, respectively, in the 2016/17 harvest). Meanwhile, only R$ 15 million (or 1% of the total contracted) was allocated to the ABC Environmental line, whose objective is to finance the environmental regularization of rural properties in accordance with the provisions of the Law on Protection of Native Vegetation (Law 12.651 / 12 – former Forest Code), that is, the restoration of APP and legal reserves (RL).[56] Conditions for improvement in interest rates relative to other agricultural credit occurred in 2018, with the reduction of the interest rate of the program in the 2018/2019 harvest to 6% per year and to 5.25% per year for the recovery of permanent preservation areas and legal reserve, making the ABC financially advantageous in relation to other rural credit lines.

As announced by MAPA, "financing of the ABC Plan (Low Carbon Agriculture) in the 2018/2019 Agricultural and Livestock Plan has already reached R$ 1.03 billion between July and November of this year, compared to the same period of 2017. Growth of 57% in the number of contracts, a 104% increase in contracted value and a 74% increase in the area financed." In December, the ABC line was suspended, according to information obtained from the accredited financial institution and also on the BNDES.[57]

According to the WWF, the economic studies and the technical details for this change (in addition to the increase of the maximum financing per credit taker from 2.2 to 5 million in ABC loans, and the possibility of acquiring inputs for recovery of APP and RL with general credit, supported in part by a partnership led by WWF, TNC, NWF, and the Gordon and Betty Moore Foundation.[58]

The mere fact of making the ABC lines relatively advantageous vis-à-vis other lines of rural credit had a significant effect, in a sense, revitalizing it. Between 2012 and 2015 the real interest rates charged on rural credit in Brazil were largely negative, since inflation generally exceeded the interest charged. By the 2016/17 harvest, however, real interest rates became positive, returning to levels above 5.0%. With the expectation of positive real interest rates for the long term, a disincentive to taking credit by the producer may occur, especially in the regions exhibiting highest risk for the ABC technological transition. With this change in the macroeconomic scenario it is noticeable that producers are more cautious with their willingness to become indebted.

In the 2016/17 crop cycle, the ABC Program applied interest rates of 8% to 8.5%/yr. Comparatively, PRONAF remains the most competitive option for small and family farmers: credit lines (for current expenses or investment) show interest rates between 2.5% and 5.5%/yr, depending on the value of the operation. Other lines, such as those available in the Constitutional Fund of the Midwest (FCO) – considered less bureaucratic and complex by rural producers – have equivalent interest rates (between 8.5% and 10.0% pa depending on the type of rural property), a fact that significantly reduces the economic appeal of the ABC Program. The 2017/2018 Harvest Plan reduced interest rates, but less than expected and without changing the competitive structure of the products.

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[56] ABC Environmental is thus the main line of credit specifically earmarked for the financing of environmental regularization in the field (Monzoni *et al*. 2017), with the potential to contribute significantly to the reach of the Brazilian NDC to restore 12 million ha of forests by 2030, in addition to the objectives of the National Vegetation Recovery Plan (PLANAVEG), launched at the end of 2017 and other international commitments assumed by Brazil, such as Bonn Challenge, 20 x 20 Initiative and Aichi-CDB targets.

[57] http://www.agricultura.gov.br/noticias/financiamentos-do-plano-abc-somam-r-1-03-bilhao-desde-julho, Accessed 10 Jan. 2019.

[58] https://www.wwf.org.br/?66802/Novo-Plano-Safra-traz-avanos-para-adequao-ambiental, Accessed 10 Jan. 2019.

Over this period, the relative importance of ABC in the Harvest Plan had been reduced from R$ 4.5 billion, for ABC while the Harvest Plan was R$ 180.2 billion in 2014/15, to 2018 when they were respectively R$ 2 billion for ABC and R$ 191.1 billion for the Harvest Plan. This represented a drop in over 50% in relative importance of the ABC credit in overall Harvest Plan resources announced.

In fact, such a decline in relative importance may be justified by the fact that the ABC plan was characterized in several years by the surplus of resources announced. According to the Report 4 of the ABC Observatory (Gurgel and Costa 2015) "in every crop year since the launch of the initiative, the demand for the resource was lower than the total available." However, the resumption from a simple change in some of its parameters, in addition to the interviews and other evidence, indicates that instead of lack of demand, these results possibly are due to a set of factors that do not facilitate that the line develops fully. From the perspective of one of the interviewees, the loss of strength of the ABC in the context of the policy formulation was also highlighted, pointing out its degree of novelty and the loss of expression in the agenda.

It is worth noting that even though most of the ABC funds are offered by public banks (Banco do Brasil, Banco da Amazônia and others), private banks are not absent from the theme (e.g., Santander, Itaú, Rabobank). Santander, for example, which is one of the largest financiers of Brazilian agribusiness, actively participates in discussions of mechanisms to improve the granting of ABC credit and the diffusion of low carbon technologies to the rural producer. There has recently been a trend in the financial market for banks to take up discussions and proposals on social and environmental guidelines applicable to the provision of credit for their customer portfolio.[59] They are stimulated by diverse initiatives such as that promoted by the World Wide Fund for Nature (WWF Brazil), in partnership with Banco do Brasil, to develop a model of guidelines for the granting of credit by the principal Brazilian public bank.[60]

There is therefore a general perception by producers who have experience with the ABC Program that it is a bureaucratic process, which demands a large volume of documentation and requires the development of a complex technical project, which, in turn, demands the support of a technical assistance company (project developer) that is competent and knowledgeable about the Program. Farmers also stress that there is a more bureaucratic project review process than that for other rural credit options and claim that there is a lack of clarity throughout the process (Observatório ABC 2017).

A case study (Belinky and Monzoni 2015) carried out in the city of Paragominas, Pará, identified the main obstacles to taking ABC credit, at the time, in this locality. Limitations in the diffusion of the ABC Plan and its credit program included:

1. The lack of land regularization as the main impediment to funding by the ABC Program;
2. Low performance and qualification of technical assistance, especially in the Legal Amazon;
3. Low dissemination of the Program by financial agents;

[59] Para uma discussão sobre esta tendência de mercado ver publicações e trabalhos da SITAWI – Finanças do Bem (https://www.sitawi.net//a-sitawi/)
[60] https://www.wwf.org.br/informacoes/?uNewsID=61143

4. Low performance of the State Management Group (GGE).[61]

In August 2014, after the identification of bottlenecks in the ABC Program disbursement processes, a Cooperation Agreement was signed among technical support services and the program.[62] This partnership generated an initiative called Capacita ABC, whose objective is to expedite the release of resources destined to the ABC Program.[63]

Another shortcoming that helps explain the low interest of the Brazilian rural producer in ABC credit is little or no knowledge of low-carbon technologies, their opportunities and benefits, and information related to the credit offer itself. This reality is sometimes verified in relation to local rural assistance, project developers and banking agents and not only with the rural producers themselves.

On the other hand, in the states where credit concession has been greater, the role of the state coordination for the management of the ABC Plan makes for a local differential.[64] Through strategic plans elaborated by state coordinators and their working groups - involving different actors -, producers became knowledgeable of this type of credit, and began to seek them out at bank branches.[65]

Incentivize the provision of ABC credit within regional financial institutions

To improve ABC credit, in addition to the question of adjusting it to ensure such adjustments within the overall Harvest Plan, where borrowers with better production models are prioritized, have easier and less bureaucratic access to financing, and with the lowest interest rates, the following points are suggested:

Regarding financial institutions, it was highlighted by interviewees that commercial banks offer a basket of services, and the remuneration of ABC is similar or smaller than the other lines of action, with a much higher operating cost. In addition, this is longer-term credit, which can lead to less turnover, receiving less. (More on this subject is taken up in the following subsection regarding ABC in Mato Grosso.) Greater motivation is necessary to revise the form of remuneration provided to bank management in order to ensure that their agencies have an interest in placing this type of credit vis-à-vis other lines.

As a first step in the direction of the transition incentive, it is important to maintain CMN Resolutions 4666, 4667 and 4668, which brought the increase of the limit of ABC per borrower to 5 million, lower rates

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[61] According to the rural producers interviewed, there is little GGE activity in the region, which contributes to the low funding of the ABC Program in Pará. It should be noted that the GGE are responsible for several cross-cutting actions of the ABC Plan in the states, including training of sector actors in the technologies of the ABC Plan.

[62] The following institutions were involved: National Rural Apprenticeship Service (SENAR), the BNDES, the Ministry of Agriculture, Livestock and Supply (MAPA), Embrapa, the Brazilian Federation of Banks (Febraban) and the Brazilian Association of Financial Development Institutions (ABDE)

[63] http://www.senar.org.br/abcsenar/capacita-abc/

[64] Impressions taken by J. Speranza, as a researcher at the ABC Observatory and who visited state coordination offices of the ABC Program in the Legal Amazon and in contacts with the MAPA Secretariat of Agricultural Development and Cooperativism, responsible for the national management of the ABC Plan.

[65] MAPA sought to support state coordination to improve local implementation of the plan through cooperation agreements, which included the transfer of resources. However, delays in the transfer of resources and/or suspension of contracts created tensions in the relations between the parties and frustrations in the states. At the same time, states with proactive and engaged management who understood the importance of low-carbon agriculture, were able to disseminate knowledge of the program and empower producers - through Field Days, Demonstration Units and other means.

of ABC than the remainder of rural credit (not counting Pronaf), as well as other changes such as the use of funds to purchase forest restoration inputs. The importance of maintaining such differentials has been highlighted by observers (Institutional interviews, Brazil 2018).

Another initiative would create ABC's action model through a specific purpose banking correspondent, to facilitate distribution (and interest in the business) in the line. It may be of great value to use correspondent banking for distribution as well as to ensure equal treatment to potential creditors. The correspondent banking figure does not hold responsibility for approving the operation, which continues with the BNDES, but facilitates, through practice, expertise and interest, requesting resources, forwarding the projects, and distributing the opportunity for solicitation. In addition, remuneration can be attractive to such actors (regardless of whether they are financial institutions or not and may at least complement them as a resource distribution channel). Such correspondents may be formed or be close to the branch.

1. ABC in Mato Grosso

Based on data from the 2017 Agricultural Census for Brazil, despite the volume and importance of rural credit, 85% of the producers did not secure agricultural credit, while 15% of them did so. In Mato Grosso, the amount that claimed to use credit was 17.4% of the producers, which implies a relatively higher penetration than the national average. Nevertheless, the highest penetration of rural credit, specifically for ABC, is the reverse in the State of Mato Grosso.

Although Mato Grosso is the largest soy producer in the country with 28.2% of national production, and also of cattle with 14.0% of the herd according to the preliminary results of the 2017 Census, only an average of 6.8% of overall ABC volume, considering the years 2017 and 2018, occurred in the state.[66] The application of resources seems to have shown greater expression in Minas Gerais, São Paulo, Goiás and Matopiba (Maranhão, Tocantins, Piauí and Bahia). The proportion of ABC in Mato Grosso is relatively low and disproportionate, even if compared to the Center-West region.[67]

The amount of financing through ABC credit in Mato Grosso also grew by only 11.4% during the past two years, which is less than half of the average national growth, which was 24.7% in the period. In 2018 there were, in all, 137 ABC credit takers in Mato Grosso (assuming that no producer or their companies have accessed ABC more than once, which is allowed as long as the maximum limit per taker is respected). Of this total, 119 investments were focused on pasture recovery or no-tillage (86.9% of the cases), which represent environmental advances more directly linked to the soil treatment bias traditionally considered in the agricultural financing policy from its initial decades. It is worth taking into account that the total number of rural producers in the Mato Grosso is on the order of 98,387, according to the 2017 census.

Only 13 investments of the ABC line were for crop-livestock-forest integration or agroforestry systems. It should be emphasized that the great majority of the cases included in ILPF are probably ILP, not counting

[66] The participation of MT in total ABC in Brazil fell from 7.22% to 6.35% in just one year, between 2017 and 2018.
[67] The ABC Observatory Report 4 - Year 2, May 2015, attributed ABC's greatest expression in Minas Gerais to "a series of activities conducted in the context of synergistic actions to the issues involved in the ABC State Plan and the State Policy on Climate Change of Minas Gerais, which encourage the adoption of the ABC Program by rural producers," pointing to the tendency of the resource to focus on the Midwest and Southeast regions, indicating the presence of a more networked and active technical assistance network.

the tree component, which is pointed out by interviewees as generating greater resistance from producers. Indeed, the "Forests" subprogram had only 4 investments in the state, and waste treatment just 1 investment. There were no cases of investment in any of the following subprograms of ABC credit in Mato Grosso: environmental adequacy or regularization; biome Amazônia; biological nitrogen fixation; nor for organic production systems.

According to one of the interviewed actors, both in the production and in the link to the certification of livestock, "in Mato Grosso ABC's resources are said to be armored, one hears it spoken of, but nobody knows who has been able to catch it" (Certifier Interview, Mato Grosso 2018).

Another actor, with extensive experience in applying more sustainable methods to livestock, highlighted: "To (provide ABC credit) gives more work to the manager (of the bank). To do the project, one has to have a technician involved, it requires a certain degree of training of the manager, an arrangement which requires greater effort of the manager, and will give him additional work. The credit line has to encourage and demand, otherwise the guy ends up going another way". In addition, the interviewee complements:

"If it is not good and advantageous for the Banco do Brasil, the manager will not sell the product. Sicredi, for example, is a very good bank to work with. It is important that cooperative banks in the region (enter the ABC). They are closer to the farmer. But when you look at the data, you have access to 0.02% of ABC and there are billions that nobody gets, but how do you get it?" (Technician Interview, Mato Grosso 2018).

It is evident that ABC is not very active in Mato Grosso. This hypothesis is based on interviews with actors and, particularly in the region of Alta Floresta, through observation in field tests carried out in the real environment ("mystery shopper" methodology). In Alta Floresta, we found it virtually impossible for producers to even request ABC credit through financial institutions present in the municipality, although the locale represents a successful case of more advanced agricultural initiatives from the environmental perspective. Alta Floresta not only counts on the existence of examples of more advanced forms of production, but also on a territory where there is a particularly favorable context with a network of actors and environmental dialogue.[68]

Mystery Shopper in Alta Floresta

Among the financial institutions present in Alta Floresta, information was obtained that both Banco do Brasil and Sicredi operate with rural credit, both with a branch in the municipal seat.[69] In summary, we found that at the Banco do Brasil, the managers responsible for general service were unaware of ABC, and ultimately, disinterested and informed of the impossibility for the client to request ABC credit, giving

[68] Such initiatives include engagement of the municipality in projects for sustainable regional development, programs like Olho D'Água da Amazônia (Amazon Water Holes); Secretariat for Development and Agriculture to supportive of sustainable production initiatives; a history of decades of activities of environmental NGOs; campus of the State University of Mato Grosso (UNEMAT) in Alta Floresta with teaching and research activities focused on sustainability; local projects with financing obtained from the Amazon Fund managed by BNDES.

[69] The team that visited these agencies included administrators of sustainable agricultural activities, with the aim of emulating the most favorable situation possible to find the path to request access to the ABC credit line. Using a "mystery shopper" methodology, we exhausted all service possibilities in each of the agencies, which involved interviews with several managers and attendants at both banks.

exclusive preference to a referral to the FCO Rural Verde, which would be “equivalent to ABC”. It was reported that the whole process had already been done for ABC credit and, after orientation, it would be necessary to redo the process to make it fit as FCO Verde.[70]

In Sicredi, it was alleged that there would be difficulties in accessing the resource by the bank, which is registered to operate in the program, had already researched it but in practice it appears cannot access the credit offering. According to this aspect, one of the interviewed actors pointed out that Sicredi did not previously furnish credit from PRONAF, but given the producers’ demand, started to operate it a great deal, which would indicate flexibility in favor of the cooperative. But they had not been able to access the ABC credit instrument to offer to their clientele.

2. Transition costs of cattle ranching

In this section we address the costs and benefits of transition to environmentally sustainable cattle production practices. We seek to calculate the comparative net benefit needed in financial instruments, to act as an incentive to adopt such sustainable practices, and how it can achieve a greater incentive effect if there is greater differentiation or prioritization of borrowers who want to undertake the transition. This analysis is not restricted to the ABC Plan, but rather to overall rural credit in Brazil. Of critical concern is the feasibility of redirecting public credit instruments to small family ranchers in agrarian settlements who have become a significant source of deforestation in rural areas of the Amazon (Valentim 2015, Valentim and Garrett 2015). Such an analysis should take heed of the historical experience with the adoption of “sustainability” credit lines under Pronaf (Godoi op cit.) as well as that of the ABC Plan.

In terms of attractiveness and the inductive potential of credit, the ABC rates were considered vis-à-vis the main conventional lines of agricultural credit, taking as a reference the lines obtained from Compulsory Resources – MCR 6.2, and Rural Savings – Controlled.[71] These two lines accounted for 24.65% and 17.07%, respectively, of the total funding applied in agricultural credit in the 2017/2018 harvest season (Assunção 2018). Describing a specific line of credit may not portray the general case. Assunção (2018) points out that in the 2016/2017 cycle, there were 20 different sources of funding and 13 programs. Sometimes the applicable rule comes from the program and sometimes from the source, resulting in many combinations. In addition, there are subprograms, which also interfere with the applicable rule, resulting in a very fragmented financial landscape. We chose to select the more general lines and the average rates, calculated by the Central Bank, which best portrays the reality faced by producers, as a basis for comparison as to whether ABC credit represents an investment incentive.

[70] The FCO Verde has one line for "Conservation of nature" and another for "ILPF". Initiatives for agroforestry systems, native species crops, microbasin recovery, ILPF, etc. are financed. All two lines of the FCO Verde fund "recovery of degraded areas and pastures", which is, according to the Bank of Brazil, where the bulk or almost all that obtained in the region of Alta Floresta is concentrated.

[71] Assunção (2018, p.10) summarized that Compulsory Resources, in accordance with the Manual of Rural Credit (MCR Section 6.2, "consist of 34% of demand deposits collected during the period of one year by Brazilian financial institutions. Most of these resources (77% in the agricultural year 2016/2017) are not destined to any specific rural credit program". Regarding Rural savings, the same source emphasizes that "Three institutions follow the demand for rural savings: Banco da Amazônia, Banco do Nordeste and Banco do Brasil. For these banks, it is mandatory to keep 60% of rural savings deposits available for rural credit for one year. Most of the resources are offered at subsidized (controlled) interest and a small share at no interest "(Assunção 2018, p.18).

Table 6: Average rural credit rates, between July and November 2018.

Taxas de Juros Pré-fixadas Médias do Crédito Rural por Fonte de Recursos - em % ao ano		
Fonte de Recursos	Período de 1/7 a 30/11	
	2017/2018	2018/2019
Recursos Obrigatórios - Pronaf	4,8	4,2
Recursos Obrigatórios - Pronamp	7,5	6,0
Recursos Obrigatórios - Demais Produtores	8,2	6,6
Poupança Rural com Subvenção - Pronaf	4,4	4,1
Poupança Rural com Subvenção - Pronamp	7,5	6,0
Poupança Rural com Subvenção - Demais Produtores	8,4	7,0
Poupança Rural Livre	9,4	9,1
LCA - Taxa Livre	10,4	9,9
LCA - Taxa Favorecida	10,0	8,3

Source: author's elaboration, based on Central Bank data. Recursos obrigatórios refer to MCR 6.2 Compulsory credit from direct deposits, and Poupança Rural refers to credit provided from rural savings deposits. LCA are letters of credit from agroindustry providing credit to producers against harvest output.

ABC has not been cheaper on average than other resources available in the case of medium or small producers, as can be seen from the average rates applicable to resources directed to family farmers (Pronaf) and medium-sized producers (Pronamp). For large producers, however, ABC has become more advantageous than traditional savings sources (6.0 or 5.25 versus 7.0%) and slightly cheaper than the average rate of compulsory resources (6.0 or 5.25 against 6.6%) for this farmer group. Using the proportions (24.65 and 17.07) mentioned in the previous paragraph to weight credit offerings, there is an average rate of 6.76% per year on combining the two sources, which gives an average reduction of 22.3% when compared to the "environmental ABC" credit line (with a rate of 5.25)[72] and 11.2% (in the case of general investments for ABC, with a rate of 6% p.a.) (Table 7).

Table 7: Differential between ABC and regular rural credit interest rates – 2018/2019

	ABC – Environmental	ABC – General
Interest Rates (ABC)	5.25%	6.00%
Mean Credit Rate – Obligatory Rural Credit Resources	**6.6%**	
Differential	20.5%	9.1%
Mean Credit Rate Controlled Resources from Rural Savings	**7.0%**	
Differential	25.0%	14.3%
Mean Proportional Credit Rate (obligatory + controlled)	**6.76%**	
Differential	22.3%	11.2%

Source: author's elaboration based on Central Bank data.

[72] The "Environmental ABC" applies to cases of regularization in respect to environmental legislation, restoration of RL or APP, restoration of degraded areas and forest management. All other ABC investment purposes apply an interest rate of 6.0% in the current harvest of 2018/2019.

1. *Credit attractiveness*

Table 8 projects the comparative benefit in using the ABC rate versus the average rate on the two main credit lines with subsidized resources, and projects the comparative benefit in the following scenarios: a) supply of subsidy to large producers only for low carbon practices, which pushes the opportunity cost toward that of freely negotiated rates, such as the "free LCA", used in this and the following case, and b) calculation of the maximum benefit (limit of the ABC line for a credit taker) versus that for free LCA. It is noticed that there is a huge potential for differentiation, even without the need to lower the ABC rate, by only prioritizing borrowers and type of credit. This conclusion is based on the notion that only for a certain size group, in this case large agricultural producers, would it be advantageous to lend at favorable rates to ensure a favorable result for environmental externalities, as targeted by the ABC line.

One could increase the attractiveness of ABC substantially by offering differential credit rates for average producers, and by making ABC features easier to access, as discussed in previous sections, which can be accomplished for any size group. As access is facilitated, the effect could substantially leverage greater participation, since ABC could reach part of those producers who do not yet access any kind of credit: 85% of the country's farmers, according to the 2017 agricultural census. Only about half of farmers who take credit obtain loans from public agents (IBGE 2018), while the remainder either take resources on advancement from traders, or self-finance their operations from profits (Araújo and Li 2018).[73] That is, facilitating ABC (or other pro-transition credit) can become a strong motivating element, since the comparative opportunity cost may be based on high market rates like those applied for direct consumer credit (CDC) or no credit at all (in the case of livestock) or have credit restricted to that provided by *Barter* and other agents in the supply chain.

Table 8: Potential for increased attractiveness without tampering with the ABC rate

	No comparative advantage (years prior to 2018/2019)	**Current advantage compared to average rate of general credit lines**	**ABC vs. freely negotiated credit rates (LCA)**	**ABC vs. freely negotiated (LCA) rates, considering credit limit per client**
Situation	ABC has excess resources, pointing out lack of demand	151 points at most (1.51% lower) 76 points at least (0.76% lower)	465 points at most (4.65% lower) 390 points minimum (3.9% lower)	465 points at most (4.65% lower) 390 points at least (3.9% lower)
Average ABC financing (2018)	R$ 394,516.41			
Theoretical average balance due (50%)	R$ 197,258.21			
Annual benefit of differential interest (calculated on average balance)	Nil	At most R$ 2,978.60 At least R$ 1,499.16	At most R$ 9,152.51 At least R$ 7,693.07	At most R$ 232,500 At least R$ 195,000

[73] According to IBGE/SIDRA, Preliminary results of the Agricultural Census of 2017, of the total of 5.1 million producers that responded in the country, only 784 thousand (15%) borrowed resources for productive purposes. Of these, 378 thousand (50%) did not take resources financed by public agencies.

Total benefit of differential interest over the contract period (10 years)	Nil	At most R$ 29,786 in 10 years At least R$ 14,991.60 in 10 years	From R$ 91,525.10 in 10 years To R$ 76,930.70 in 10 years	From R$ 2,325,000 in 10 years To R$ 1,950,000.00 in 10 years
Observed result	——	- 57% increase in the number of contracts; - 104% increase in the value contracted; - 74% increase in area financed	Higher inductive potential	Higher inductive potential

Source: authors' elaboration; average ticket value calculated from data from the Rural Credit Matrix.

Although, as the actors report, ABC credit continues to be more laborious and difficult to access than other options, downward interest rate adjustment was accompanied by a major increase in demand for ABC credit between July and November of 2018 as compared with the same period the previous year. A modest 0.5 – 0.75% decline in interest rates corresponded to a 57% increase in the number of contracts, a 104% increase in the contracted value, and a 74% increase in the total area financed (Table 6). This suggests that much of the attractiveness would lie in the relatively cheaper credit line rather than in the price itself. Nevertheless, the data in Table 6 show that a producer who holds credit of half the average taken by ABC beneficiaries (R$ 394.5 thousand over 10 years) would obtain a benefit of at least R$ 15 thousand over that period with the modest interest differential analyzed even when compared with the lowest average rate of rural credit lines.

In order to arrive at credit measures necessary to induce transition, a more thorough analysis should distinguish between productive activity, size of the producer and degree to which they have complied with environmental legislation. The issue of enforcement is crucial, because the activities financed by ABC that reconcile production with the preservation of legally protected areas could become more advantageous. However, this advantage depends on the extent to which the forest legislation is binding.[74] The question of attractiveness should be attuned to the scope of the direction of the policies of support and the prioritization of specific activities, a matter of adapting the structure of pro-transition incentives.

Recommendation: Subsidize large farms solely for transition and post-transition maintenance costs. Small-scale family producers should continue to be fully financed at subsidized rates.

The following subsections rely on the experiences of TNC in São Felix do Xingu (SFX), Pará and PECSA, in Alta Floresta-MT, to further detail the conditions that affect productive transition.

[74] The amnesty from forest restoration conveyed by the 2012 revision of the forest code for deforestation prior to 2008 significantly undercut environmental protection on private lands throughout Brazil (Soares-Filho *et al.* 2013).

2. *São Félix do Xingu* [75]

The transition to sustainable intensification practices in TNC's SFX project required a total annual average investment of US$ 1,335 ± 619/ha (with a range from US$ 750 to 2,595/ha).[76] The cost varied considerably because the initiative dealt with properties at different scales and whose pastures presented varying degrees of degradation with the objective of testing the cost and feasibility of transition under different scales and conditions. It should be noted, however, that the size range in the pilot did not include small scale settlers whose needs for transition are distinct, and whose access to environmental credit lines has been insignificant.

The strategy put in place in SFX is based on:

1. the land-saving effect of intensification, decreasing demand for land in relation to the business as usual (BAU) scenario;
2. a "moderate" intensification approach (leading to an average of three but not more than four AU/ha[77]);
3. the adoption of the BPA regimen of best agricultural practices) of Embrapa, which was chosen for the scope of the approach, with a focus on the whole property, human resources management, including wages and expenses, animal welfare, traceability, soil management and pasture, including rotational grazing and no-tillage for feed grain; and
4. restoration of environmental liabilities.

The program also included training and monthly visits of rural technicians for technical support and to monitor pastures and herds. The cost of implementing BPA also considered the maintenance of infrastructure and investment costs (housing, buildings, operating costs, machinery and equipment) and administrative costs.[78] On average, about 46% of the investment was associated with environmental restoration, 32% with pasture improvement or reform and 22% with BPA adoption.

The estimated internal rate of return (IRR) and net present value (NPV) indicate that the intensification approach to sustainable livestock farming was profitable on farms with more than 400 hectares of pasture but not in those where pasture areas were less than 150 hectares. Productivity projected for the pilot

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[75] For the analysis of SFX, data from Garcia (2017) and provided by the project's technical manager Fabio Ramos (Agrosuisse 2017) were employed.

[76] The average annual investment in the intensification of the properties of the project was higher than that reported in other intensification initiatives for cattle raising in Amazonia (between US $ 633 and US $ 893, including the purchase of animals) in which environmental liabilities were not considered.

[77] 1 AU is taken as equivalent to 450 kg in live animal weight.

[78] Below, a detailed list of expenses considered:

1. Values of payroll and contracted services;
2. Mineralization, feed and consumption values;
3. Values of vaccines and medications;
4. Values of technical advisories and consultancies in accordance with the profile of each owner and/or administrator;
5. Administration costs;
6. Infrastructure maintenance costs (fences, buildings, etc.);
7. Maintenance costs of machinery and equipment;
8. Investments in machinery, implements and equipment;
9. Investments in pens, fences, salt licks and watering troughs; and
10. Adjustments in the values of the different animal categories.

farms in the project in general yielded returns that have outpaced intensification investments, ensuring the feasibility of transition to a sustainable intensification approach, except for two farms with less than 150 ha of pasture, which would need 12 years to payoff, yet the projected income would remain in deficit or be marginally profitable.

In Table 9 below, we further delineate this result, considering initially the level of soil degradation and the recovery method used.

Table 9: Classification and method of recovery of degraded pastures

Level of degradation	Restoration method
Low / Medium	Pasture maintenance
Medium / High	Pasture reform and formation
Medium / High	Pasture reform and formation + Crop-pasture integration (ILP)

Source: Agrosuisse (2017)

The results of the financial indicators, grouped by level of degradation (Table 10), indicate that over a 12-year period, all the averages between the properties are higher in both total NPV and IRR, the lower the level of degradation. Scenarios 1 and 2 are associated with different deadlines for full adoption of BPA, the first being finalized in five years and the second with adoption during a shorter period of two years.

Table 10: Financial indicators grouped by level of degradation

	*Scenario 1**			*Scenario 2***		
Group – Level of degradation	**NPV (R$)**	**IRR (%)**	**Payback (Yrs)**	**NPV (R$)**	**IRR (%)**	**Payback (Yrs)**
Group 1 (7% a 17%)	2,649,901.95	17%	8	2,179,706.52	13%	8.2
Group 2 – (20% a 23%)	824,256.02	8%	8	506,806.16	4%	8.7
Group 3 – (27%)	673,566.56	11%	8.3	529,069.66	9%	9
Group 4 – (20%-23%) ILP	2,416,496.83	9%	9	1,980,062.70	14%	9

*Source: Agrosuisse (2017). Notes: BPA adoption period - *5 yrs; **2 yrs*

The NPV and the IRR in Scenario 1 are greater than those in Scenario 2. In all groups, except for the IRR of Group 4, the investment return period does not show a significant difference between scenarios. We can hypothesize that achieving recovery of environmental and productive areas and the implementation of best practices in two years does not result in improvement of financial indicators when compared with their adoption over a longer period.

The IRR indicates a variation between 4% (which would fall below the financial discount rate) up to 14%, representing a profitability above the most conservative financial rates of the market (rural savings). The payback return on investment, when net returns become positive with the amortization of the values of accumulated investments, indicates an average between 8 and 9 years. Indeed, the results of the financial indicators, when grouped by property area, indicate that in the period of twelve (12) years, all averages between properties are positive, both in total NPV and in IRR.

Table 11: **Financial indicators grouped by pasture area**

	Scenario 1*			Scenario 2**		
Group – Pasture area	**NPV (R$)**	**IRR (%)**	**Payback (Yrs)**	**NPV (R$)**	**IRR (%)**	**Payback (Yrs)**
Group 1 – (0 to 500 há)	-400,224.25	-	11.00	-470,516.69	-23.13	11.5
Group 2 – (500 to 1,500 ha)	894,591.46	12.61	8.00	707,153.00	10.43	8.25
Grupo 3 – (> 1,500 ha)	3,047,075.73	20.21	7.33	2,464,150.98	13.8	8

*Source: Agrosuisse (2017). Notes: BPA adoption period - *5 yrs; **2 yrs*

However, segregating by size of the pasture area (Table 11), both the overall and relative NPV (R$/ha) obtained by the group with properties with less than 500 ha were negative due to the high ratio between investments required and the return on the production system. The NPV at the end of the period in groups with larger properties indicates feasibility of the investments made. Except for those farms with small pasture areas, all had positive results with annual IRR ranging from 7 to 35% per year. Additionally, estimates of the median IRR, considering Scenario 1 of adoption of BPA in five years, was 10% per year. If the farms below 500 ha are disregarded, the average IRR of the remaining properties would be 14%. The median NPV was R$ 755.97/ha, considering all cases, and R$ 999.94/ha, considering only farms above 500 ha in size. The results for larger farms indicate that the proposed intensification approach to sustainable livestock farming is economically viable and can generate environmental and social benefits, including a 54% increase in the number of hired workers, improved landowners' management skills, and worker training.

Estimates for the 13 pilot farms indicated that in year 12 of the project, the emissions generated by enteric fermentation and use of fertilizer in the scenario of sustainable intensification would be twice that generated in non-intensification scenarios (see section 3.2.1). However, these emissions would be more than counterbalanced by avoided deforestation and restoration of permanent preservation areas (Garcia *et al.* 2017).

However, such static projections seem to ignore the perspective that, with greater profitability, the farmer can expand the herd to new land with legal deforestation. The project considered that the properties were already established and consolidated, that is, the division of environmental, production and non-usable areas were defined by georeferencing. There were cases in which the farms reduced their pasture areas and increased environmental protection areas, but it was not considered that they would consequently increase pasture area beyond the properties, since productivity would make up for the loss in pasture area.

Faced with the transition costs incurred, the technical and financial results showed that the investment in sustainable intensification, with the adoption of BPA, pasture intervention and environmental restoration, was more economically rewarding than extensive grazing and the conventional financial market. This positive result was observed even with the intensification model adopted, based on a conservative load capacity of 3 AU/ha to avoid negative environmental impacts associated with overgrazing, manure and fertilizer use, and CO_2 and methane emissions.

Incidentally, among the problems and difficulties faced by cattle ranchers in São Felix do Xingu, the most frequently mentioned are the lack of technical assistance, access to credit, lack of own resources, inadequate transportation infrastructure and bureaucracy.

1. ***PECSA***[79]

The Amazonian Sustainable Ranching (Pecuária Sustentável da Amazônia, S.A - PECSA) initiative aims at transparency as portrayed by the traceability of animals and the monitoring of results, environmental conservation ensuring the protection and restoration of natural resources and the reduction of greenhouse gases, training of the labor force, and seeks to optimize productivity and results. It also employs Embrapa's BPA as its main technical reference, focusing on the entire property. In addition, PECSA adopts standards developed by GTPS and the Global Round Table on Sustainable Beef (GRSB).[80]

The total investment including improved livestock, machine-hours, animal welfare, etc. averaged R$ 9,000/ha (or approx. US$ 2,329). 61% of the investment goes on the land. In cases where the initiative was to restore the APP, this action represented 7% of the total investment, representing a four-year process of assisted regeneration. Costs of pasture renovation and vegetation restoration were reported at R$ 4,000/ha. PECSA reports that maintaining and/or restoring APP brings environmental benefits by conserving both water quantity and quality, soil quality, animal welfare (providing shade and reducing temperature). Erosion and silting are avoided, resulting in an increased productivity, which can allow attaining stocking rates of four or more head/ha.

By raising the benefit with an impact on production, receptivity toward environmental measures changes. The impact of ensuring continuously available running water for the cattle increases at least 5 to 10% of the herd's performance. To favor this benefit, the size of the watering tank increases, tripling the access area for the animals.

However, cultural factors are pointed to as barriers to adoption of sustainable technology. For example, one of the responsible technicians suggested:

1. "The rancher tends to put money only in what he sees, which is cattle. Putting so much money into the soil (with limestone, phosphorus, potassium) that is invisible but it is necessary";
2. Many cattle ranchers, even when convinced with proven results, would not make the necessary investment with their own resources. The solution that underlies the PECSA operation was to take over the operation having the owner as a partner in the results;
3. In the sale price, there is no premium accorded to environmental criteria, and the bonus due to the quality of the meat itself is indicated as too low and insufficient to act as an incentive, R$ 5 or 6/@, equivalent only to a 3 to 4% increase.

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[79] The case of PECSA was based on information in Ermgassen et al. (2018) and provided by the actors interviewed responsible for the management of the initiative, as well as information collected on field visits and institutional material.
[80] https://grsbeef.org/

According to PECSA technicians, if an accounting is made of the return from the valorization of the farm, pasture improvement, infrastructure, environmental compliance and benefits, there is an annual IRR of 25 to 30%. Nevertheless, although PECSA included pilot projects on smaller farms than was the case with the TNC in Pará, the feasibility of implementing the intensified model on smaller farms was shown to be negative. It therefore remains necessary to consider other options for reaching the smaller ranchers whose role is nevertheless essential in the production chain. Such a strategy should focus on organization of beneficiaries and technical assistance rather than seeking a rapid transition toward more intensive production practices.

Table 12 summarizes the pilot experience undertaken to date in São Felix do Xingu and Alta Floresta by TNC and PECSA, with a view toward elucidating the factors which might induce expansion of these practices at a larger scale among ranchers in the Amazon region.

***Table 12*: Summary of pilot experience in SFX and PECSA**

<table>
<tr><th>Initiative</th><th>Average investment</th><th>Return</th><th>Funding source</th><th>Scalability</th></tr>
<tr><td>São Félix do Xingu</td><td>US$ 1,365/ha</td><td>Positive over a 12-year period, for ranches > 400 ha at an IRR between 10.4 and 20.2% varying by initial pasture condition and ranch scale</td><td>Financing via TNC</td><td rowspan="2">Upscaling may be financially feasible, but cattle ranchers have neither the funds for investment, nor the culture to invest in land improvements. They prefer to invest in cattle. The importance of credit is paramount. If credit is unavailable, as a rule, there is no investment; furthermore, environmental improvements will only be made if required by law (even if these investments are shown to be profitable for production).</td></tr>
<tr><td>PESCA</td><td>US$ 2,329/ha</td><td>Increased yield by 30 to 35@/ha. Stocking rate can increase up to 4 AU/ha.
Including land value appreciation, annual returns achieve an IRR between 25% and 30%.</td><td>External sustainable commercial credit, 5% p.a. + EUR variation</td></tr>
</table>

Source: own elaboration

In conclusion, the experiences of TNC and PECSA found that without intervention, the cattle rancher will not make the investment in intensification. He has neither an investor profile, nor the money. The cattle rancher invests in cattle. Land is often degraded by the practice of extensive grazing. As a result, the rancher may choose to sell a portion of the herd and improve the pasture or take credit specifically to improve the pasture. Or even lease the land to a farmer to plant soy. In short, he will only make the investment if he has access to credit or his own resources, and environmental improvements are only made if required and enforced by law. A strategy of intervention that combines better credit terms, particularly for small and medium ranchers, with technical assistance and training throughout the transition period will be needed to take the beneficial results of these pilot efforts to scale.

1. Soy and integrated system transitions [81]

Regarding soy, the transition cost was considered based on experience with large properties, typical of soy plantations in the Amazon basin of Mato Grosso. The properties of the soy planters interviewed range from 2 thousand to 70 thousand ha; reference values were obtained from producers with properties averaging about 9 thousand ha.

Soy producers have taken credit to offset the considerable equipment investments required to plant and harvest areas at this scale in time to avoid harvest losses due to early rainfall. These investments also facilitate the rapid planting after soy harvest of a second crop, be it maize or cotton, which must take advantage of a relatively short rainfall window to ensure germination and crop growth. Additionally, more precocious seed varieties have been developed, that further facilitate this additional crop cycle.

The transition between isolated and integrated production systems has been leveraged by availability of ABC and other public and private investment credit. Nevertheless, the transition to integrated systems has generally been initiated by ranchers rather than soy producers, perceiving the synergies between pastures and crops in the same field (see also Garrett *et al.* 2017 and Cortner *et al.* 2019). The use of pasture legumes or other leguminous cover crops is advantageous for posterior soy rotations, reducing the need for nitrogen fertilizers. Additional investments are required for fencing and watering of cattle, that may delay or impede the transition. The addition of trees as shade for animals, windbreaks and fuelwood is weighed against the opportunity cost of land use for crops or open pasture.

Conventional to No-Till

Transition in soy production systems began with the transformation from conventional tillage to no-till crop production. This transition was motivated considerably by the perception that NTP improves productivity without requiring substantial additional production costs. Producers generally perceive that NTP improves both soil quality and production systems overall. It does however require an initial investment in planting equipment to drill and inject agrochemicals and seed rather than plowing the soil. According to one producer interviewed, "No-till increases productivity by 18%. It avoids revolving the soil, saves fuel and reduces the use of machinery."

"Direct planting for us in the Central-East (of Mato Grosso), where we have strong rainfall, is fundamental, because with conventional planting we would be subject to erosion and environmental damage with silting of rivers and springs. We can affirm that conventional planting generated an output of 45 to 50 sacks of soy per ha. Today, we produce up to 70 sacks/ha."

It should be noted that, over time, other factors may have favored an increase in production; the change does not refer to the beneficial impact of NTP alone. For example, the continual improvement of crop varieties has made a significant contribution to productivity.

Another factor promoting crop productivity enhancement in soy operations is soil decompaction and correction, with costs cited between R$ 670 and 720/ha. "When you decompact the soil and correct soil

[81] The transition cost information for different practices was provided by Mato Grosso soy farmers interviewed, and from discussion in the literature.

acidity it can bring a productivity increase of 5 to 10 sacks/ha." In Cerrado, soil correction is widely viewed as an essential first step to achieve an acceptable level of productivity.

No-till (Roundup Ready) transgenic to conventional (non-GMO) systems

A second transition underway in soy production systems is that of a partial return to non-GMO seed. This has been prompted by the growing weed resistance to glyphosate, as described in section 4.1.2. As one grower described: "Conventional soy receive 30% more insecticides and herbicides, but they receive on sale a premium of US$ 3.00 per sack. There is no difficulty in obtaining funding to produce with conventional soy. Transgenic systems have less weeds and fewer caterpillars,[82] which leads to the need for fewer applications, but results in greater infestation of stinkbugs."[83]

The return to conventional systems has reached as many as 15% of producers, according to the Instituto Soja Livre ((GMO) Free Soy Institute) created by researchers at Embrapa and the producer association APROSOJA to provide support to this movement,[84] but is subject to price fluctuations, resulting in recent sales of conventional soy at the GMO rate. The price differential owes itself to demand from European and other markets for non-GMO products. This transition is price-motivated rather than due to resistance on the part of producers to adoption of GMO varieties per se, but it does lend itself to concern by producers to control by multinational agribusiness of the technological destiny of the soy enterprise. There has also been some resistance from traders due to the need to segregate crop purchases according to production practices. Bunge, one of the major grain buyers active in Brazil, has been reportedly willing to acquire conventional soy, but is concerned about the need to both store and transport grains along separate pathways, resulting in the decision to transport conventional soy directly to the port rather than separate storage facilities.

International market pressures

GMO-free soy can fetch better prices, but in future, there is concern that soy produced in areas that continue to suffer from deforestation pressures will be exposed to trade barriers. "In Europe, after 2020, it will be very difficult to market products at risk of deforestation," said one soy certifier. The threat of market discrimination represents a significant driver toward more intensive crop and cattle production systems, as discussed below.

2. Certification and transition

This subsection questions which drivers have been responsible for encouraging the transition to a low-carbon, sustainable agriculture in Brazil, as well as the limits and challenges to leverage the transition, so it may predominate throughout the Brazilian food system.

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[82] The velvetbean caterpillar *Anticarsia gemmatalis* Hübner is the main defoliator of soy in Brazil.
[83] The neotropical brown stink bug, *Euschistus heros* (F.) is the most important pest species occurring in Brazilian soy.
[84] http://sojalivre.com.br/

Reputational risk, sustainability commitments in value chains and environmental certification

Markets should be conceived as social constructions, subject to public judgments and therefore influenced by ethics and morals (Abramovay 2004, 2012). This interpretive view explains movements toward creation of sustainability commitments in value chains, associated with the proliferation of environmental certification mechanisms. Certification aims to improve communication between actors in value chains, from producers to consumers, regarding sustainable innovations, such as efforts being made to rid productive chains of deforestation, or to find solutions that reduce food losses and waste throughout the agricultural system. Such innovations are accompanied with provision of information to the final consumer to affect purchase choices. Certification supports this process of communication by the producer and the choice to be made by the consumer.

Certification may exist based on socio-environmental criteria such as the B Corp. system,[85] generally conditioned by a third-party audit, or by means of self-declaration or market labelling. These two models, which require different degrees of trust between actors in the value chain, are not mutually exclusive and can coexist simultaneously.

Several market labels have been developed in Brazil with respect to sustainability of beef. Walmart, for example, launched the Xingu Herd meat brand in August 2016 aimed at disseminating “responsible animal husbandry” in Brazil. Beef sold in supermarkets is produced under unprecedented standards of sustainability in the Brazilian Amazon as part of the *Do Campo à Mesa* (from Field to Table) initiative[86] (Figure 29) which commits itself to zero deforestation along the meat chain.

Figure 29: Walmart Xingu Herd Brand. Source: Walmart

Figure 30: Carbon Neutral label. Source: Embrapa Gado de Corte

In the same line of action, Embrapa’s Beef Cattle center is working on the creation of a Carbon Neutral (CCN) meat label (Figure 30), vesting the brand with the image of meat embodying low or neutral GHG emissions, obtained through ILPF systems. According to Alves *et al.* (2017) the primary goal of the CCN label is to certify that meat originating under the given standards had the cattle’s enteric methane

[85] Certified B Corp. businesses meet verified social and environmental performance standards, public transparency and legal accountability, to balance profit and purpose. See: https://bcorporation.net/directory/we-first-branding. We note that PECSA, which has encouraged a new business model along the transition to a low carbon agriculture, is the first cattle company in Latin America to receive the B Corp. certification.

[86] Source: https://www.walmartbrasil.com.br/noticias/carne-mais-sustentavel-da-amazonia-chega-ao-walmart/

emissions neutralized during its production process by trees introduced in the farming system. It also ensures that due to tree shade, cattle were exposed to more comfortable thermal conditions, indicating a high level of animal welfare. CCN labelling would be subject to third-party auditing by regulatory or representative authorities in the beef value chain, with Embrapa's supervision and technical support.

Among the certification experiences presented, it is valid to distinguish two differentiated drivers behind their conception: i) positive incentive, or ii) punitive reaction. In the first case certification represents a premium to the producer who can gain access to the label by voluntarily joining the system. It benefits from a positive image vis-à-vis the market, being able to access differentiated niches (conscious consumption) or even breaking through social-environmental barriers or safeguards imposed by the consumer market, be it domestic or international. In the second case, particularly considering the example of the Xingu Herd, it can be said that it was partly created by the retail sector - in this case Walmart - in response to the defamatory Greenpeace (2008, 2015) campaigns that denounced the presence of deforestation in the beef productive sector (see Box 1). Taking this issue directly to the consumer, Greenpeace (2015) recently classified the main Brazilian supermarket chains based on criteria related to the presence of deforestation in the meat production chain, exposing the issue on the supermarket shelf (Figure 31). Experiences such as Walmart's Xingu Herd seal, which occur concomitantly, connected and dependent on tracking systems for beef origin, are recognizably a response to the Greenpeace "Meat Sauce" campaign.

Figure 31: Pão de Açúcar meat trays received a Greenpeace label questioning the origin of the meat. Source: Greenpeace.

The Carrefour network is another that has also created a meat tracking platform to ensure that what is exposed in its network is free from deforestation and from slave labor and produced in areas that are not classified as protected or as indigenous territories. The Carrefour platform called Sustainable Livestock was launched at an event heralded by corporate and government officials who jointly signed a commitment to end illegal deforestation in Brazil in the Mato Grosso state capital, in August 2016. This event was followed by a broader corporate strategy denominated "Act for Food", aimed to promote a new business model grounded in the challenges of food system transition.

Despite the advances towards the creation of sustainability commitments in the Brazilian beef chain, there are several challenges inherent in the environmental certification of meat and its related tracking mechanisms. One technical aspect is that tracking systems are still fragile and not completely secure, especially along the first links in the calf breeding and fattening chain. Thus, despite public and corporate commitment to penalize deforestation associated with the beef chain, control of indirect impacts from the point of origin of the animal is not yet adequately performed.

In other words, tracking is effective only from the slaughterhouse onward, until it reaches the consumer's table. The breeding and fattening of calves operate through decentralized and capillary supply chains between thousands of small and medium cattle ranchers, making it difficult if not impossible to monitor the meat in this productive phase.[87] To help solve this problem and improve the overall tracking system, Carrefour has announced a partnership launched in July 2018 with the support of the Carrefour Foundation and IDH (The Sustainable Trade Initiative), whose objective is to promote sustainable calf production in more than 450 medium and small properties in the Amazon biome of Mato Grosso. The ultimate goal is to create capacity for calf rearing and fattening and beef traceability systems to ensure they are 100% free from deforestation starting at the source of the value chain.[88] The program was later joined by NatSource, leading to the definition of Verified Sourcing Areas (VSAs) with the same geographical focus.[89]

A second challenge is that, although the retail sector has responded to reputational risk by investing in products and labels to offer and communicate the exposure on its shelves of meat free from deforestation or carbon neutral, the consumer is still unable to distinguish meat with a sustainable label from other quality characteristics. This has made it difficult to justify charging a premium for the acquisition of products differentiated on environmental grounds.

Recent modeling by De Oliveira Silva *et al.* (2016) shows a paradoxical relationship between meat demand and deforestation rate. The model results suggest that reduced consumption, motivating lower demand and hence price decline, leads to less productive beef systems, associated with higher GHG emissions intensities and total emissions, whereas increased production can lead to more efficient systems, reducing both per kg and total emissions. Therefore, in opposition to the debate about shifting diets, with reduced meat consumption, this paper demonstrates the importance to stimulate increased production, encouraging the adoption of more intensive and sustainable production systems.

Finally, it should be recalled that consumers in many municipalities in Brazil where supermarket chains are not present, remain exposed to meat which has not been slaughtered or dressed according to sanitary requirements and where the origin of the animals is unknown. On the supply side, the origin of over 15%

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[87] Episodes such as the IBAMA Cold Meat Operation in March 2017, which investigated 14 meatpackers in Pará, Bahia and Tocantins who bought 58,000 head of cattle, produced on 26 farms with areas seized by IBAMA for illegal deforestation in the Amazon, reveal the fragility of tracking systems.

[88] https://www.idhsustainabletrade.com/news/grupo-carrefour-fundacao-carrefour-e-idh-lancam-programa-voltado-a-producao-sustentavel-de-bezerros/

[89] https://www.idhsustainabletrade.com/news/vsa-pilot-mato-grosso-brazil/

of the animals marketed for slaughter in Mato Grosso, Rondônia and Acre was unregistered, while on the demand side, over 8% of the meat marketed in Rondônia lacked sanitary inspection (CEPEA 2019).

Consumer preferences, sustainability commitments in value chains and accountability

Another driver that has positively influenced the transition to low carbon and best farming practices is increasing global consumer concern about what is consumed. This includes, for example: concerns about animal welfare, an end to illegal deforestation, repudiation of slave labor and degrading working conditions, valuation of family production, preference for organic food and/or less use of antibiotics.

Similar experiences have begun in Brazil with a focus on the final consumer. The previously described experience involving Walmart in its Xingu Herd project, also involved TNC's Field to Table and the meatpacker Marfrig, which commits itself to buying and slaughtering the cattle and Walmart selling the certified meat.[90] For example McDonald's, in partnership with PECSA, ICV and the meatpacker JBS, through the Novo Campo program, committed to buying meat from areas certified to be free from deforestation. McDonald's became the first in the fast food segment to purchase meat from verified areas through a beef tracking system. The goal of the effort over the coming years since its initiation in 2016, is to achieve 100% of the meat used in the network from areas guaranteed to be free of deforestation.

These two examples reveal an important effort to leverage pilot experiences to a market dimension, able to offer in quantity (scale) and periodicity (system stability and regularity) the meat the two chains demand. In this sense, the NGOs' investments demonstrated the technical feasibility of producing with better standards, increasing productivity without the need to advance the agricultural frontier. The initial incentive to adopt intensified production practices has proven less enticing than some had imagined, despite proven technical viability and creditworthiness (see previous section). Leaders expect more cattle ranchers will adopt intensified practices as their risk-averse neighbors pioneer the enhancements brought by Embrapa and NGOs such as TNC and ICV. From their perspective the next step is to engage more cattle ranchers who will help scale up the operation to market magnitude.

This discussion is also illustrative of the experience within another agricultural chain, in the soy case, where it is clear that the influence of consumer preferences on sustainability is not specific to the meat chain alone. The Soy Moratorium and socio-environmental embargoes and safeguards promoted jointly with domestic and international grain traders and oil crushers arose from this context.

There begins to exist a greater level of pressure on the part of the consumer for criteria and standards for what ends up on the dinner plate, be it soy itself or processed products (oils, meal and press cake) and their derivatives (pigs and chickens, for example, because of the animal rations derived from soy).

Like the movement observed with the beef chain, stimulated by the NGOs that act through denunciation and combating deforestation along the soy chain, new business models have been devised, based on tracking and monitoring systems, to guarantee that the soy produced are derived from areas free of illegal deforestation. The discussion regarding use of transgenics vs. conventional soy has also arisen in this

[90] https://www.valor.com.br/agro/4576625/carne-rebanho-xingu-chega-ao-varejo-do-pais

context. Multi-level and multi-stakeholder networks (RTRS and the Soy Moratorium) advance in the discussion of more ambitious commitments, e.g., moratorium on expansion of soy in the Cerrado, and in ways to improve the monitoring system of the Moratorium to avert the continuance of soy production in the Amazon biome where its production has expanded into previously deforested areas. Supermarket chains such as Carrefour participate in these networks, seeking means to reduce the carbon footprint of their supply chains by reducing the radius of supplies, and supporting local and small-medium scale producers.[91]

In the context of the current Brazilian administration, while commitments made by the private sector continue to be honored, the rollback of public environmental regulation leads us to remain pessimistic regarding progress in non-state regulation in the near future.

Similarly, despite the efforts and advances, an investigation of commitments that have recently proliferated around sustainability patterns along value chains, reveals that there is a lack of monitoring and verification of the reach of commitments publicly communicated by economic agents. One in five commitments identified has an expected date that has expired, or has never had an expected date, or has never had progress information available. One-third of the 447 companies with identified commitments have at least one commitment that is inactive (McCarthy *et al.* 2016). This agenda is therefore one that has only begun to take hold, and much more remains to be accomplished.

4. CONCLUSIONS AND RECOMMENDATIONS

1. Improvement in the food systems and policy context toward the Amazon region

In conclusion, with regard to our primary concern with the efficacy of credit instruments as drivers of productive transformation in cattle and soy enterprises in the Amazon, it may be emphasized that we found a significant incentive effect at the macro level in Brazil (57% increase in contracts) when the ABC financing interest rate was reduced slightly. However, this growth in commitment to invest in low-carbon agriculture was not reflected in a similar movement in the Amazon nor among family farmers.

Our field research discovered low operationality of the ABC credit scheme for low-carbon agriculture in the Alta Floresta region of the Amazon biome of Mato Grosso. Such a finding seems to be supported by the data, with low penetration and representativeness, showing a decline in contracts in relation to the remainder of the country. Several actors we interviewed emphasized the lack of possibilities for credit access within reach of the producers, leading the ABC credit to be characterized as "armored resources".

Furthermore, our fieldwork demonstrated that there is little knowledge on the part of the managers responsible for the service at the principal financial services agencies in the region (Banco do Brasil and Sicredi). This apparent reticence to engage with ABC financing appears to be fundamentally due in the case of the Banco do Brasil, to interest in utilizing other credit lines having a better cost-benefit ratio from the financial agent’s perspective, rather than the inability or difficulty to train lending staff with the

[91] https://www.consumidormoderno.com.br/2018/10/02/carrefour-lanca-movimento-act-for-food-e-se-destaca-ao-aderir-tendencia-das-marcas-em-adotar-causas-sociais/

peculiarities of the instrument. In regard to Sicredi, barriers in access to the instrument appear to have made it difficult for the institution to offer access, despite an apparent willingness to pursue this option.

Although other regional credit lines such as the FCO Verde may surpass the objectives of the ABC Program, the restriction in access to ABC is remarkable. One means to surmount this barrier would be to deploy ABC-only banking correspondents to play a role as a credit channel to improve such distribution and allocation of resources. Should resources become scarce, they can be targeted at carbon-sparing technologies other than pasture renovation, though this has been the most attractive practice for application of ABC resources to date. A more deliberate emphasis on availability of low-interest resources to assist farmers to comply with environmental restrictions by restoring degraded APPs could be fortuitous. The distribution of ABC credits through other financial agents, such as cooperative banks, is also likely to improve matters, boosting adherence to the scheme.

Despite these limitations, that are pronounced in the Amazon region, it appears that public or private banks, whether by punitive measures or by economic incentives such as through ABC credit, play an important role in reorienting agricultural production in Brazil towards a new development model that reconciles productivity gains with recovery and preservation of natural and ecosystem resources. This can be affirmed due to the historically important role of credit in disseminating good agricultural practices since the creation of public agricultural credit instruments in Brazil in the 1960s.

To this end, we must address the challenges, limits and obstacles identified by this study in the field of agricultural credit regulation and financing, using the tools that were recently created to intensify the transition to low carbon agriculture in Brazil. Furthermore, the role of other agents along the value chain, particularly that of meatpackers, soy crushers and supermarket chains in support of this transition is essential. As observed by one keen observer of the Amazon cattle industry:

> *"In short, the success of pledges and agreements depend on stronger implementation steps or milestones in the short–run - such as punishments and market constraints if certain goals have not been met. Past experience has shown that farmers and agribusiness respond in a pragmatic way when pressures and incentives are clear and consistent. Without clear pressure from outside the industry (market, society and public agents), it is likely that many slaughterhouses will not make commitments and agreements will not be effectively implemented. In this scenario, thousands of farmers in the Amazon would continue to slash and burn forests to raise cattle.*" (Barrreto, *et al*. 2017; our translation).

Positive pilot intensification experiments in livestock production are still limited. In the absence of credit and policy incentives, such as rural extension, it is difficult to replicate them on a large scale, reducing the possibility of changing current patterns.

Ranchers are generally resistant to investing in improved productive systems, even if it is profitable, requiring they be “brought to water” through induction. It is even more difficult, in the absence of an induction credit system, to target investments aimed at providing ecosystem services (e.g., restoration of APPs), even when they are beneficial to the sector itself.

It is therefore recommended to transform the Harvest Plan to incorporate an inductive character into best production practices. Such incentives need to be meaningful, allowing greater ease to take credit, comparatively cheaper interest rates for environmental lines, and prioritization of resources for producers who have made or want to make an environmental transition. Large producers should only have access to subsidized credit in lines that provide greater environmental benefits, while small and medium producers should be favored not only with credit but with access to technical assistance and mentoring through the transition toward more sustainable production models.

The following specific recommendations are made with respect to support to small scale family farming.

A - Credit rate differential, applying in both cases: i) Environmentally specific lines; and ii). Traditionally accessed lines (applicable for example if one accesses existing Pronaf lines such as “More Food” or the “Costing” line to apply such resources toward agro-ecological or organic production.

B - Ease of access for those who have a conservation differential. For example, those that practice agroforestry, or demonstrate the absence of an existing native vegetation deficit.

The above principles also apply to the Harvest Plan as a whole.

In the case of Pronaf, the credit policy must occur or seek articulation with public policies that involve the following elements: 1 - support to short commercialization circuits; 2 – access to institutional markets; 3- technical assistance committed to agroecology; 4 - Social organizations that perceives the importance of sustainability for the future of family farming.

Our study recommendations thus point to the need for changes in agricultural credit policy as follows:

1. To carry out an adequate evaluation of environmental factors as a basis for granting credit, such as the creation and consultation of an "Environmental Serasa" mechanism for creditworthiness screening.

2. Facilitate access to resources of the Low Carbon Agriculture Credit (ABC Credit) facility: ABC resources should become available through a banking correspondent, promoting equity in access to the request and interest in the business, through intermediary agents.

3. Improve the attractiveness of ABC credit. There has been no lack of demand for environmentally sound credit, but there is a lack of relative attractiveness and inducibility in credit policy, and there are bottlenecks in ABC's business model regarding access.

4. Rely on predetermined production models to provide estimates of reasonable results per ABC-funded project. This greatly simplifies the project and reduces unnecessary transaction costs, while ensuring more robust estimates of results. Monitoring the benefits in terms of reducing emissions would also be more practical.

5. Create differentiated credit for forest restoration. Producers have either received the traditional credit offer or applied the ABC investment resources only on "pasture reform". The other low-carbon loan lines are not well publicized.

6. Perform technical monitoring of investment operations with direct reporting to the financing bank. Such monitoring should be contracted directly by the bank, in order to monitor the operation.

7. Favor the credit for investment and seek a long-term view with stable rates.

1. Improvement in expectations of the TEEBAgriFood Framework

It is clear from this pilot application of the TEEBAgriFood Framework, that its structure compels the appraisal of a wide range of concerns, from the choice of inputs and production systems through to the final consumption of products by consumers, and their social and environmental externalities along the value chain. The feasibility of exploring all corners of this complex system in the context of two of the major agribusiness chains operative in Brazil: soy-maize and beef cattle, overlaid by the complex megadiverse Amazon biome has been extremely challenging, and there is much more to be accomplished and learned. The team involved has benefited from a transdisciplinary perspective and willingness to further share this experience as well as to pursue further investigation of the situation in the field with an open mind. We look forward to sharing this learning experience and advancing in understanding of how to apply the tools of TEEBAgriFood to the resolution of immediate and pressing problems of the global food system.

3. Areas for further research in the context of TEEBAgriFood

The following lines of additional research have been proposed by reviewers and have emerged during the research as potentially fruitful avenues to include in ongoing TEEBAgriFood studies on these themes in Brazil and elsewhere:

1. Adopt a marginal abatement cost framework to demonstrate emissions reductions from alternative land use practices in a more policy relevant way (with reference to de Oliveira *et al.* 2015);

2. Incorporate in the analysis the concepts and tools of water footprint and virtual water flows, nutrient flows, etc. to reflect export of natural capital and change in socio-economic metabolism (see Gerbens-Leens, Mekonnen and Hoekstra 2013);

3. Identify the effectiveness of consumer pressures to internalize forest protection 'value' in the price of agricultural and food products to influence the decoupling of agriculture and cattle ranching from forest conservation (see paradoxical results in de Oliveira *et al.* 2016); and

4. Consider more explicitly the employment effects of agricultural intensification and the labor linkages among farming systems at different scales.

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