AGRICULTURAL POLICIES IN DEBATE

Unlocking the Brazilian potential: the necessary incentives to engage farmers in decarbonization

CAMILA DIAS DE SÁ
CLAUDIA CHERON KÖNIG
NIELS SØNDERGAARD

APD
DIÁLOGO AGROPOLÍTICO BRASIL · ALEMANHA
AGRARPOLITISCHER DIALOG BRASILIEN · DEUTSCHLAND

APD | DIÁLOGO AGROPOLÍTICO BRASIL · ALEMANHA
AGRARPOLITISCHER DIALOG BRASILIEN · DEUTSCHLAND

The Agricultural Policy Dialogue Brazil-Germany (APD) is an interchange mechanism for knowledge and information on bilateral and global agri-environmental challenges. Germany has been developing similar initiatives with several countries for more than two decades, and they are essential references for the development of APD in Brazil.

The activities of the APD are based on the Memorandum of Understanding signed by the Ministry of Agriculture, Livestock, and Food Supply (MAPA, acronym in Portuguese) and the German Ministry of Food and Agriculture (BMEL, acronym in German). Representatives of these Ministries, Agribusiness, Academia, and Civil Society of Brazil and Germany participate in the Dialogue.

The objective is to understand better critical issues of agricultural and environmental policies in the face of growing agri-environmental challenges and climate change. The exchange and dissemination of knowledge occur through seminars, forums, conferences, publications, and exchange trips.

SCN Quadra 1 Bloco C salas 1102-1104
Ed. Brasília Trade Center Brasília - DF
Tel.: +55 61 9 9964-3731
contato@apd-brasil.de
www.apdbrasil.de
APD Brasil Alemanha
APD Brasil Alemanha

With support from

Federal Ministry
of Food
and Agriculture

by decision of the
German Bundestag

MINISTRY OF
AGRICULTURE, LIVESTOCK
AND FOOD SUPPLY

Implemented by

GFA CONSULTING GROUP
General Agent BMEL
Berlin Office

IAK AGRAR CONSULTING

AGRICULTURAL POLICIES IN DEBATE

Unlocking the Brazilian potential: the necessary incentives to engage farmers in decarbonization

CAMILA DIAS DE SÁ

CLAUDIA CHERON KÖNIG

NIELS SØNDERGAARD

São Paulo, November 2022.

ABOUT THIS STUDY

This study is used as a reference document for the APD | AGRICULTURAL POLICY DIALOGUE BRAZIL • GERMANY. The content of this study is the sole responsibility of the authors, and any opinions expressed herein are not necessarily representative or endorsed by APD.

AUTHORS

Camila Dias de Sá

Professor and researcher at Insper Agro Global, expert on agribusiness with a focus on the agricultural inputs industries and agro-industrial chains. Camila is interested in themes related to agri-environment and international trade. She is an agronomic engineer (Esalq-USP) and holds a PhD in administration/economics of organizations (FEA-USP).

Claudia Cheron König

Researcher at the José Luiz Egydio Setúbal Foundation and CORS-USP, São Paulo. She holds a PhD in Business Administration from the University of São Paulo and a Master's in International Business from Friedrich-Alexander-Universität-Erlangen-Nürnberg, Germany. She has a postdoctoral degree in organizational economics, with a focus on bioeconomics, from the University of São Paulo.

Niels Søndergaard

Niels holds a PhD in International Relations from the University of Brasilia, Brazil (2018), a Masters in Global Studies with a major in Political Science from the University of Lund, Sweden (2014). His research focuses on agricultural production, trade, and governance.

Table of contents

Executive summary

The acceleration of the global climate crisis has spurred efforts to promote the necessary transition towards deep decarbonization of economies worldwide. Carbon pricing may provide an important tool to internalize costs of greenhouse gas emissions amongst the responsible economic agents, and to bend incentives towards mitigation initiatives. Due to substantial contributions to Brazilian GHG emissions, great reductions could be made within agriculture and livestock production if proper incentives were created to discourage harmful production practices while promoting sustainability initiatives. Such positive environmental outcomes would be exacerbated by Brazil's dimension and extensive natural resource endowments, which positions it in the role of an agro-environmental power. This report assesses the opportunities and challenges of implementing sector-wide decarbonization schemes, including mandatory carbon pricing and voluntary initiatives, and their potential in terms of adoption of low-carbon production practices. The report treats the following central points and makes a range of policy recommendations within different issue dimensions:

The technical dimension

- Brazil has a significant potential for Natural Climate Solutions (NCS) given the country's extensive natural resource endowments. The agricultural and livestock sector also stands in a key position in this regard, and necessarily needs to be included in any plans with the purpose of reducing GHG emissions from ecosystems and harness their potential to store carbon.
- Beyond reforestation and avoiding natural vegetation conversion, a large share of Brazilian comparative advantages in NCS derive from practices that improve the carbon content in the soils and spur more rational input use, such as no-tillage, biological nitrogen fixation, integrated systems, and the general potential for agriculture and livestock sustainable intensification. All of these practices could be scaled significantly with substantial sustainability gains.
- One of the most significant initial challenges for implementation of low-carbon mitigation projects within agriculture and livestock regards the provision of the necessary resources and know-how to embark upon the transition. Government

engagement and public-private partnerships can be highly important in this regard, especially in relation to small- and medium-sized producers.

- Technical assistance is an important factor in encouraging the dissemination of low-carbon practices in Brazil. There is evidence that through personalized technical assistance farmers can raise productivity, increase their income, and obtain a reduction in CO_2 emissions as a result of combining carbon sequestration and avoided emissions.
- The specific Brazilian climatic and soil conditions permit year-round cultivation, and up to three annual harvests. This reality should be considered in the process of defining and adapting MRV methodologies. Current efforts to create large-scale information systems that join databases on the results of varying agricultural interventions in different Brazilian biomes with models of emissions dynamics can be important to lower MRV costs.
- Implementation of proper MRV systems is key to successful carbon credit generation or to differentiate the product to the final consumer, including price premiums for the adoption of sustainable practices. This must be a scientifically robust standard, recognized by the market and viable for farmers.

The Institutional dimension

- An institutional framework to foster carbon pricing economic incentives in favor of mitigation efforts is crucial. Governments must create appropriate regulatory frameworks for the mandatory carbon pricing of the most emission-intensive economic sectors. Therefore, creating the necessary institutional pillars for domestic carbon pricing, but also to underpin the growth of voluntary markets stands as an important task for Brazil
- In order to spur deep decarbonization within the Brazilian economy, the most emission intensive sectors, hereunder agriculture and livestock (including land use change), will need to be subjected to a comprehensive framework for emission reductions with mandatory coverage to ensure a transition towards a low carbon agriculture.
- Certification integrity is critical to guaranteeing confidence in any emission reductions. The agricultural sector should be held to the highest standards within the market, even if this reduces the scope of projects potentially eligible for certification.
- Confronting native vegetation loss through swift and rigid legal enforcement to reach the goal of zero-illegal deforestation becomes an indispensable condition to provide credibility around the general context for Brazilian NCS solutions.

The Economic dimension

- Carbon pricing and NCS potentials provide a mix of positive and negative economic incentives to spur the move towards low carbon production, though solutions and specific mitigation policies should be context-specific
- The viability of carbon credit generation ultimately hinges on their price and implementation costs. Prices have historically been low, although they have increased more recently. The costs of implementing are still high. Scaling mitigation projects and certification could lower entry costs, and small and medium-sized producers may be included through cooperatives.
- Demand for carbon credits within the voluntary market has been increasing rapidly in recent years and is set to continue along an exponential growth curve. If Brazilian players become eligible to supply compliance markets, this would be associated with a substantial potential demand, but likely also depend on a mandatory carbon pricing scheme within the country.

The Social dimension

- Beyond technical and institutional challenges, cultural factors also play a role in nurturing rural producers' skepticism. This may be partly overcome through efforts to highlight the diverse benefits associated with carbon mitigation initiatives, such as improved productivity and soil fertility.
- Even if the cultural barriers are overcome, many Brazilian farmers will hardly be able to engage in projects to adopt best practices or participate in carbon markets on an individual basis. Coordination of this process by agents pooling resources and providing collective goods will be necessary.
- Carbon credit generation should nonetheless be thought of as one amongst several benefits of transitioning towards low carbon agriculture. It is important to promote the understanding amongst producers that the increase in the stock of carbon in the soil promotes productivity gains.
- Socio-environmental co-benefits are important to spur positive reverberations of mitigation projects within the agricultural and livestock sector. Ensuring no-harm and maximizing co-benefits can also help supporting a more holistic sustainability approach within GHG mitigation projects.

Abbreviations

ABC	|	Agricultura de Baixo Carbono (Low Carbon Agriculture)
ALM	|	Agriculture Land Management
APD	|	Agropolitical Dialogue
ARR	|	Afforestation / Reforestation / Revegetation
BNF	|	Biological Nitrogen Fixation
CCBA	|	Climate, Community, and Biodiversity Alliance
CCP	|	Core Carbon Principles
CDM	|	Clean Development Mechanism
CLFi	|	Crop, Livestock, Forest integration
CPIs	|	Carbon Pricing Instruments
ESG	|	Environmental, Social, Governance
ETS	|	Emissions Trading System
GHG	|	Greenhouse Gas
IBRA	|	Instituto Brasileiro de Análises (Brazilian Institute of Analysis)
IPCC	|	Intergovernmental Panel for Climate Change
ITMOs	|	Internationally Transferred Mitigation Outcomes
MRV	|	Measurement, Reporting, Verification
NbS	|	Nature-based Solutions
NCS	|	Natural Climate Solutions
NDC	|	Nationally Determined Contributions
PES	|	Payment for Environmental Services
PMR	|	Partnership for Market Readiness
PNMC	|	Política Nacional sobre Mudança do Clima
REDD+	|	Reducing Emissions from Deforestation and Forest Degradation (plus)
SDG	|	Sustainable Development Goals
SINARE	|	National System for the Reduction of Greenhouse Gasses
SOC	|	Soil Organic Carbon
UNFCCC	|	United Nations Framework Convention for Climate Change

1. Introduction

The increasingly salient manifestations of a global climate crisis have meant that this issue has come to define agro-environmental agendas worldwide. As human activities have raised the risk that crucial planetary boundaries will be crossed, climate change now stands as one of the most urgent contemporary ecological threats (Rockstrom et al. 2009; Steffen et al. 2015). Agriculture and livestock production is closely interconnected with the risks of exceeding planetary boundaries related to land-use, water scarcity, phosphorus and nitrogen cycles, and biosphere integrity, and mainly, climate change (Springmann et al. 2018; Willett et al. 2019). Production of agricultural commodities such as beef, soybeans, palm oil, and wood products are closely associated with processes of land-use change with detrimental climate impacts (Henders et al. 2015; Pendrill et al. 2019), which ultimately also could trigger important ecological tipping points (Lovejoy & Nobre, 2018; 2019).

Attempts to mitigate the negative effects of agriculture on the global climate system have gained increasing attention in recent years. They now encompass different initiatives ranging over sustainable intensification, agroforestry experimentation, reduction of fertilizer application, decoupling of food production from deforestation, and other changes to conventional modes of production and consumption. Given the scale of the sector's current contribution to the global climate crisis, a transition in the direction of low-carbon agriculture can become an essential lever for change in global climate mitigation efforts. This is not least the case with the Brazilian agricultural and livestock sector. Through both its direct and indirect emissions, this sector represents the largest source of Brazilian Greenhouse Gas (GHG) emissions. Considering the size of the area dedicated to crops or pastures in Brazil, - approximately 250 million hectares - as well as the extreme variation between the most and less emission-intensive modes of production, a huge mitigation potential exists through adoption of low-carbon practices at the sectoral level. Moreover, given the relatively clean character of the Brazilian energy matrix, which is based largely upon hydropower, the agricultural sector stands as the single most important challenge from a climatic perspective.

The current report engages with the question of how mechanisms for carbon pricing and trading may support improved sustainability outcomes within Brazilian agriculture. More specifically, we aim to provide an overview of the current landscape of incipient Brazilian carbon market mechanisms, and to highlight the opportunities and challenges which they provide in terms of lowering sectoral emission levels. Carbon pricing has been defended as an important step to bend economic incentives in favor of a low-carbon development (Edmonds et al. 2019; Stiglitz & Stern 2017; van den Bergh & Botzen, 2020). However, different scholars have also cautioned about the risks which reliance on market mechanisms can pose in this regard, - especially with respect to integrity of emission reductions (Green, 2017; Ervine, 2018; Schneider & La Hoz Theuer, 2019; Schneider et al., 2019).

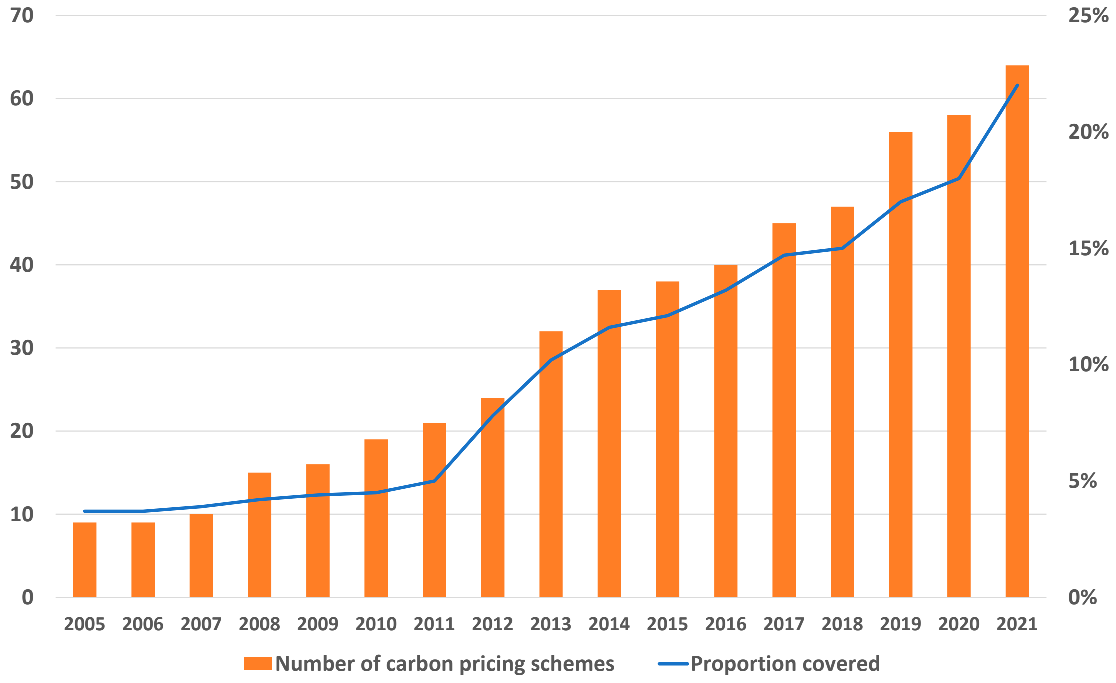
This report also draws on knowledge obtained by one of the authors, who attended the event "Expert Dialogue: low-carbon agricultural commodity production", held in June 2022 at the Center for Development Research at the University of Bonn, Germany. The forum, organized by the Brazil-Germany Agropolitical Dialogue (APD), was part of an exchange trip to meant at sharing knowledge and perspectives about carbon markets and agricultural sectors of the two countries. The author traveled at the invitation of the APD together with researchers from important research organizations in Brazil, as well as interlocutors from the private sector and civil society. With these insights in mind, we aim to provide a realistic and balanced outlook on existing efforts and the future potential to spur emission reduction through carbon pricing.

In section 1, the report initially presents an outline of essential concepts, trends and players within global carbon markets, as well some key data on Brazil's emissions profile and potential to participate within them, with specific regards to the opportunities in the agricultural sector. The section 2 engages with some of the most important challenges in this regard, related mainly to regulatory frameworks, certification integrity, cultural obstacles, and economic factors. In section 3, opportunities related to comparative advantage, demand, and co-benefits are examined. Section 4 treats some of the available options to adjust incentives to promote mitigation efforts through carbon pricing. Section 5 examines the technical challenges and potential solutions to support sectorial inclusion within carbon pricing mechanisms. The conclusion sums up our results and presents our general recommendations.

1.1. International carbon markets and pricing mechanisms

Attempts to mitigate global GHGs emissions have taken many different forms. Central amongst these initiatives are the efforts to price emissions, to make the responsible economic agents internalize the associated costs. **Carbon Pricing Instruments (CPIs)** rely on the view of climate change as a market failure, which is addressed through a change in the economic incentives structure (Steer & Hanson, 2021; Hingne, 2019). As a result, the proportion of global GHG emissions covered by CPIs has risen from around 5% in 2005 to 22% by 2021, as can be read from Figure 1.

Figure 1 – Global GHG emissions covered by carbon pricing (proportion in % between 2005-2021)



Source: World Bank (2022)

The most common regulatory arrangements for CPIs are either a **carbon tax** or an **Emissions Trading Schemes (ETS)**. Carbon taxes are generally applied as a fixed price on GHG emissions corresponding to 1 ton of CO_2 in terms of global warming potential. ETS arrangements, on the other hand, work through the capping of emissions within particular economic sectors and/or jurisdictions. Often, a number of emissions quotas ("the right to emit") are distributed between the regulated entities to be traded between agents covered by the scheme, and the price is determined through supply and demand. Entities subjected to either carbon taxing or included in ETS schemes can mainly be found within emission-intensive sectors where accounting of GHGs is relatively easy. When carbon pricing is a publicly mandated requirement, the markets that arise to ensure conformity through purchases of emissions quotas are known as **compliance markets**. Through the notion of **Internationally Transferred Mitigation Outcomes (ITMOs)**, the Paris Agreement of 2015 permits states to trade CO_2 emissions in order to comply with their respective reduction goals. However, so far, this has not resulted in the emergence of substantial international carbon markets based on ITMOs.

When carbon pricing is not a legal requirement, trading of emission mitigation occurs within **voluntary markets**. By their nature, voluntary markets are more flexible, and rely on the monetization of mitigation or sequestration projects, as private buyers seek to offset emissions made elsewhere. Generation of **carbon credits**, referring to 1 ton of CO_2 equivalent, within these markets depends on buyers' confidence in these products. A range of different sequestration and mitigation projects can thereby lead to the generation of carbon credits, - which frequently also has resulted in serious problems of **integrity**, when there is doubt about the robustness of the carbon credits. In order to confront integrity issues, different mechanisms have been devised, such as independent certification agencies or offset mechanisms related to compliance markets.[1]

1.2. The Brazilian context

Due to its size and extensive natural resource endowments, Brazil stands in a central position within the global climate regime, meaning that the country's course of action becomes important in either aggravating or mitigating the climate crisis. Especially the Brazilian agricultural sector stands in a key position, as sustainability measures within this sector would be important in mitigating Brazilian GHG emissions. Agricultural and livestock producers could thereby become part of the solution to this problem, as a huge potential exists either through the conservation of the native vegetation inside the farms, or by the adoption of more modern and land-intensive production models, and by introducing practices that increase carbon stocks in the soil. While most of the current deforestation in the Amazon biome or the frontier regions of the Cerrado is illegal (Valdiones et al., 2021) and should be confronted through swift public action, Brazilian law permits deforestation under certain circumstances[2]. Financial incentives can help spur above-the-law conservation and the adoption of sustainable practices with positive mitigation outcomes.

1 By 2020, the Verified Carbon Standard (VCS) accounted for the largest amount of carbon credits generated, followed by the Gold Standard and American Carbon Registry. The Clean Development Mechanism (CDM) devised as an offsetting mechanism under the Kyoto Protocol was the second-largest source of carbon credit generation.

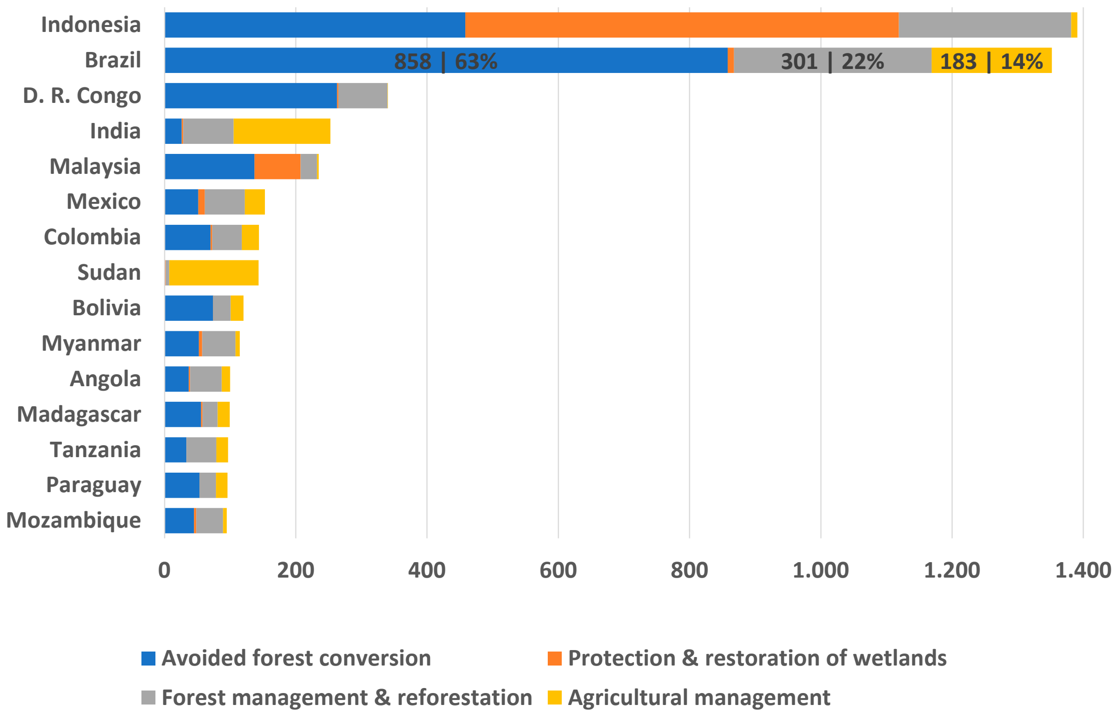
2 Private rural properties in Brazil need to keep a so-called legal reserve of intact native vegetation, at a proportion which varies from 20-80% of the property according to the biome. Those who have native vegetation exceeding this level can legally deforest it, in cases when a permission has been given.

Brazilian natural resource endowments could provide certain comparative advantages for the country within global carbon markets. Land use strategies, such as conservation and reforestation projects currently constitute some of the most economic alternatives for emission reductions. The World Bank (2022) suggests that carbon credits generated from forestry and land-use projects increased 159% over 2021, accounting for more than a third of total credit issuances. From being a source of net emissions early in this century, by 2030 forests could become an important carbon sink if proper governance arrangements are pursued. Beyond forestry projects, the implementation of practices of low-carbon agriculture also contains a considerable potential for emission reductions within Brazilian agriculture. Nature-based Solutions (NbS), which rely on enhancing natural activities to help address societal challenges, have attracted significant attention in recent years. Falling under the NbS umbrella, Natural Climate Solutions (NCS) refer explicitly to conservation and management initiatives that reduce GHG emissions from ecosystems and harness their potential to store carbon (Seddon, 2020).[3] Cost-effective Natural Climate Solutions (NCS) may offer globally substantial climate mitigation in the coming decades. In this context, tropical countries deserve attention, as they hold around 60% of global NCS potential (Griscom et al. 2017). From a climate perspective, improved land management is needed to achieve the Paris Agreement's temperature target, and in the tropics, the potential for additional land carbon storage is greatest.

Brazil is very well positioned for large-scale NCS mitigation in the near term, since it holds at least 21% of the tropical NCS potential at "cost-effective" levels (<100 USD $MgCO_2e$-1) (Griscom et al., 2020). When it comes to the global NCS potential, Brazil could account for 15% of the total (McKinsey Nature Analytics, 2021). Hence, together with Indonesia, the country accounts for the brunt of the potential for cost-effective NCS solutions (Figure 2).

3 NbS encompass a wide range of actions, such as the protection and management of natural and semi-natural ecosystems, the incorporation of green and blue infrastructure in urban areas, and the application of ecosystem-based principles to agricultural systems. The concept is grounded in the knowledge that healthy natural and managed ecosystems produce a diverse range of services on which human wellbeing depends, from storing carbon, controlling floods and stabilizing shorelines and slopes to providing clean air and water, food, fuel, medicines and genetic resources. NbS is an 'umbrella concept' for other established 'nature-based' approaches such as ecosystem-based adaptation (EbA) and ecosystem-based mitigation, eco-disaster risk reduction and green infrastructure. More recently, the term 'natural climate solutions (NCS)' entered the lexicon (Seddon, 2020, p.2).

Figure 2 – Top 12 tropical countries in terms of total cost-effective NCS (Tg CO_2e yr–1) and its pathways to climate change mitigation



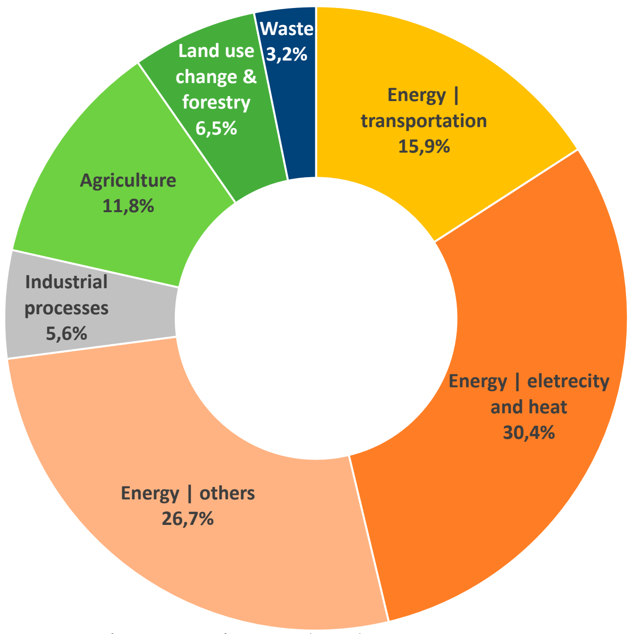
Source: authors' elaboration based on data retrieved from Griscom et al. (2020). Note: Units are mean annual million metric tonnes of CO_2 equivalents during the period 2030-2050 (TgCO_2e yr-1)

Despite the great potential of climate change mitigation outcomes related to forest resources, Brazil also has significant options related to agriculture and land management, which represents 14% of the total. Compared to the major providers of NCS solutions, Brazil is among the few that have the financial weight or the capacity to attract the necessary investments in order to scale the adoption of NCS projects. International co-financing could accelerate NCS implementation as long as it is supported by institutional capabilities and good governance.

With specific regards to agriculture and land management, climate financing for soil is improving, and there is a growing focus on agriculture under the Paris Agreement. Since 2018, the Koronivia Joint Work on Agriculture within the UNFCCC has explored mitigation potential within agriculture and soils, encompassing improvements in soil organic carbon (SOC), soil health and soil fertility under grassland and cropland, as well as integrated systems (UNFCCC, 2018). Globally there are also a variety of new private-sector initiatives on SOC that promise sufficient funding and potential results (Bossio, et al. 2020).

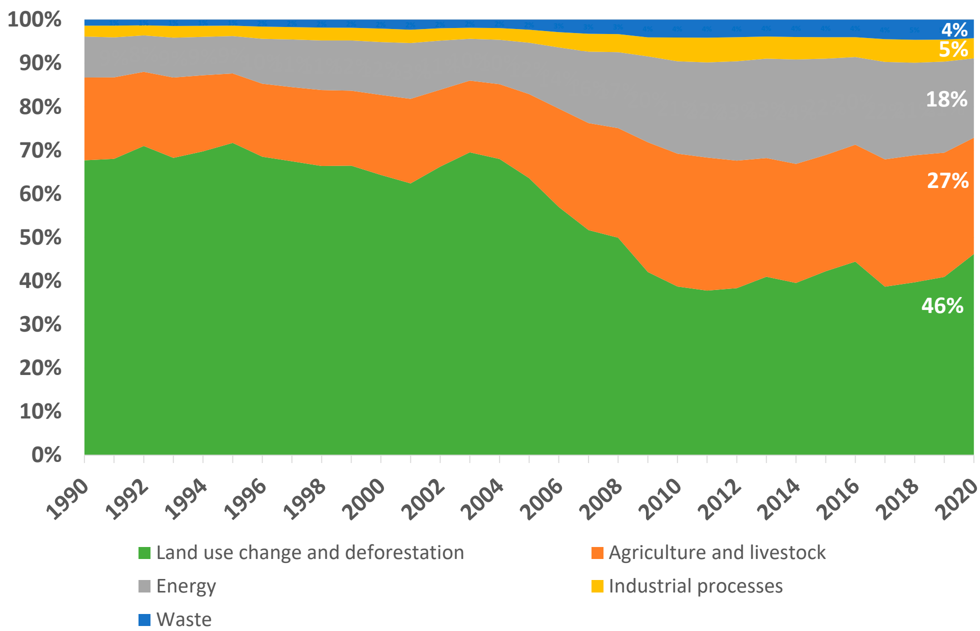
Brazil's geographical location in predominantly tropical biomes means that GHG emission from native vegetation loss are elevated. However, it simultaneously also means that the potential for additional land carbon storage is significant. Worldwide, emissions largely originate from the energy sector, which accounts for 73%. Emissions from agriculture, land use change, and forestry represent slightly more than 18% (Figure 3). In Brazil these two emitting sectors account for 73% (Figure 4).

Figure 3 – Proportion of global GHG emissions by emission source in 2018



Source: Climate Watch/CAIT (2022)

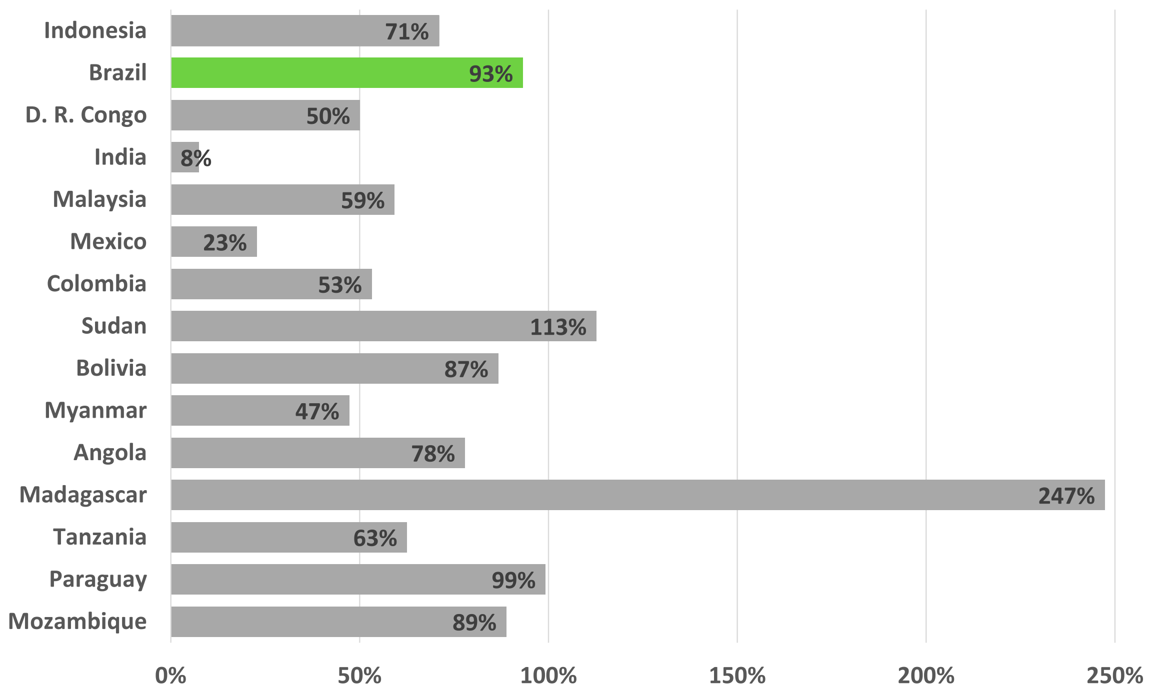
Figure 4 – Historical evolution of the proportion of Brazilian emissions by source



Source: SEEG (2021)

Many tropical countries have an emission profile with a large share of deforestation and land use. In comparison with other countries, the great potential of these countries in NCS should therefore not be viewed only in absolute terms, but also in a relative perspective in relation to the size of its emissions. This proportion is important in terms of balancing the country's total GHG emissions (Figure 5). In the case of Brazil, this proportion highlights the importance of encouraging the adoption of sustainable agricultural practices to fulfill its climate commitments. It is noteworthy, that despite the mitigation potential, the CO_2 emitted and removed by the soil is not yet accounted for in Brazilian national emission inventories. Therefore, it has not yet been computed for verification purposes of the country's climate goals (Potenza et al., 2021).

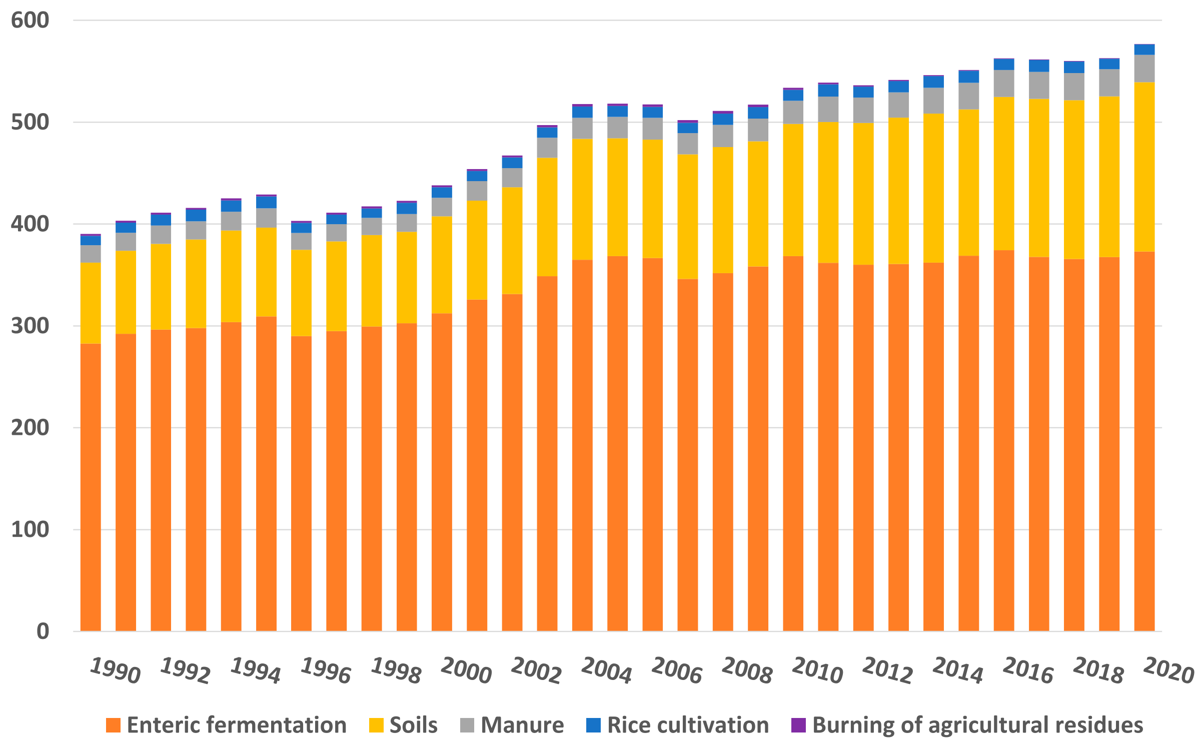
Figure 5 – NCS as a percentage of total national GHG emissions from the Top 12 tropical countries in terms of total cost-effective NCS



Source: authors elaboration based on data retrieved from Griscom et al. (2020) and Climate Watch/CAIT (2022). Note: for this calculation, national emissions as of 2019 were used.

From the emission profile of Brazilian agriculture (excluding land-use change), it can be observed that activities such as livestock production (through enteric fermentation) and soil management account for the main share of sectoral emissions (Figure 6). Consequently, sustainable intensification of livestock, recovery of degraded pastures by conversion to well-managed pastures, low-carbon agriculture or reforestation, adoption of integrated systems, and strategies to reduce nitrogen fertilization are important parts of the solution for the country's engagement in the climate agenda. In this context, soil carbon storage represents a large share of the Brazilian potential. Globally soil carbon represents 25% of the potential of NCS and comprises 47% of the mitigation potential of agriculture and grasslands, apart from delivering multiple ecosystem services (Bossio et al. 2020).

Figure 6 – Emissions from Brazilian agriculture and livestock. By source in millions of tons of CO_2eq (excluding land use)



Source: SEEG (2021a)

2. An overview of the challenges for Brazilian agriculture and livestock sector within carbon markets

Under the Paris Agreement, Brazil has committed to a 50% reduction by 2030 in relation to 2005 emissions, through its National Determined Contribution (NDC). The elaboration of domestic institutional foundations is a defining feature of states' ability to engage within its climate commitments. Assessing the process of materialization of the institutions aimed at advancing the integration to this market thereby becomes an important initial analytical focus point.

2.1. Regulatory mechanisms for carbon pricing in Brazil

Brazil has been a pioneer in the development of Clean Development Mechanism (CDM) projects during the Kyoto Protocol. The country registered its first project activity in 2004 and accounted for a large share of CDM initiatives. Brazil was also one of the first countries to locally establish the necessary legal bases for the development of CDM projects. This provided important experience and institutional capacities for engaging with the domestic regulatory and legislative challenges to facilitate a more integrated global carbon market in line with the Paris Agreement (Mozzer & Pellegrino, 2018; Bittencourt; Busch; Cruz, 2018).

In 2009, Brazil instituted a national policy for climate change (*Política Nacional sobre Mudança do Clima*, PNMC, in its portuguese acronym). This has provided an important institutional platform for structuring a Brazilian ETS mechanism. In 2010, the Low Carbon Agriculture Plan (Plano ABC) was adopted, containing different measures to support mitigation efforts within the Brazilian agricultural sector. In 2021, the updated version "Plano ABC+" was launched. Moreover, the revision of the Brazilian Forest Code in 2012 also comprises provisions (Article 41) meant to facilitate Payments for Environmental Services (PES). These provisions allow the government to institute a program to support and encourage environmental conservation and sustainable rural production. Although Article 41 of the Forest Code has not yet been regulated up to 2022, in 2021, Brazil enacted a National Payment Policy for Environmental Services (Law 14,119). This policy recognized initiatives for the conservation and recovery of native vegetation, water sources and biodiversity in rural and urban areas, as well as the sustainable management of agricultural, agroforestry and agrosilvopastoral systems (Pinto; Guimarães, Moutinho, 2022). In 2019, the National Biofuels Policy (RenovaBio), an incentive policy to expand the use of biofuels in the Brazilian national energy matrix, was officially launched.

Under the coordination of the Ministry of Economy and the World Bank, the Partnership for Market Readiness - PMR Brazil project - aimed to discuss the convenience and opportunity of including carbon pricing in the package of instruments for the implementation of the National Policy on Climate Change (PNMC) in the period post-2020. The project ended in December 2020, with the recommendation of an Emissions Trading System – ETS (Albuquerque et al. 2021). The PNMC anticipated that specific guidelines for a low carbon economy would be detailed in the form of a federal decree. This decree number 11.075 would only be published in May 2022, nearly 13 years after its stipulation in PNMC. Although the decree signals the executive's readiness to establish the institutional foundations for a regulated carbon market, many issues are still under discussion, mainly those regarding the timelines and sectorial obligations to reduce emissions.

Beyond the juridical insecurity associated with the executive decree, - which could undergo significant changes with short notice - the decree's formulation is not clear with respect to the obligation for emission reductions. As it stands, it appears to permit regulated agents to comply with their targets through purchases of offsets, thus not differentiating between the regulated and the voluntary markets. Moreover, it does not specify deadlines for reaching these objectives, and whether there will be consequences for those sectors who fail to comply with reduction goals. The different economic sectors must present their decarbonization strategies and expected trajectories within a maximum period of one year from the date of the publication of the decree. Yet, specific sectoral plans and their goals will be established by the Ministries of Environment, Foreign Affairs, and other related administrative bodies. In this sense, the targets will not be imposed, but rather treated in discussions with specific sectors, even though the final word will be up to the Interministerial Committee on Climate Change. Therefore, some analysts fear that the sectoral targets could turn into wider agreements that favor the interests of specific regulated sectors. Moreover, the prospects of mitigation plans with differentiated timelines for each sector could facilitate lobbying on behalf of business groups seeking to postpone the phasing in of their mitigation obligations.

The decree institutes the SINARE (the National System for the Reduction of Greenhouse Gasses) which should function as a center for registration of emission reductions, compensations, and credit transfers. The SINARE will also accept registries for carbon lifecycle emissions, carbon flows from native vegetation, soil and blue carbon, and units of carbon stock without any need for certification. By presenting the guidelines for the elaboration of the so-called Sectoral Climate Change Mitigation Plans, the document presents a range of technical limitations in the conceptual definitions about what can be considered as carbon credits, methane credits, and emission reduction credits, etc. These concepts apparently reflect an attempt to integrate environmental assets into the carbon market, since the traditional "cap & trade" model does not allow for the pricing of other assets. However, some of these concepts are unique on a global basis, such as the methane credit, which has been met with nearly unanimous critique, given that in nearly all markets, methane emissions are measured and traded in units of CO2 equivalents. A central concern is that the existence of more than one measure could spur problems of double counting, thus compromising climate additionality. Another point of critique is that such credits originating from Brazil may not be internationally accepted.

In sum, even though it has been acclaimed by the government as a decree which establishes a regulated carbon market in Brazil, it does not create a cap and trade or carbon taxing system in which the emission goals established by the regulating entity are reached through emissions licenses/quotas, and not only by the use of carbon credits. The decree thereby appears to restrict itself to organizing voluntary demand for carbon credits, with an opportunity bias in the generation of carbon credits. It does not impose emission limits, which otherwise would be necessary for an effective internalization of negative externalities through carbon pricing. A positive point within the decree regards the presence of agriculture and livestock production amongst the sectors meant to be subjected to regulation. Apart from demonstrating a degree of coherence of public policies in terms of including all of the most important emitting sectors, this also converges with net-zero commitments assumed by large companies and creates a range of opportunities for this sector to engage actively with the mitigation of GHG emissions. The necessary legislative process that provides more legal certainty, through specific legislation, for the creation and regulation of a domestic carbon market, as already provided for in the PNMC, began with the bill 528 which will be discussed later in section 4.1.

2.2. Certification Integrity

Globally, NbS are getting attention in international policy and business rhetoric. This has also been evident in Brazil, and companies dedicated to generating carbon credits from the preservation of the Amazon have been gaining traction and large investments (Adachi, 2022). In terms of public policies, the Low Carbon Agriculture Plan (Plano ABC) was recently extended until 2030 (see section 3.1). NbS represents an opportunity to tackle both climate mitigation and adaptation challenges usually at reasonable costs and also provide additional social and environmental benefits.

For the Brazilian agricultural and livestock sector to engage within global carbon markets, it becomes critically important to ensure the integrity of the carbon credits emitted and the emission reduction they represent. Robust carbon credit protocols, therefore, need to be structured according to a range of key integrity principles, to which it becomes imperative to adhere in order to be able to market these offsets at the international level. We treat six of these key principles, considered as no-harm, permanency, no-leakage avoidance, no-double counting, additionality, and independent verifiability.

First of all, guaranteeing that carbon mitigation projects **bring no harm** to people and the environment in which they are implemented is primordial to guarantee integrity. This implies the need to pay attention to potentially affected local communities and populations, establishing meaningful consultation processes to gain their consent, and involve them in a way that ensures equitable distribution of project revenues. As so-called "green grabs"[4] have gained much public attention in recent years, this balanced and more holistic sustainability approach to mitigation projects has become even more imperative. It also converges with the need to avoid a myopic focus on GHG mitigation in project design, which despite being the principle desired outcome, also should be considered in conjunction with a variety of socio-environmental key performance indicators. As a minimum, no harm should be detected in relation to other sustainability parameters. In a practical sense, this also means that producers and other actors interested in engaging in carbon credit generation need to present a strictly compliant sustainability performance, both with regards to the direct repercussions of the project implementation but also more broadly on the property level.

4 Green grabbing refers to the appropriation of land areas for conservation purposes which excludes or directly expel local communities from these areas in a way that affects their livelihoods.

Trade-offs can arise if climate mitigation policy encourages NCS with low biodiversity value, such as afforestation with non-native species or low diversity plantations. This can result in maladaptation, compromising other regulating and cultural ecosystem services. In this sense, one must ensure that natural solutions can achieve their potential to tackle both the climate and biodiversity crises (Seddon, et al., 2020). As the Brazilian market is more mature in terms of valuing climate mitigation (carbon emissions) than in relation to valuing environmental services more broadly, this trade-off should not be neglected by public policy makers and by agents operating in the NbS market. Ensuring a healthy transition to a low carbon economy while preserving biodiversity is key to achieving more resilient environments.

A second critical integrity principle concerns **permanency** of emission reductions. This hinges on the ability to define robust contractual and other institutional mechanisms to ensure that effectuated and future reductions on which project baselines rely will not be reversed. This naturally requires longer planning horizons than many rural producers are accustomed to operate with, given that carbon captured in soil or biomass needs to remain stored for at least 20-30 years. The largely tropical character of Brazilian agriculture means that soil-permanency differs from that of temperate agriculture in many respects, which calls attention to the need for improved and more calibrated Measurement, Reporting, and Verification (MRV) procedures and technologies.

An alternative approach to the issue of permanency is based on the installation of portfolio-wide buffer reserves (each project contributes with a share of the credits achieved) that works as an insurance scheme. For any event, either intentional or unintentional, that causes sink reversals or carbon stock losses, credits held in the buffer account will be released and permanently canceled. Most voluntary carbon market standards operate with buffer reserves (Bossio et al., 2020).

Avoiding **leakage** of emission-producing activities constitutes another central integrity principle for carbon credit generation. Leakage refers to the process whereby the reduction in emissions in the area or activity in which the project is implemented is displaced to other areas and/or activities. Leakage is likely to occur whenever the geographic scope of an intervention is limited in relation to the general scope of the targeted activity (Wunder, 2008). It is therefore a problem with no easy solution. Jurisdictional initiatives, for example, can reduce the level of leakage, but not completely eliminate it. Very rigid regulations that cover the entire Brazilian territory in an isonomic way would, however, likely face widespread resistance. In relation to Brazilian agriculture, displacement of deforestation from one jurisdiction and property to another, or between areas within the same property, as a consequence of project-related conservation activities constitutes a classical example of leakage (Newell et al. 2013). Another form of leakage relates to processes of sustainable intensification. Environmental gains from intensified production, for example, in the form of land sparring and/or reduction in breeding cycles thus run the risk of being undercut if they do not lead to a reduction in the total area dedicated to production, or if ranchers simply chose to increase stocking rates. Leakage monitoring can be associated with significant difficulties of assessing indirect effects of projects, and is therefore a highly complex process.

A central point of attention in the debates about GHG offsets and carbon markets regards to risk of **double counting**. When the same emission reductions are accounted for in more than one single jurisdiction, property, project, etc. problems of double counting become evident, which implies the risk of undermining confidence in carbon trading systems (Schneider & La Hoz Theuer, 2019). Double counting has often been discussed with attention directed towards the level of national jurisdictions, highlighting the risks that weak accounting systems would mean that the same reduction gains could appear in the carbon inventories of two different countries. In the context of Brazilian agriculture, a risk also exists that insufficient monitoring systems could mean that the same reductions could be accounted for in different projects. In order to avoid double counting, the creation of comprehensive and detailed national registries has been proposed as a solution (Schneider et al., 2019). This calls attention to the establishment of robust institutional arrangements to guide transactions within any future schemes for a Brazilian carbon market, and the need to cover all sectors, projects, and regions within such a system.

The principle of **additionality** is particularly central with regards to assessments of the potential of Brazilian agriculture to engage within global carbon markets. In line with this principle, projects can only be considered as eligible for carbon credit generation if a strong case can be made that their GHG reductions would not have occurred in their absence. With regards to innovative technologies and production systems within the Brazilian agricultural and livestock sector, this principle could pave the way for financing of projects with the potential to mitigate or sequester large amounts of CO_2. However, it also means that when production systems with a positive emission profile become common practice within the sector, - for example, due to possible economic advantages - they gradually loose their additionality, and consequently, the potential to generate carbon credits. This may be the case with regards to crop-livestock integration or no-till, which both contain a significant mitigation potential compared to conventional modes of production, but due to their increased outputs now have become widespread within Brazilian agriculture. For example, Verra considers it as additional if less than 20% of producers in a region adopt a given practice (Verra, 2020). In this case, an eventual additionality could be obtained through the continuous improvement of practices, as a "stacking" of sustainable interventions that can prove additionality over time.

Another significant point of discussion concerning additionality relates to conservation of native vegetation within Brazilian private properties. According to the Brazilian Forest Code, land holders need to preserve between 20-80% of the property, depending on the biome in question, - the so-called legal reserve. As the legal reserve is a requirement which rarely can be found outside Brazil, some voices from Brazilian agribusiness claim that even though maintaining the legal reserve intact is required by law, they should be entitled to generate carbon credits corresponding to the amount of CO_2 stocked in these areas. Although this perception is common within the Brazilian agricultural sector, it is very unlikely that international buyers and other actors within the emissions trading sector would consider legally mandated conservation as additional. Overcoming this entrenched perception of entitlement to monetize legal reserves may become one of the main hurdles to convince Brazilian farmers and ranchers to engage within global carbon markets through above-the-law conservation efforts, which are much more likely to be considered in accordance with the principle of additionality.

Finally, guaranteeing **independent verifiability** of emission reductions and carbon credits generated within Brazilian agriculture also becomes critical to ensure integrity. Initially, this requires the development of an institutional structure of third-party verification at the market level, hinging on project certification by internationally recognized certifiers and proven methodologies. Most importantly, certification should be independent of project implementers in order to avoid conflicts of interest. On the practical level, certification depends on robust MRV systems. MRV are key to register and document effectuated carbon sequestrations deriving from project implementation and operations. As such, consolidation of uncontroversial and technically proven MRV specifically geared to the tropical conditions of Brazilian agricultural and livestock production is vital, as we shall see in coming sections.

2.3. Cultural factors

Along with regulatory aspects, social and cultural factors also influence producers, and are of great importance in relation to the challenges of implementing a carbon market. Producers need to adapt to institutional arrangements and adhere to environmental rules. Moreover, they also face expectations to adopt environmental best practices. That is, beyond the purely technical challenges, social issues, including cultural, economic and political constraints, are equally complex and often ignored (Amundson & Biardeau, 2019; Bradford et al., 2019; Thamo & Pannell, 2016; Thamo et al., 2020).

Apart from seeking to increase efficiency levels, producers also establish behavioral patterns through the influence of cultural and normative aspects. In other words, the behavior of producers is defined not only by regulatory norms, laws and rules, but especially by expectations and social acceptance within the environment in which they are inserted. Replicating good practices from successful first movers can both be important in motivating others to change their modes of production, but also change collective perceptions and accelerate sustainability compliance through social pressure. The effectiveness of adopting sustainable practices depends on bottom-up participation, strengthening the channels necessary for the dissemination of results and intervention models. An environmental governance system must consider the public-private-society interaction. The government can play an important role in assuming leadership, but must consider the cultural differences between the regions and the individuals that operate within the sector.

The adoption of low-carbon practices in Brazilian agriculture entails the need to confront skepticism and a somewhat conservative mentality amongst producers. Although traditional practices often represent outdated modes of production that compromise both productivity and the environment, they are often very persistent and deep-rooted. Soil carbon dynamics are complex, and for producers to sequester carbon they need to adopt practices such as crop rotation, soil management, drainage, etc. Yet, the prospects of monetizing carbon sequestered in agricultural soils has spurred a drastic increase in public and private interest. Proponents of these programs present carbon sequestration from agricultural soils as a win-win solution, serving climate goals and as a source of income for farmers. However, this framing often overlooks the significant challenges associated with the successful implementation of a soil carbon market.

Many Brazilian farmers and ranchers show resistance to adopt more sustainable production practices because of attachment to traditional modes of production and aversion towards new technologies (Bungestab, 2012). Changes in some practices and means of production can also present challenges for producers, as this requires more structured planning and new knowledge inputs (Nobre & Oliveira, 2018). Evidence also suggests that the lack of precursors and innovators in the region can hamper the diffusion and adoption of sustainable technologies (Mattila et al., 2022). Consequently, engaging with carbon markets is associated with a number of additional challenges. The notion of carbon markets is also still relatively abstract. According to a study published in 2022, 50% of producers still do not understand how the carbon market works and fear that the changes could compromise their production outputs (Ferreira et al., 2022). Behavioral change, therefore, often depends on the ability to demonstrate that decarbonization is associated with agronomic benefits, which often materialize over time.

Increasing carbon stocks in the soil means that it will retain more organic matter and, overall, the soil fertility and quality is higher and more conducive to plant development, producing a virtuous circle of yield increases and improved profitability. Even in the absence of monetization potential from interventions in agricultural management through the carbon market, adopters may still receive recognition through price premiums. In this case, consumer appeal can be ensured through certifications, labeling, and voluntary commitments.[5] Currently, given the incipient stage of development of this market in Brazil, carbon should not provide an end in terms of monetization, but rather be viewed as a consequence of better practices or as a means to improve productivity. The prospects, however, are more promising when looking outside Brazil. In 2022, the first large-scale issuance of carbon credits from soil management practices in an area of about 40 thousand hectares was announced in the USA (Florentino, 2022). The EU plans to present an official certification framework for carbon sinks by the end of 2022 (European Parliament, 2022). Meanwhile other mechanisms emerge. In Germany farmers engage in farming practices that store carbon in the soil, while companies purchase these carbon storage services, However, this is still restricted to a private market that is not accounted for in the national greenhouse gas inventory.[6]

5 Brazilian coffee producers using methods certified as sustainable are getting paid up to 50% more than market price for their crops under private contracts with foreign roasters seeking to improve their environmental image (Lewis and Trevisani, 2021)

6 Approximately 30 Euros are paid for one ton of CO2.

In Brazil, the process of property succession by younger generations can become key in spurring the transition towards low-carbon agriculture. These generations are generally more positively minded towards new technologies and socio-environmental issues. However, significant concerns remain, related to economic viability, contractual obligations, eligibility for credit lines, and costs associated with verification of carbon stocks (Thompson et al., 2022; Thamo & Pannell, 2016; Ritter & Treakle, 2020). Soil carbon measurements rely on a combination of soil sampling and field modeling to measure carbon sequestration. So, given the high transaction cost, companies must be transparent about this and work on their communication to earn farmers' trust. For carbon markets to be successful in attracting broad producer participation, such challenges will need to be addressed. The transition of production practices entails high initial costs for farmers and ranchers, and low returns during the transition period. It, therefore, requires a change in behavior that can only be achieved if producers are convinced of the economic feasibility and profitability of adopting the new production system. This also implies a broader discussion on the need for good governance and effective public policies that prioritize lasting support programs that promote sustainable alternative livelihood activities adapted also to small producers.

2.4. Economic factors

Ultimately, projects to mitigate GHG emissions from the Brazilian agricultural and livestock sector will necessarily hinge on the degree to which they are economically viable. Carbon pricing varies substantially across different parts of the world. While the cost for emitting a single ton of CO_2 equivalent in compliance markets in some cases surpass US$100, prices within voluntary markets tend to be much more depressed (World Bank, 2022). In Brazil, market agents report prices in the range of 10 US$/ton in the case of most projects, such as REDD+. Higher prices can be found in some cases, such as 20US$/ton for ALM (Agriculture Land Management - recovery of pastures and conversion to agriculture) and US$30/ton for ARR (afforestation / reforestation / revegetation). The generally relatively low price level (around US$8-10 depending on the issuing year) imposes a range of limitations to the type of mitigation projects and activities that are economically viable. Whether prices may increase in the intermediate term likely depends on the establishment of a proper institutional structure for carbon pricing at the national level, - especially if a robust compliance market is created – and on associated demand factors, which are treated in the coming section.

A significant growth in voluntary markets at the global level could also have repercussions within Brazil. This would mainly depend on the degree to which entities within the country would be able to provide a large supply of high-quality credits for interested global buyers at the given price level. At low prices, costs for project administration, certification, and to cover different types of risk factors could account for a substantial share of revenues, which further complicates project development. In the case of projects involving landscape conservation, high opportunity costs in agricultural expansion zones can provide significant obstacles (Garrett et al. 2022). Moreover, the long standard contract periods in which rural producers need to guarantee the continuation of mitigation activities can also be unattractive to this group, - especially considering the short-term economic time horizons that characterize this sector. In these cases, carbon mitigation projects could be more attractive as one amongst many components in broad-spanned efforts to move towards more sustainable production models. As seen in the cases of integrated systems or no-tillage system, such productive transformations often reconcile economic and sustainability gains. In this perspective, monetization of GHG mitigation through carbon credit generation could constitute an additional incentive to pursue this course of action. Moreover, independently verified mitigation efforts could also serve to add a premium for products with specific sustainability characteristics, such as meat produced in agroforestry systems.

The ability to scale carbon mitigation projects also stands as an important factor in order to make them economically viable within the Brazilian agricultural and livestock sector. By themselves, many small and medium sized producers neither possess the knowledge resources nor the financial means to undertake initial project development and verification costs. Such projects are therefore much more likely to become economically viable by pooling their resources in common efforts to create large joint projects, which can help decrease margin costs per unit of carbon credit generated. This nonetheless requires significant coordination efforts between a number of different participants. Rural cooperatives may stand in an important position to assume such responsibility, as they can guide collective action to confront initial challenges of engaging within carbon markets, - a task with which they have much experience in relation to input and credit provision, - as we shall show in section 4.3.

3. Opportunities for the Brazilian agricultural sector to engage in the carbon markets

3.1. The supply side; comparative advantages

Brazil stands in a key position to become an important supplier of carbon credits through natural vegetation conservation, reforestation, as well as through the adoption of more modern and land intensive production models at a low cost per ton of CO_2 sequestered. Through REDD+ initiatives, Brazil has shown substantial potential, sometimes being called as the "Saudi Arabia of REDD+", although project development has thus far been relatively complex. Reforestation projects can also play an important role in complementing agricultural production through the wide array of environmental co-benefits, such as biodiversity and water resource preservation. Such co-benefits also mean that monetization of carbon sequestration is only one amongst many potential gains. In 2016, Brazil announced the goal of allocating 12 million hectares for restoration and reforestation. This potential may even be greater, as the country has about 90 million hectares of degraded pastures, of which a part can be used for this purpose.

Companies dedicated to generating carbon credits from forest preservation have been gaining ground in Brazil for some time. Yet, the interest in reforestation activities to restore legal reserves in non-compliant properties has led to the emergence of a second wave of companies, such as Mombak and Regreen, whose projects provide for the restoration of deforested areas. Timber management may or may not enter the business model. In both models based upon avoided deforestation and reforestation, the revenue from the sale of carbon credits serves as an alternative income for rural producers and ranchers (Adachi, 2022).

Another important Brazilian comparative advantage concerns the mitigation potential through the implementation of sustainable agricultural land management to increase carbon stocks in the soil. This potential becomes even more significant considering that many farmers either do not adopt or only apply part of the wide range of existing sustainable practices, leaving room for improvements through all-around implementation.

Increasing the soil organic matter is crucial in this regard, as it both serves to raise productivity and to sequester carbon. As a carbon sink, the soil is nonetheless finite, as CO_2 levels will tend to stabilize after 20-30 years of proper management.[7] Next, we briefly list different agricultural land management practices, roughly outlining their potential for coverage in terms of area, mitigation and co-benefits.

Brazil is one of the countries in which the practice of **no-tillage** has been most widely implemented. Around 35 million hectares - at least 60% of the Brazilian grain crops adopts the practice (Fuentes-Llanillo, 2021), which also corresponds to around 85%-90% of the soybean area (Embrapa, 2018). No-till is beneficial for soil quality and adaptation of agriculture to climate change, but its role in mitigation is less consensual (Powlson et al., 2014). Recent findings from the most important agricultural regions of the world indicate that no-tillage can avoid SOC losses, partially limiting CO_2 emissions from agriculture. Moreover, when in association with increased crop frequency and the inclusion of cover crops, no-tillage can promote soil carbon sequestration, improving soil quality and adaptation to climate change (Nicoloso & Rice, 2021).

The so-called "no-tillage system" or "good quality no-till", when the three principles of conservation agriculture - no tillage plus permanent soil cover and crop diversification through crop rotations and/or associations - are applied together increases the efficiency of no-tilling to increase soil organic matter. Compared to conventional practices when the soil is plowed, "no tillage system" can lower CO_2 emissions by 0,5-0,6 ton/CO_2/year/hectare. As the complete no-tillage system is adopted by only a small proportion of those who employ the practice, the wider dissemination along with adoption of other practices, such as the integration of soy farming with forests, can provide substantial emission reductions for this crop (Possamai et al., 2022; Estevam, 2022; Nepomuceno, 2020).

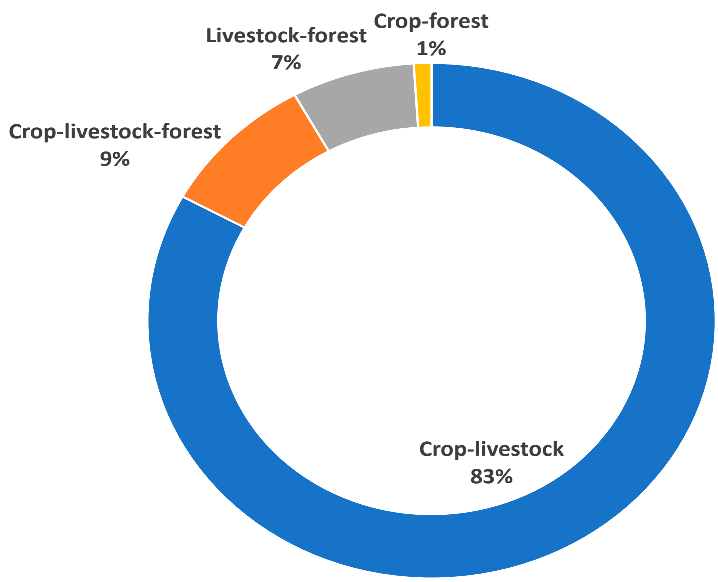
Biological nitrogen fixation (BNF) is the use of inoculated seeds in which the plant acquires nitrogen through association with bacteria in the roots that fix the N2 present in the atmosphere, transforming it into forms that can be assimilated by plants. BNF is the main source of nitrogen for the soybean crop and can provide all the nutrients that the crop needs (Hungria & Mendes, 2015). This technique is cheaper than supplying nitrogen fertilizers and mitigates emissions from chemical fertilization. BNF is widely

7 According to Bossio et al. (2020, p.392), "SOC saturation refers to a maximum capacity of the soil to retain organic carbon, meaning that SOC does not increase indefinitely. The time before a saturation state is reached will vary greatly depending on soil type, management intervention, climate regime and pre-existing SOC depletion. Maintaining high SOC stocks requires some form of maintenance even after a new steady state is reached and no further mitigation benefits accrue".

adopted in Brazil saving around US$ 14 billion/crop on fertilizers substitution and avoiding the emission of 68 Mt CO_2eq/year (Estevam, 2022; Nepomuceno, 2020).

Crop-livestock-forest integration (CLFi) covers an estimated area around 20 million hectares (Polidoro et al. 2020).[8] This intervention positively affects soil by increasing carbon and nitrogen contents, nutrient retention and cycling, water retention, and reducing erosion soil losses. The trees provide thermal comfort for the animals and improves economic diversification, yielding environmental, social and economic benefits. CLFi is considered a promising alternative to recover degraded pastures and offers potential to produce beef with significantly lower carbon footprints than existing alternatives. Nonetheless it requires a deep technical understanding of both crop, livestock, and forestry, as well as the dynamics of the integration of these systems. As 83% of integrated systems currently are based only on crop and livestock integration, an important challenge concerns the introduction of the forestry component to increase carbon sequestration (see Figure 7). Rede ILPF, an organization that promotes agroforestry systems, has set a goal to reach 35 million hectares of CLFi by 2030 (Rede ILPF, 2021a). Increase of rural credit to ensure implementation capacity for farmers, as well as technical and management assistance are fundamental to increase the adoption (Porto, 2021).

Figure 7 – Estimated proportion of each CLFi modality in Brazil



Source: Rede ILPF (2021b)

8 The term CLFi encompasses the four possible combinations of integrated systems: crop-livestock-forest, crop-livestock, crop-forestry and livestock-forestry.

Sustainable intensification within the Brazilian livestock sector encompasses different actions in the livestock sector aimed at improving its productive efficiency. Brazil has 161 million hectares of pastures, of which 90 million are degraded low-productivity areas. This means that vast land resources could be made available for either agricultural production or reforestation projects if the overall efficiency of ranching was increased. Transitions towards well-managed pastures or integrated systems can raise productivity by some 400-500% and mitigate the emission of 4 ton /CO_2/year/ hectare, while capturing 6 ton/CO_2/year/ hectare. The reduction of slaughter time through genetic improvement is also part of the livestock intensification strategy. Food supplementation through the use of methane production inhibitors as 3-Nitrooxypropanol (3NOP), tannins and essential oils are additional actions to reduce emissions in the sector.

Box 1 – On the differences between temperate and tropical agriculture.

Solar radiation drives photosynthesis that indirectly is one of the factors that determines yield, depending on the efficiency by which a crop captures light and converts it into biomass during the growing season. High levels of insolation therefore differentiates crop frequency in tropical contexts. On the other hand, photosynthesis, decomposition, and respiration rates are determined partly by climatic factors, most importantly soil temperature and moisture levels. For example, in the cold wet climates of the northern latitudes, rates of photosynthesis exceed decomposition, resulting in high levels of SOC. Arid regions have low levels of SOC mostly due to low primary production, while the tropics often have intermediate SOC levels, due to high rates of both primary productivity and decomposition from warm temperatures and abundant rainfall. Temperate ecosystems can have high primary productivity during the summer when temperature and moisture levels are highest, with cool temperatures during the rest of the year slowing decomposition rates such that organic matter slowly builds up over time. While climatic conditions largely define global patterns of soil carbon, other factors that vary on smaller spatial scales interact with the climate to determine SOC levels. For example, soil texture — the relative proportions of sand, silt, and clay particles that make up a particular soil — or the mineralogy of those soil particles can have a significant impact on carbon stocks. Additionally, the processes of erosion and deposition act to redistribute soil carbon according to the topography of the landscape, with low-lying areas such as floodplains often having increased SOC relative to upslope positions. In short, temperate soils have a higher carbon content, but with less permanence. In these contexts, even though the decomposition is lower, the technological model does not spur the increase of biological material, and therefore the accumulation potential is lower. In tropical environments with higher humidity, the carbon content is lower due to greater decomposition, but the technological model of cultivation in Brazil (greater crop rotation given the crop frequency) enhances the increase in productivity and the more rapid accumulation of carbon in the soil. It is due to the greater possibility for soil carbon sequestration given the crop frequency. The difference lies in the high addition of biomass throughout the year, which increases the carbon content in the soil.

Source: Nicoloso & Rice, 2021; Ontl & Schulte, 2012

Given the size of the Brazilian agricultural and livestock sector, the adoption of all these interventions demands bulky investments, thus highlighting the potential importance of carbon-based financing in spurring the acceleration of the proliferation of these practices. ABC+ Plan, the Low Carbon Brazilian Agriculture Plan comprising the period from 2020 to 2030 is a public policy to support low carbon agriculture that encompasses dedicated lines of credit and mitigating GHG emissions targets through a range of innovative technologies.[9]

Table 1 – Technologies and adoption targets of the ABC+ Plan in terms of area and GHG mitigation

Technologies	Expansion target (in million hectares)	GHG mitigating emissions targets (in million tons CO_2/eq.)
Recovery of degraded pastures	30,0 M ha	113,7
No-tillage system (complete)	12,5 M ha	13,0
CLFi and agri-forestry systems	10,1 M ha	72,0
Planted forests	4,0 M ha	510,0
Irrigated systems	3,0 M ha	50,0
Bio-inputs	13,0 M ha	23,4
Animal waste treatment	208 M m3	277,8
Intensive finishing slaughter	5 M heads	16,2

Source: Mapa (2021)

Demand for carbon credits and Brazilian carbon markets

Domestic and international demand for verified carbon credits stands as a crucial precondition in terms of defining the scope for the future development of carbon markets in Brazil. At the global level, demand appears to be accelerating. In 2022, 36 sub-national regions and 46 national jurisdictions had stated their aim of reaching net zero emissions, and currently 68 carbon pricing initiatives exist, covering 23% of global emissions (World Bank, 2022). Modeling shows that cooperation around the Article 6 of the Paris Agreement could substantially reduce costs of implementing national NDCs (Edmonds, et al. 2019). Yet, so far, only around 5% of GHG emissions are covered by pricing schemes within the necessary price range between US$ 40-80/tCO_2 (Stiglitz & Stern 2017; World Bank, 2020). Moreover, 46% of regulated emissions are still covered by a price below US$10 (Postic & Fetet, 2021). With specific regards to voluntary markets, prices for carbon credits

9 In the 2022 Crop Plan, the resources allocated to the ABC Plan represented only 2% of the total amount (Assad, 2022).

generated through forestry and land use have been relatively depressed, reaching only an average level of US$5-6 in 2021, although this represents a noticeable growth compared to previous years (Donofrio, et al. 2022). However, looking further into the future, the need to comply with current commitments has been associated with a necessary 15-fold growth in voluntary compensations towards 2030 (TSVCM, 2020). Other estimates suggest that a market of 1-5 gigatons of CO_2e could arise until 2030, with as much as two thirds directed towards NbS, which amounts to tens of billions of dollars (Steer & Hanson, 2021). The growth of global carbon markets could thereby, potentially, lead to a significant rise in demand for carbon credits from Brazil, given that the proper institutional conditions to guarantee integrity and interconnection of carbon markets are in place.

Companies worldwide are increasingly making different forms of emissions commitments to become net-zero with varying timelines towards 2050. Especially companies in emission-intensive industries facing difficulties in terms of completely neutralizing their carbon footprint could seek to offset remaining emissions through purchases of carbon credits on international voluntary markets. This could lead to a growth in demand for credits generated in Brazil, and notably, within its agricultural and livestock sector, where the potential for emission reductions is most significant. Thus, international actors already account for a substantial share of the demand for Brazilian carbon credits, which in some cases receive premium prices for demonstrable socio-environmental co-benefits. At the global level, by 2022 independent voluntary mechanisms accounted for 74% of the issuance of carbon credits (World bank, 2022). Yet, despite its upwards trajectory, international carbon pricing revenues from voluntary carbon credit generation is still significantly limited. This is exemplified by the fact that in 2022, the size of the voluntary market represented slightly more than US$1 billion, of total global carbon pricing revenues of US$84 billion (World Bank, 2022).

Moreover, integrity problems have also become evident as a consequence of the myriad of private offsetting schemes which have emerged in recent years. This calls attention to the importance of a coherent and strong institutional framework to guarantee carbon credit verification, if confidence in the voluntary market is to be assured. Moreover, Brazilian public and private actors have often not made concerted efforts to seize opportunities to attract mitigation projects to the country, which means that many existing opportunities have been neglected. International regulated markets could potentially become a substantial source of demand for Brazilian carbon credits. This would nonetheless hinge on the creation of an international compliance market for carbon credits. The COP26 represented a significant step in this direction, as progress was made in regulating Article 6 of the

Paris Agreement. However, if a significant number of domestic compliance markets would permit the use of carbon credits, this could spur demand for credits emitted abroad. Controversies related to the issue of carbon offsetting and concerns related to environmental justice are nonetheless likely to dampen the degree to which international carbon credit purchases will be permitted to substitute effective domestic reductions.

Domestic buyers represent another potential source of demand for carbon credits generated within the Brazilian agricultural and livestock sector. Pledges made by companies to reduce their emissions could feed this demand, as part of their mitigation efforts to become net-zero could be met by credit purchases. Most recently, a growing number of companies have made such commitments, which actors in the agricultural sector would stand in a key position to help fulfill. The Brazilian voluntary offset market has undergone a noticeable growth from the late 2010s and until today, and new market entrants have attracted growing amounts of capital for projects. Yet, as a middle-income country facing significant economic hardships in recent years, voluntary demand from Brazilian actors is nonetheless likely to remain limited within the most proximate future.

The prospects for the materialization of a Brazilian compliance market could be associated with a growth in domestic demand for carbon credits. However, given the relatively low carbon intensity of the Brazilian energy matrix and the small share of its manufacturing sector, this demand is also bound to be limited. In the absence of clear guidelines on how targets will be monitored, estimates of domestic demand become extremely vague. Thus far, much of Brazilian demand for carbon credits has had a speculative character, as opportunistic market players buy inexpensive carbon credits in the expectation of selling them with a substantial profit in the future. Another potential source of demand could become evident in a more indirect manner through the sale of products with low-carbon features embedded within them.

This is especially relevant in the agricultural sector, where beyond-the-law conservation efforts on properties or production within agroforestry systems could make for important features in supporting the international marketing of these products. Finally, related to the low domestic demand for carbon credits, the “supply” of projects with the potential to generate large amounts of credits has also been relatively limited, meaning that when demand materializes, it has often not been realized. Proper de-risking of projects plays an important role in this respect, as the willingness to undertake these efforts is key to the ability to attract projects, just like the presence of a stable legal and regulatory framework.

3.2. Co-benefits[10] for better social inclusion

The Paris Agreement recognizes the central role of protecting forests in keeping global temperature rise under control. This also includes protecting the people who inhabit these areas. More than 1.6 billion people depend to some degree on forests for their livelihoods. In relation to the UN Sustainable Development Goal (SDG) 13 on climate action, carbon pricing could be the link that addresses these issues simultaneously. As the potential benefits of carbon projects reach beyond the reduction and removal of GHGs, many imply a range of so-called "co-benefits". Such policies and measures can contribute to the development of sustainable economies, especially in developing countries at the local community level.

The question of the existence of socio-environmental co-benefits of carbon projects and the implications of the increasing commodification of carbon credits are central to a broader assessment of the social impacts of these initiatives. A study reveals that each ton of CO_2 offset not only funds the reduction of carbon emissions, but can also generate up to US$664 in additional economic, social and environmental benefits (ICROA, 2014). Project developers and buyers of forest carbon credits often state that positive impacts beyond GHG flows are the main reason they are active in the carbon market. While entities purchasing forest carbon credits may be motivated by co-benefits, the value of these "beyond carbon" impacts is rarely monetarily captured. Ongoing efforts to improve measurement and communication about benefits of forest carbon projects – and to increase demand for the resulting emission reductions – can enable project developers to create more opportunities for local communities and more effectively protect ecosystem services associated with forests. On the other hand, a range of negative experiences from offsetting initiatives with extremely low degrees of integrity has raised serious doubts about the mitigation potential of this mechanism, as well as its socio-environmental reverberations. These projects should therefore be held to the highest standards for integrity in carbon credit generation (see section 2.2) in order to gain confidence as a credible mechanism for effective emission reductions.

From a demand perspective, co-benefits are increasingly becoming the decisive factor for corporations to choose between offset projects. To certify co-benefits, several "complementary" certifications are focused on the social and environmental impacts of carbon offset projects, such as the Climate, Community, and Biodiversity Alliance (CCBA). The co-benefits can be outlined in three umbrella categories (TSVCM, 2021):

10 Co-benefits are any positive impacts, beyond the direct mitigation of GHG emissions, resulting from carbon offset projects.

1. Environmental co-benefits: related to biodiversity, and focused on protecting life on earth, improving air quality and protecting water and soil. Conserving habitats for endangered species, reducing illegal logging and other forest resources, and protecting the biodiversity of critically endangered and vulnerable species.
2. Social co-benefits: these include improving community employment opportunities, access to energy, gender equality, and access to community health and education services. They also comprise education for local communities about alternative livelihoods that respect and protect the natural environment, and reforms giving women equal rights to economic resources, effective participation, and equal opportunities for leadership.
3. Economic co-benefits: include improved job creation, education and technology transfer opportunities, in addition to inclusiveness and sustainable economic growth.

Employment opportunities created by carbon projects can include protecting reforested areas, managing agroforestry farms, and engaging in opportunities such as sustainable agriculture. These roles expand a local community's income stream and contribute to the growth of a sustainable economy which, in turn, promotes social co-benefits such as educational opportunities.

Box 2 – Association of Social Carbon Credit Producers of the Caatinga Biome

Association of Social Carbon Credit Producers of the Caatinga Biome is a pioneering initiative in Brazil, which aims to provide a development option in the São Francisco region while seeking to regenerate the environment and reduce inequality. The idea is to integrate small landowners into a network that preserves two to three hectares of the biome, but are unable to enter into a bureaucratic and expensive process of generating and selling certified carbon credits. The association has producers with preserved areas of Caatinga in Bahia, Pernambuco, Alagoas and Sergipe.

Fonte: Chiaretti (2022)

Growing corporate demand for co-benefits

Carbon credits can provide a vehicle for pricing services with more abstract value, such as ecosystem services. Compared to other types of mitigation projects, such as renewables, NbS projects have been championed as being of higher quality due to their various co-benefits and, consequently, worthy of price premiums. Increasingly, corporate social responsibility strategies and ESG targets highlight these needs through carbon offsets, prioritizing carbon credits with well-documented co-benefits.

The broader trend within carbon markets to move towards greater commodification of carbon credits has been highlighted as a necessary step for the market to gain volume and scale. This also implies that co-benefits would be more likely to be found in niche markets, while certification of the weight of carbon credits would depend on a more common baseline of basic criteria that determine their commercialization. The Task Force on Scaling Voluntary Carbon Markets is currently developing a set of Core Carbon Principles (CCPs) for establishing common quality parameters for carbon credits, which is likely to spur the movement towards greater commodification.

It is worth mentioning that according to research by the American Forest Foundation, 29% of carbon credit buyers evaluate projects based on co-benefits and 26% on their commitment to diversity, equity and inclusion (Goodman, 2022). Carbon credits which include multiple SDG targets are usually traded at a premium, because an increasing number of companies prefer those in their portfolio to demonstrate the organization's broader positive impact for consumers and investors. Overall, however, the concept of co-benefits being embedded in a carbon offset standard is associated with noticeable complexities. While the unit of exchange for carbon offsets is simple – one ton of carbon dioxide equivalent (tCO_2e) – the same is not true for co-benefits. Due to the high variability in the metrics used, and the many different ways projects report impacts, co-benefits are not as easily quantified. Because of this, certain carbon offset verification principles are less applied to co-benefit impacts.

Carbon offsets are numbered and cannot be banked by more than one buyer to avoid double counting. However, in some cases, it is difficult to attribute these co-benefits to a specific project. In this sense, buyers become increasingly sophisticated in their claims to ensure that their funds deliver the intended impacts by improving standards for monitoring co-benefits. Unlike carbon offsetting, which is accounted for at harvest or in the year in which emission reductions occurred, tracking impacts year to year is sometimes challenging. Although certification of co-benefits covers defined accounting periods and therefore is limited in time, neither project developers nor purchasers tend to think about the impacts of co-benefits in terms of periods, but rather in social outcomes. Enhancing project-level co-benefit metrics that support the SDGs, as well as government-to-government agreements to prevent tropical deforestation is critical, as these global efforts necessarily expand to larger geographic scales. Providing funding for co-benefits would also encourage project developers to more accurately monitor and report on impacts, thereby ensuring they occur and allowing investors to channel funding where it is most needed.

4. Adjusting the incentives to promote mitigation efforts through carbon pricing

The carbon market is by no means a new invention; its pre-development and potential exploration phase has already been completed at an accelerated speed, due to the urgency imposed by climate change. However, the acceleration and incorporation phase requires the development of a series of regulatory mechanisms that offer technical and legal support for the expansion of the market. Comprehensive regulation is critical to ensure high integrity across the carbon market value chain. The "Taskforce on scaling voluntary carbon markets" details a series of governance structures across the value chain, which are important not only for the voluntary carbon market, but also for the regulated market. At the most diverse stages of the carbon chain, governance requires defining roles and responsibilities and the governance architecture necessary to minimize conflicts of interest. New bodies will need substantial expertise and resources, and great care must be taken to consider diversity and balanced representation, especially in relation to the Global South and/or tropical countries, in which many projects are hosted. Finally, given the global nature of the carbon market, it is important that international regulators and governance bodies communicate and coordinate to promote safe and transparent markets in all jurisdictions.

4.1. The challenges for pricing schemes in Brazil

Calibrating institutional designs for carbon pricing in such a way that they bend economic incentives in favor of large-scale mitigation efforts is crucial to spur deep decarbonization. Governments will therefore need to create regulatory frameworks for the mandatory carbon pricing of the most emission-intensive economic sectors. In the case of Brazil, agriculture and livestock production represents some of the largest emission sources (confer Figure 4). Any participation in possible future compliance markets will thereby be strongly dependent on the existence of a Brazilian emissions cap converging with the country's NDC in order to establish baseline scenarios in relation to which any additional reductions can be commercialized. Yet, as offsetting as a means to meet national NDCs is a highly controversial issue both within Brazil and globally, carbon credits trading through voluntary markets – without corresponding adjustments - may initially appear as the most viable international trading option for Brazilian actors.

Creating the necessary institutional pillars for a domestic compliance market stands as an important task. This would also support the growth of voluntary markets. Brazil has several comparative advantages, which need an adherent institutional framework to become competitive advantages. Existing methodologies from leading global certifiers with the highest standards and most experience in carbon credit certification may provide important support. However, a number of challenges exist for the creation of a comprehensive economy-wide framework for carbon pricing in Brazil. Central amongst these factors is the political variable, and more specifically, obstacles due to resistance in Congress and at the Federal governmental level.

Upon the establishment of the PNMC in 2009, there was a period of legislative "void", marked by the absence of efforts to structure a national regulatory framework. This is mirrored by developments at the global level, with the collapse of the Kyoto Protocol, and a following lack of momentum, illustrated by the timid outcome at COP15 in Copenhagen. This only changed with the approval of the Paris Agreement in 2015. An allowance market with imposition of binding mitigation goals still does not appear to be consensual within Brazilian society. This is reflected in Decree 11.075 that proposes the creation of sectoral plans. As already discussed in section 2.1, the scope of the decree is highly limited, meaning that it needs to be completed by other regulatory developments. In this sense, a crucial aspect concerns the fact that the cap-and-trade model as conceived in developed countries is not ideal for valuing other ecosystem assets.

The Bill 528, currently circulating in the Brazilian Congress, provides for the establishment of a regulated domestic carbon market. As of the time of writing this report, the proposal is waiting for the developments of the COP27. Throughout its elaboration, the document received several contributions from civil society, counting, for example, the Brazilian Center for Sustainable Development (CEBDS). On the eve of COP 26 in 2021, some consensus around the text was reached, resulting in a degree of support from sectors previously averse to regulation, such as manufacturing and agribusiness. In its most recent version, the PL has many amendments that make it difficult to anticipate how its final version will be formulated. The original proposal was amended by the rapporteur, and in its current form it does not impose financial costs on companies with high emission rates, treating carbon offsetting as a "voluntary action". As it stands, the proposal suggests that actors who emit above their target should buy credits in the voluntary market, and those who emit below the target do not gain any benefits. However, the prevailing understanding is that this formalization of the voluntary market does not create a consistent demand for carbon credits, and therefore does not have the robustness to ensure deep climate mitigation. Most economic sectors are generally aligned around the need for a regulated carbon market in Brazil, largely due to the possibility that global trading partners impose taxes on imports from countries that fail to reduce their emissions.

The growing global pressures for the responsible economic agents to take concrete actions towards mitigation, means that invariably, Brazilian agro-exporters are bound to internalize emission costs in some way. With environmental enforcement and carbon pricing, this can either occur through a managed process of increasing domestic demands for compliance, or as a consequence of international pressures through measures such as carbon border adjustments and market exclusion because of environmental due diligence legislations.

Implementing carbon pricing within the Brazilian agricultural and livestock sector is nonetheless a highly complex task, not least because of the large number of producers, as well as incomplete land tenure registers and monitoring and tracing systems for animals, and informal modes of production and marketing, etc. Large swaths of the sector will thereby necessarily have to be excluded from initial attempts to install frameworks for carbon pricing, and mitigation efforts pursued through other regulatory measures and technical assistance. However, certain "choke points", such as slaughterhouses or grain processing facilities are nonetheless easily monitored and could thereby function as a point at which taxes are imposed on products based on volume transactions. However, given the extreme degree to which especially beef products, but also soy can vary, depending on the relative embodied deforestation and different modes of production adopted at farms and ranches, carbon taxing at this point based on volumes would equally affect compliant and non-compliant products. It would thereby only incentivize decreases in consumption and not provide any specific incentives to adopt more sustainable production practices. Therefore, focus needs to be directed towards the farm/ranch level, in order to reward compliance at this point.

Currently, land taxes in Brazil are extremely low, which provides an incentive for the continuation of low-productivity livestock production, as the depressed cost of the land factor makes for a very low breakeven point of these operations. Extensive livestock production is also associated with some of the highest environmental costs and lowest economic gains. Moreover, historically, rural producers have had incentives to deforest and leave the areas as pastures in order to be able to make land claims according to the homestead principle. Thus, raising land taxes to the point at which extensive low-productivity livestock production becomes less economically attractive would incentivize transitions towards more productive operations. Tax incentive structures could also be tailored in such a manner that compliance with legal reserve requirements would entail lower tax burdens, with the opposite being the case for non-compliant producers. This could be important to spur legal adherence, but also to incentivize conservation efforts that could be monetized when legal reserves grow beyond the proportion of the requirements in the law. Credit policies and technical assistance provide potentially important tools to bring producers into legal compliance through the use of such positive incentives. Finally, sectoral agreements, through which a broad commitment to reduce carbon intensity of production is made by producer organizations could also help to bring about change.

The aforementioned pathways to reduce emissions from the Brazilian agricultural and livestock sector through a new structure of economic incentives do not necessarily imply the initial generation of carbon credits. However, they fundamentally change the logic of production by incorporating environmental costs amongst producers. This hereby provides an important point of departure to spur the implementation of low carbon practices, which in turn also holds a potential for the generation of carbon credits by frontrunners whose mitigation efforts go beyond legal requirements. However, as mentioned earlier, the establishment of a comprehensive regulatory framework to spur intense sectorial efforts to adopt low-carbon production practices and reduce current levels of GHG emissions becomes key to shield Brazilian agro-exports against international backlash and indirect imposition of levies on emission-intensive Brazilian exports.

4.2. Coordination and governance

A comprehensive view of the incentives needed to engage the agricultural sector in a carbon pricing market should consider three key barriers to be overcome: (i) measuring the effectiveness of the interventions through a robust MRV system (see 5.2), (ii) mobilizing investment, and (iii) overcoming governance challenges.

While forestry projects are, in general, facilitated by a small number of actors involved, the opposite is the case concerning initiatives within agriculture that demand significant coordination efforts for the development of large-scale projects as well as willingness to undertake a thorough de-risking. Most farmers do not possess either the know-how or the necessary resources to adopt advanced land management practices. The same is true for the certification process for emission reductions on an individual basis. So, there is a need for an aggregator or "midfielders" with knowledge of the market, - a function that can be assumed by cooperatives or input companies. Notably, farmers and credit cooperatives could play an important role in facilitating links to the carbon market and undertake critical coordination activities. This could help lower certification costs and also prevent that possible benefits from carbon credit generation are reaped only by first movers from multinational companies and large agribusiness entities. Brazil has 1.2 thousand cooperatives in the agriculture and livestock sectors that account for more than 1 million members (OCB, 2022). Some of them have an extensive structure of technical assistance in the field and provision of services with great capillarity. In general, they have a detailed database of cooperative members, which may include georeferencing properties, satellite images, among other information. Such a structure facilitates the construction of an inventory of carbon stock in the soil and of areas of legal reserves and permanent protected areas inside farms. Thus, cooperatives are fully capable of acting as aggregators and coordinators of initiatives in the carbon market. Many are even positioning themselves to act in this way when institutional barriers are solved.

Another role that needs to be played concerns the development and calibration of carbon dynamics models. Currently, several initiatives in different stages of development are being implemented in Brazil: Embrapa, Regrow, Instituto Brasileiro de Análises (IBRA), among others[11]. Some of them work by developing their own models, while others seek to adapt pre-conceived models to regional conditions in Brazil. Model adaptation requires the support of databases with field information, as well as improved digitalization to collect, organize and transmit data properly. In a broad context of fulfilling decarbonization commitments, robust information systems are likely to increasingly acquire value as a product/service. This could be important, not only to support a carbon credits market, but also for the market for certification and labeling, ensuring the credibility of sustainable practices by the producers.

The organization and coordination of these different actors is still underway in Brazil, and therefore it is still early to say what or how the dominant conformation should be. However, it is evident that there is a need to allocate sufficient resources for research, as well as the coordinated engagement by Brazilian representatives in international forums to inform and disseminate knowledge about NCS conceptions adapted to tropical climatic conditions.

11 For more information see: https://www.agtechgarage.news/regrow-obtem-aprovacao-de-modelo-para-quantificar-sequestro-de-carbono-no-solo-nos-eua/

5. The technical dimension of carbon markets

The establishment of functioning carbon markets, as well as the prospects of Brazilian agricultural producers engaging in them, hinges on the proper management of a number of technical challenges. The carbon market, as well as NbS, involve new technologies, rules and legislation, new organizations or even new projects, concepts or ideas. This becomes especially relevant regarding projects with co-benefits, which may be involved in changes interrelated to new practices, configurations of groups of actors, beliefs and values, networks and policies.

In the technological dimension, training and technical support make projects viable, change the view of producers to appreciate the agroecological system and grasp its cultural values and economic potential. Helping to systematize experiences and investments, establishing connections and networks, and maximizing impact is the basis for this transition. In other words, the technological dimension is directly supported by collaborations between actors, exchange of knowledge and learning. This also becomes key to ensure quality products, with greater ecological efficiency and potential for insertion within the global market, which ultimately raises producers' income.

5.1. Technical assistance

Technical assistance is an important factor in encouraging the dissemination of low-carbon practices in Brazil. Agriculture is a highly heterogeneous sector, in which two extremes coexist; while some farms adopt cutting-edge practices, many still use extensive, low-productivity ones. For example, although no-till has been widely adopted in Brazil, reaping the full sustainability benefits of this practice requires a degree of knowledge that many farmers still lack. Technical assistance becomes central in this regard, as it can help farmers adopt rotation based on a greater variety of crops. Another example is the livestock sector, where there is a huge disparity among ranchers, ranging from those who still count on deforestation to increase production areas with low yields, to others who adopt efficient pasture management.

A study by Bragança et al. (2022) presents evidence that providing Brazilian ranchers with personalized training in sustainable pasture restoration generates long-term economic and environmental benefits. The study found that Cerrado farmers who received group training and personalized technical assistance were able to raise cattle productivity and increase their income by 39%, - a model the researchers say can be replicated in the Amazon region. Ranchers trained over two years have seen an increase in livestock productivity and income, and a reduction in CO_2 emissions over the program period. It is estimated that there was a reduction of 1.19 million tons of CO_2 emissions through the combination of carbon sequestration and avoided emissions.

Bragança et al. (2022) also analyzed the impact of the ABC program's pasture restoration training for around 1,4 thousand ranchers. One group received no training, the other received 56 hours of training, and the last one received the training course plus additional personalized technical assistance, which included monthly visits by field technicians. According to the data, only ranchers who received training and technical assistance showed significant improvements in productivity, revenue and carbon mitigation. The course alone had no impact. This highlights the importance of technical assistance to help producers go beyond monocultures, improving productivity and environmental performance.

Production systems such as CLFi are complex, but hold an immense environmental potential. An important challenge concerns the introduction of the forest component to increase carbon sequestration (see Figure 7). However, this step requires technical assistance, as it increases the complexity of managing the three interconnected components within this production system. Although the labor and dedication required to engage in CLFi demands important management transitions, successful CLFi adoption is associated with significant financial returns. This is illustrated by the example of the Santa Brígida Farm, in the state of Goiás, which before the implementation of CLFi, operated with a loss of US$ 40/ha, but after 14 years of transition generated a profit of US$1400/ha (Porto, 2021). The generation of carbon credits could thus serve as an additional pull factor, further increasing the potential profits of these companies. The international capital generated through carbon credits can play an important role in stimulating this transition, compensating for the lack of credit to cover the initial costs of adopting more sustainable and modern production systems, as well as the lack of sufficient public engagement in this process.

5.2. Measurement, Reporting, and Verification (MRV)

Different carbon certification methodologies have been developed for sustainable agricultural land management. Notable examples include soil carbon quantification, N2O emission reductions quantification through fertilizer reduction, sustainable grass management, and reduction of enteric methane emissions from ruminants through the use of feed ingredients (Verra, 2022). Nevertheless, worldwide, only 1% of carbon credits issued in the voluntary market originate from agriculture (So et al., 2022). In Brazil, the volume of credits generated within the sector is not very high, and limited mainly to the use of biodigesters for the treatment of swine manure. In order to verify that the planned emission reductions within carbon mitigation projects effectively occur, MRV systems become essential tools. A range of challenges nonetheless exists for MRV implementation to ensure effective GHG reductions within the Brazilian agricultural and livestock sector.

Projects with focus on the dynamics of soil carbon flows have a large mitigation potential in Brazil. Adapting MRV methodologies to measure carbon in the tropical soils is nonetheless a complex task. For example, research has already shown that in a Brazilian context, it makes sense to measure carbon at least to a depth of one meter (Barioni et al., personal communication, June 30, 2022; Martin-Neto, 2022). However, digging trenches in the ground to make soil samples from different layers is highly time consuming and resource demanding. Satellite imagery can provide a more cost-effective alternative, and these technologies have seen noticeable advances in recent years. However, satellite images are not yet capable of registering carbon flows in layers deeper than the topsoil, where tree root nets have a significant sequestration potential. In Brazil, there is still a lack of development of algorithms that interpret the images properly, and for advances in the automation of image processing. Another example regards projects based on the creation of integrated systems. Here, the complex array of flows of different GHGs with varying atmospheric lifetimes from the system's different plant and animal components makes it a highly complex, - and controversial - task to assess the project's overall carbon balance. The complicated process of implementing solid MRV means that very few farmers have been able or qualified to undertake this task on an individual basis, not least due to the elevated entry costs associated with the handling of the information systems.

Another key point related to MRV implementation regards the adherence to carbon integrity principles, namely permanence. Within agriculture, carbon stocks tend to be highly temporary, as production practices, or climatic conditions can release large amounts of GHGs. In that regard, efforts aiming at the large-scale implementation of MRV systems will need to strike a balance between being sufficiently democratic to permit wide horizontal adoption, but simultaneously sufficiently robust for buyers to have trust in the permanence of carbon stocks sequestered. In order to confront this dilemma, the notion of temporary credits, with a shorter lifetime spanning from 15-20 years, has been defended. However, it is highly uncertain whether this concept will be accepted as convergent with predominant notions of the principle of permanence amongst global carbon certifiers.

There is more scientific consensus around the dynamics of carbon and its permanence in the soil within temperate environments. Although results for Brazilian conditions have not yet been widely published in scientific outlets, as much research is in progress, evidence found by Embrapa points to chances of greater permanence of carbon in tropical conditions. This is mainly because of differences in technological models and agricultural practices, as well as the types of soils, its structure and microbial activity. In temperate climates, disturbances can easily affect permanence. In Brazil, beyond the lower demand for plowing, evidence suggests that more than half of the stored carbon accumulates at deeper layers, below the 30 cm of topsoil. Brazilian researchers at Embrapa have produced evidence that carbon stability is greater in the deeper layers, although it is still uncertain how much (Barioni et al., personal communication, June 30, 2022).

Some examples illustrate the need to advance MRV methodologies adapted to Brazilian conditions. For example, studies carried out by *Embrapa Florestas* shows that the conversion of natural pastures to forest plantations has the potential to increase the stock of carbon in the soil depending on the species, its production cycle, and the type of soil and climate. The study also updated the soil carbon change index used by Brazil to qualify land use conversion to forest plantations. While the index that had been used - according to the IPCC 2006 - penalized the carbon stock in the soil by 33%, the new index calculated by Embrapa Florestas suggests a penalty of 5%, that is, the loss of carbon in soils converted to forest plantations would be in the order of 5% and not 33%, as suggested by the index previously used (IPCC, 2006; Zanatta et al., 2020). Another example is the evidence collected by Embrapa in partnership with Bayer in a pilot carbon farming initiative. The researchers identified an average carbon footprint of 783 kg CO_2 eq per ton of soybeans amongst a group of producers who adopted low-carbon agricultural practices. The number represents a reduction of up to 80% compared to the average of the main international databases (Embrapa, 2022a).

Box 3 – Bayer Pro Carbono

Bayer Pro Carbono *is part of a coordinated strategy by the company, encompassing initiatives in ten other countries. In Brazil, it has been formulated as a public-private partnership with Embrapa that selected approximately 1,800 soybean and corn producers - in 16 Brazilian states that met environmental and social compliance requirements. The participating producers received a management plan for good agricultural practices, such as crop rotation and no-tillage for the three years of the program. By July 2022, more than 300,000 soil samples had been collected and analyzed. The objective is to monitor productivity results and the accumulation of carbon in the soil over a period of three years, with the intention of remunerating producers who reduce GHG emissions through the use of positive incentives at a later stage. Such incentives include access to differentiated credit, more attractive agricultural insurance, and facilitation of the purchasing of inputs and in the process of adopting more sustainable practices. The goal is to include them in the carbon pricing scheme, as part of the climate solution, whenever this might become possible. More strategically, the program intends to drive the adoption of sustainable agronomic practices and develop science-based solutions.*

Source: Bayer (2022); Anselmi (2022)

The complexities of implementing robust MRV systems within Brazilian agriculture means that many rural producers today would face larger costs of measuring carbon sequestrations than they would gain from selling carbon credits. Transactions costs of certifications deriving from MRV implementation are thereby a key factor in defining the scope for implementing carbon projects in Brazil. As discussed in section 2.4, farmer collectives could play an important role in terms of pooling MRV costs. In this regard, the *Rede ILPF* has engaged in different cost-sharing schemes combined with technical assistance for MRV implementation.

Confronting the above-standing challenges related to MRV implementation stands as an important task for Brazilian agricultural and livestock producers to engage in carbon markets. Devising standardized procedures and disseminating knowledge of sectorial best practices appears as an important challenge in this respect. Some technical dialogues have been underway within the sector. So far, these discussions have not yielded significant results, but recently progress has been made. Importantly, digitalization has been defended as essential to lowering MRV costs, as technological gains and advances in innovations associated with the fourth industrial revolution, such as AI, machine learning, robotics, drones, and the internet of things can lower marginal costs per carbon credit. Yet, these innovations are only available to more capitalized operations. This could partially be remedied by the creation of open source public data archives of carbon flows and stocks within the Brazilian landscape, which could yield important information that would not need to be generated at the individual property. Most recent advances in carbon credit MRV methodologies adapted to agriculture have also adopted an incremental approach, which works by "adding up" individual mitigation steps. This could facilitate the process of MRV implementation and transition towards low carbon agricultural practices, which thereby becomes a gradual process yielding higher and higher returns in terms of carbon credit generation as farm practices improve over time.

Crucially, NbS need to be grounded in robust understanding of the geographical distribution of the biomes of the world, the value of their biodiversity and their ecological resilience (Seddon et al., 2020). Specific NCS interventions each have their own mitigation estimates, trade-offs and co benefits. No-tillage, cover cropping, enhanced crop rotations and grazing management are in fact broad sets of activities, each with potentially very different impacts on SOC, different N2O emissions, and different feasibility. An activity that builds organic carbon within one soil type might be ineffective on a different one (Bossio, et al. 2020). Adapting MRV methodologies to local conditions is also critical, especially considering how important characteristics differentiate Brazilian tropical agriculture from temperate models. The potential of Brazilian agriculture to sequester carbon comes from the possibility, in the tropics and subtropics, of cultivating the land throughout the year, and thus harvesting up to three crops annually, generating greater biomass production that increases the carbon input into the soil. Along with the use of different cultures between one crop and another, these are characteristics to be incorporated and considered in the adaptations of MRV models (Novaes et al. 2022). The challenges to be overcome become even greater when considering the heterogeneity of soils and climates found in the country.

The methodological challenge concerns the estimation of soil carbon in a scenario with a limited amount of data to supply carbon dynamics models. The aggregation of the model with the data collected in the field provides greater reliability in the estimates. The accumulation of data will allow the gradual correction of the model. The objective is to arrive at protocols with sufficient credibility and accuracy for decision making that are scalable at a feasible cost. Progress has been made to measure carbon content - which is costly, time-consuming and requires analytical agility by the traditional dry-combustion method. An alternative method based on the use of laser (LIBS), whose technology, developed by Embrapa, has already been transferred to the private sector (Agrorobotics), has recently received approval by Verra as certifiable for measuring carbon in the soil. The technique allows faster analysis speed at a cost at least 50% cheaper

(Embrapa, 2022b; Martin-Neto, 2022; Villas- Boas et al., 2020ab). Another method reaching commercial scale in Brazil is near-infrared spectroscopy. Through a technological solution called Specsolo, developed in partnership between Embrapa Solos and the IBRA, which associates the method with a library with more than 1 million analyzed soil samples and artificial intelligence, increasing the efficiency of the analysis and reducing costs (Specsolo, 2022; de Santana et al., 2019). The main challenge is to scale existing techniques so that different areas can be measured. This involves simplification without losing rigor and accuracy, and without increasing uncertainty too much. This becomes critical to provide a scientifically robust standard, recognized by the market and viable for farmers.

In Brazil, questions have been raised regarding the possibility of "tropicalizing" the predominant technical conceptions undergirding the global carbon market, which so far mainly has been biased according to the context found in the Northern Hemisphere. Decarbonization can be a source of competitive advantage, and Brazilian competitiveness is at stake in defining the standards that will guide the era of global decarbonization. Measurement and accounting are intimately related to the successful provision of finance. Devising reliable and context-specific metrics to agriculture is therefore very relevant. Otherwise it is possible that part of the demand will continue to prefer credits generated by NCS that only use more consolidated methodologies, such as projects in the forestry sector. In the absence of offsetting projects in agriculture, another path will be certification and labeling with a view to adding value and differentiation to the consumer market. Regardless of how the different market mechanisms will be consolidated, integrity is key. In this regard, radical decoupling of the agricultural and livestock sector from its contribution to deforestation, which is the main source of Brazilian GHG emissions, becomes an indispensable condition to provide credibility around mitigation projects within the sector. Only then will the potential carbon credits generated by a positive carbon balance in Brazilian soil be fungible on the world market.

6. Final Remarks

Carbon pricing can play an important role by providing incentives for the adoption of responsible agriculture land management both for farmers and ranchers who still rely on unsustainable practices. It is conceived as an instrument for deep decarbonization, which through a mix of positive and negative incentives spurs the transition towards a low carbon economy. In order to foster consistent mitigation efforts, it becomes crucial that all the main economic sectors responsible for Brazilian GHG emissions are covered by some kind of mandatory carbon pricing scheme. The specific instruments applied should nonetheless be contextually sensitive, meaning that a "one size fits all" model is difficult to conceive. The extremely heterogeneous character of the Brazilian agricultural and livestock sector, spanning from smallholders to megafarm operations means that many different tools are needed to spur decarbonization efforts. In this context, carbon markets could provide a model for attracting funding and capital for more sustainable agriculture. If it adopts proper integrity principles and robust MRV methodologies, the carbon market could for a limited period of time help support efforts to make the bioeconomy viable within a Brazilian context. Ideally, carbon trading by 2050 should no longer be necessary, as economies should have come close to net zero emissions.

Brazilian agriculture stands in a strategic position to play an important role in global decarbonization, as long as the operational framework is based on scientific soundness for the observance of the principles of integrity. It thus becomes important to devise economic incentive structures that encourage the adoption of more sustainable practices. Preferably, such initiatives should be accompanied by other measures that incorporate the theme of biodiversity maintenance, water use and local livelihoods in the appreciation of these assets at a global level. Along these lines, it makes sense for producers to be concerned with increasing/maintaining organic matter in the soil. This could yield a wide range of benefits, including a greater stock of carbon, regardless of potential monetization via the carbon market. This would permit the country to transform its comparative advantages in NCS into competitive advantages, to prompt the transition towards a low carbon economy. It is nonetheless important that the enthusiasm for mitigating global warming from NCS does not reduce the urgent need to rapidly reduce fossil fuel consumption by large emitters. The carbon market for NCS must serve to finance the adoption of technological innovations for climate mitigation and potential co-benefits in the supplying countries, and not for the purpose of compensating for the maintenance of obsolete energy systems by large emitters.

References

Adachi, V. (2022). Mombak quer gerar créditos de carbono de reflorestamento (e está levantando um fundo para isso). Capital Reset, Aug, 24. Retrieved from: https://www.capitalreset.com/mombak-quer-gerar-creditos-de-carbono-de-reflorestamento-e-esta-levantando-um-fundo-para-isso/. Accessed: 8/29/2022

Albuquerque, L.; Gavioli, L.; Margulis, S.; Barreto, C. Clemente, F.; Goulart, J.; Esposito, S. Oportunidades para o Brasil em mercados de carbono. International Chamber of Commerce (ICC) Brasil and Way Carbon. Retrieved from: https://d335luupugsy2.cloudfront.net/cms/files/5818/1634247006RELATORIO_ICCBR_FINAL.pdf. Accessed: 8/28/2022

Amundson, R..; Biardeau, L. (2018) Soil carbon sequestration is an elusive climate mitigation tool. Proceeding of the National Academy of Sciences, 115(46), 11652-11656.

Anselmi, A. (2022). A construção da bioeconomia brasileira [Webinar]. Fundação Getúlio Vargas - EESP. https://www.youtube.com/watch?v=LYEh1k7hsxI. Accessed: 9/10/2022

Assad, E. D. (2022). Só 2% do Plano Safra vão para agricultura de baixo carbono, critica pesquisador Eduardo Assad. [Interview to] Cristiane Fontes & Marcelo Leite. Jornal Folha de São Paulo, São Paulo, 28, Jun. Retrieved from: https://www1.folha.uol.com.br/ambiente/2022/06/so-2-do-plano-safra-vao-para-agricultura-de-baixo-carbono-critica-pesquisador-eduardo-assad.shtml. Accessed: 6/28/2022.

Bayer (2022). AgroBayer Brasil. Carbono Bayer. Retrieved from: https://www.agro.bayer.com.br/pro-carbono. Accessed: 7/22/2022.

Bittencourt, S. R. M.; Busch, S. E.; Cruz, M. R. (2018). O mecanismo de desenvolvimento limpo no Brasil. In Frangetto, F. W. O., Veiga, A. P. B. O., & Luedemann, G. O. (Ed.). Legado do MDL: impactos e lições aprendidas a partir da implementação do Mecanismo de Desenvolvimento Limpo no Brasil como subsídios para novos mecanismos (pp. 43-58). Brasília-DF: Ipea.

Bossio, D. A., Cook-Patton, S. C., Ellis, P. W., Fargione, J., Sanderman, J., Smith, P., ... & Griscom, B. W. (2020). The role of soil carbon in natural climate solutions. Nature Sustainability, 3(5), 391-398.

Bradford, M.A., Carey, C.J. , Atwood, L. , Bossio,D. , Fenichel, E.P. , Gennet, S., ... & Wood, S. A. (2019). Soil carbon science for policy and practice. Nature Sustainability, 2 (12), 1070-1072.

Bragança, A., Newton, P., Cohn, A., Assunção, J., Camboim, C., de Faveri, D., ... & Searchinger, T. D. (2022). Extension services can promote pasture restoration: Evidence from Brazil's low carbon agriculture plan. Proceedings of the National Academy of Sciences, 119(12), e2114913119.

Bungenstab, D. J. (2012). Sistemas de integração lavoura-pecuária-floresta: a produção sustentável., 2. ed. – Brasília, DF: Embrapa. Disponível em: https://www.embrapa.br/en/busca-de-publicacoes/-/publicacao/938814/sistemas-de-integracao-lavoura-pecuaria-floresta-a-producao-sustentavel. Accessed: 8/24/2022.

Chiaretti, D. (2022). Caatinga tem primeira cooperativa de crédito de carbono do Brasil. Jornal Valor Econômico, 8, Jul. Retrieved from: https://valor.globo.com/brasil/noticia/2022/07/08/caatinga-tem-primeira-cooperativa-de-credito-de-carbono-do-brasil.ghtml. Accessed: 9/8/2022.

Climate Watch. Historical GHG Emissions. 2022. Washington, DC: World Resources Institute. Available online at: https://www.climatewatchdata.org/ghg-emissions. Accessed: 8/29/2022.

de Santana, F. B., de Souza, A. M., & Poppi, R. J. (2019). Green methodology for soil organic matter analysis using a national near infrared spectral library in tandem with learning machine. Science of the Total Environment, 658, 895-900.

Donofrio, S.; Maguire, P.; Daley, C; Calderon, C.; Lin, K. (2022). The Art of Integrity. State of the Voluntary Carbon Markets 2022 Q3. Ecosystems Marketplace.

Edmonds, J.; Dirk, F.; Clarke, L.; de Clara, S.; Munnings, C. (2019) The Economic Potential of Article 6 of the Paris Agreement and Implementation Challenges. Carbon Pricing Leadership Coalition. IETA.

Embrapa - Empresa Brasileira de Pesquisa Agropecuária (2018). Visão 2030: o futuro da agricultura brasileira. – Brasília, DF: Embrapa.

Embrapa - Empresa Brasileira de Pesquisa Agropecuária (2022a). Agricultores do programa PRO Carbono apresentaram pegada de carbono até 80% menor do que padrões internacionais. News - Portal Embrapa. Retrieved from: https://www.embrapa.br/en/noticias/-/asset_publisher/d5zeAgqx3Tw9/content/id/70501284. Accessed: 9/5/2022.

Embrapa - Empresa Brasileira de Pesquisa Agropecuária (2022b). Tecnologia LIBS para medir carbono no solo recebe certificação internacional. 08, Sep. Retrieved from: https://www.embrapa.br/en/busca-de-noticias/-/noticia/73554602/tecnologia-libs-para-medir-carbono-no-solo-recebe-certificacao-internacional. Accessed: 9/9/2022.

Ervine, K. (2018): How low can it go? Analysing the political economy of carbon market design and low carbon prices, New Political Economy, 23(6), 690-710.

Estevam, C. G.; Lima, C. Z.; Pavão, E. M.; Assad, E. D.; Pinto, T. P. (2022). Potencial de mitigação de gases de efeito estufa das ações de descarbonização da produção de soja até 2030. Observatório de Conhecimento e Inovação em Bioeconomia. FGV/EESP. Retrieved from: https://eesp.fgv.br/sites/eesp.fgv.br/files/2022.02.16_-_potencial_de_mitigacao_de_gases_de_efeito_estufa_das_acoes_de_descarbonizacao_da_soja_ate_2030.pdf. Accessed: 5/30/2022.

European Parliament (2022). Legislative Train. Retrieved from: https://www.europarl.europa.eu/legislative-train/carriage/carbon-removal-certification/report?sid=6001. Accessed: 10/5/2022.

Ferreira, N.; Djanian, M. & Mokodsi, A. L. (2022). A mente do agricultor brasileiro 2022. McKinsey. Retrieved from: https://mente-do-agricultor.mckinsey.com/#links. Accessed: 9/13/2022.

Florentino, J. (2022) Indigo conclui emissão recorde de créditos de carbono na agricultura. Valor Econômico, Jul. 01 São Paulo. Disponível em: https://valor.globo.com/agronegocios/noticia/2022/07/01/indigo-conclui-emissao-recorde-de-creditos-de-carbono-na-agricultura.ghtml. Accessed: 7/19/2022.

Garrett, R. D., Grabs, J., Cammelli, F., Gollnow, F., Levy, S. A. (2022). Should payments for environmental services be used to implement zero-deforestation supply chain policies? The case of soy in the Brazilian Cerrado. World Development, Vol. 152, p. 105814.

Goodmann, N. (2022). A Snapshot of Trends Among Carbon Buyers. AFF - American Forestry Foundation. 28, Feb. Retrieved from: https://www.forestfoundation.org/why-we-do-it/family-forest-blog/a-snapshot-of-trends-among-carbon-buyers/?utm_source=newsletter&utm_medium=email&utm_term&utm_content=See%20the%20Full%20Results.&utm_campaign=FFCP. Accessed: 9/02/2022.

Green, J. F. (2017). Don´t link carbon markets. Nature, Vol. 543 (7646), 484-486.

Griscom, B. W., Adams, J., Ellis, P. W., Houghton, R. A., Lomax, G., Miteva, D. A., ... & Fargione, J. (2017). Natural climate solutions. Proceedings of the National Academy of Sciences, 114(44), 11645-11650.

Griscom, B. W., Busch, J., Cook-Patton, S. C., Ellis, P. W., Funk, J., Leavitt, S. M., ... & Worthington, T. (2020). National mitigation potential from natural climate solutions in the tropics. Philosophical Transactions of the Royal Society B, 375(1794), 20190126.

Henders, S; Persson, U.M; Kastner, T. (2015). Trading forests: land-use change and carbon emissions embodied in production and exports of forest-risk commodities. Environmental Research Letters, Vol.10/Issue12, 125012.

Hingne, A. (2019) Unlocking the potential of carbon market mechanisms in the Paris Agreement. World Resources Institute. December 5th, 2019. Retrieved from: https://wri-india.org/blog/unlocking-potential-carbon-market-mechanisms-paris-agreement. Accessed: 9/02/2022.

Hungria, M.; Mendes, I. C. (2015). Nitrogen fixation with soybean: the perfect symbiosis? In: de Bruijn, F. J. (Ed.). Biological nitrogen fixation. v.2. Hoboken, New Jersey: John Wiley & Sons, Inc., 2015. p. 1009-1023.

ICROA (2014), "Unlocking the hidden value of carbon offsetting", Available at:http://s3-eu-west-1.amazonaws.com/ncp-cdn/downloads/ICROA_Unlocking_the_Hidden_Value_of_Carbon_Offsetting.pdf. Accessed: 9/02/2022.

IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. Retrieved from: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_00_Cover.pdf. Accessed: 10/5/2022.

So, I.; Haya, B.; Elias, M. (2022). Voluntary Registry Offsets Database, Berkeley Carbon Trading Project, University of California, Berkeley. Retrieved from: https://gspp.berkeley.edu/faculty-and-impact/centers/cepp/projects/berkeley-carbon-trading-project/offsets-database. Accessed: 9/15/2022.

Lewis, J. T.; Trevisani, P. (2021). Storing Carbon Holds Growing Appeal for Brazil's Farmers. The Wall Street Journal, 6, Jul. Retrieved from: https://www.wsj.com/articles/storing-carbon-holds-growing-appeal-for-brazils-farmers-11625565600. Accessed: 9/7/2022.

Lewis S. L; Wheeler, C. E.; Mitchard, E. T. A.; Kock A. (2019). Restoring natural forest is the best way to remove atmospheric carbon. Comment, Nature 568.

Lovejoy, T. E.; Nobre, C.(2019) Amazon tipping point: Last chance for action. Science Advances, Vol.5, N.12, eaba2949.

Lovejoy, T. E.; Nobre, C.(2018) Amazon Tipping Point. Science Advances, Vol.4, n.2, eaat2340.

Ma Y., An X. (2018) Exchange rate changes, income gap and economic growth: an empirical study based on different stages of economic development. Economist, 9, 78–87.

Mapa - Ministério da Agricultura Pecuária e Abastecimento (2021). Plano Setorial para adaptação e mudança do clima e baixa emissão de carbono na agropecuária: 2020 a 2030. Retrieved from: https://www.gov.br/agricultura/pt-br/assuntos/sustentabilidade/plano-abc/arquivo-publicacoes-plano-abc/plano-setorial-para-adaptacao-a-mudanca-do-clima-e-baixa-emissao-de-carbono-na-agropecuaria-2020-2030.pdf. Accessed: 4/20/2022.

Martin-Neto, L. (2022). A construção da bioeconomia brasileira [Webinar]. Fundação Getúlio Vargas - EESP. https://www.youtube.com/watch?v=LYEh1k7hsxI. Accessed: 9/10/2022.

Mattila, T. J., Hagelberg, E., Söderlund, S., & Joona, J. (2022). How farmers approach soil carbon sequestration? Lessons learned from 105 carbon-farming plans. Soil and Tillage Research, 215, 105204.

McKinsey Nature Analytics (2021). Nature and Net Zero. McKinsey & Company & World Economic Forum, May 2021. Retrieved from: https://www3.weforum.org/docs/WEF_Consultation_Nature_and_Net_Zero_2021.pdf. Accessed: 9/12/2022.

Mozzer, G. B. & Pellegrino, G. Q (2018). MDL e a construção do conhecimento em quantificações de redução de emissões de GEEs: da proposta inicial ao programa de atividades. In Frangetto, F. W. O., Veiga, A. P. B. O., & Luedemann, G. O. (Ed.). Legado do MDL: impactos e lições aprendidas a partir da implementação do Mecanismo de Desenvolvimento Limpo no Brasil como subsídios para novos mecanismos (pp. 61-81). Brasília-DF: Ipea.

Nepomuceno, A. (2020). Soja carbono neutro [Webinar]. Confederação da Agricultura - CNA. Retrieved from: https://cnabrasil.org.br/noticias/live-promovida-pela-cna-debate-soja-carbono-neutro. Accessed: 9/08/2022.

Newell, R. G.; Pizer, W. A.; Raimi, D. (2013) Carbon Markets 15 years after Kyoto: Lessons learned, new challenges. Journal of Economic Perspectives, Vol. 27, n.1, 123–146

Nicoloso, R. S.; Rice, C. W. (2021). Intensification of no-till agricultural systems: An opportunity for carbon sequestration. Soil Science Society of America Journal, 85(5), 1395-1409.

Nobre, M. M.; Oliveira, I. R. (2018) Agricultura de baixo carbono: tecnologias e estratégias de implantação. Embrapa, Brasília, DF. Disponível em: https://www.embrapa.br/en/busca-de-publicacoes/-/publicacao/1101744/agricultura-de-baixo-carbono-tecnologias-e-estrategias-de-implantacao. Accessed: 9/08/2022.

Novaes, R. M. L., Tubiello, F. N., Garofalo, D. F. T., de Santis, G., Pazianotto, R., & Matsuura, M. D. S. (2022). Brazil's agricultural land, cropping frequency and second crop area: FAOSTAT statistics and new estimates. Retrieved from: https://www.embrapa.br/en/busca-de-publicacoes/-/publicacao/1140492/brazils-agricultural-land-cropping-frequency-and-second-crop-area-faostat-statistics-and-new-estimates. Accessed: 9/5/2022.

Ontl, T. A., & Schulte, L. A. (2012). Soil carbon storage. Nature Education Knowledge, 3(10).

Organização das Cooperativas Brasileiras (2022). Anuário Coop 2022. Retrieved from: https://anuario.coop.br/ramos/agropecuario. Accessed: 6/19/2022.

Pendrill, F; Persson, U.M; Godar, J; Kastner, T. (2019). Deforestation displaced: trade in forest-risk commodities and the prospects for a global forest transition. Environmental Research Letters. Vol.14, Issue.5.

Pinto, E.; Guimarães, A.; Moutinho, P. (2022). Pagamento por Serviços Ambientais no Brasil. Agropolítica em debate. Diálogo Agropolítico Brasil - Alemanha. Retrieved from: https://apdbrasil.de/wp-content/uploads/2022/08/Pagamento_por_servicos_ambientais_no-Brasil_PTBR.pdf. Accessed: 9/07/2022.

Polidoro, J. C., de Freitas, P. L., Hernani, L. C., dos Anjos, L. H. C., Rodrigues, R. D. A. R., Cesário, F. V., ... & Ribeiro, J. L. (2020). The impact of plans, policies, practices and technologies based on the principles of conservation agriculture in the control of soil erosion in Brazil. Authorea Preprints. Retrieved from: https://www.authorea.com/doi/full/10.22541/au.158750264.42640167. Accessed: 7/21/2022.

Porto, M. (2021). O futuro das pastagens brasileiras: a revolução da integração lavoura-pecuária-floresta [Webinar]. Insper Agro Global - Insper. https://www.youtube.com/watch?v=7b8Gfm6XzqY. Accessed: 9/14/2022.

Possamai, E. J., Conceição, P. C., Amadori, C., Bartz, M. L. C., Ralisch, R., Vicensi, M., & Marx, E. F. (2022). Adoption of the no-tillage system in Paraná State: A (re) view. Revista Brasileira de Ciência do Solo, 46.

Postic, S.; Fetet, M. (2021) Global Carbon Accounts 2021. Institute for Climate Economics.

Potenza, R. F.; Quintana, G. O.; Cardoso, A. M.; Tsai, D. S.; Cremer, M. S.; e Silva, F. B.; … &.Azevedo, T. (2021). Análise das emissões brasileiras de Gases de Efeito Estufa e suas implicações para as metas climáticas do Brasil: 1970 – 2020. SEEG/Observatório do Clima. Retrieved from: OC_03_relatorio_2021_FINAL.pdf (seeg-br.s3.amazonaws.com). Accessed: 7/20/2022

Rede ILPF (2021a). Rede projeta 35 milhões de hectares com sistemas de ILPF até 2030 | Embrapa. Retrieved from: https://redeilpf.org.br/rede-projeta-35-milhoes-de-hectares-com-sistemas-de-ilpf-ate-2030-embrapa/ Accessed: 10/28/2021.

Rede ILPF (2021b). ILPF em números. Rede ILPF. Retrieved from: https://www.redeilpf.org.br/images/ILPF-em-Numeros-Rede-ILPF-2021.pdf. Accessed: 10/28/2021.

Ritter, T.; Treakle, J. (2020) Why Carbon Markets Won't Work for Agriculture. Institute for Agriculture and Trade Policy. Available online at https://www.iatp.org/documents/why-carbon-markets-wont-work-agriculture. Accessed: 9/7/2021.

Rockstrom, J.; Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., ... & Foley, J. A (2009). A safe operating space for humanity. Nature, Vol. 461 (7263). pp.472-475.

Schneider, L., Duan, M., Stavins, R., Kizzier, K., Broekhoff, D., Jotzo, F., ... & Hood, C. (2019). Double counting and the Paris Agreement rulebook. Science, 366(6462), 180-183.

Schneider, L., & La Hoz Theuer, S. (2019). Environmental integrity of international carbon market mechanisms under the Paris Agreement. Climate Policy, 19(3), 386–400.

Seddon N.; Chausson A.; Berry P.; Girardin C. A. J.; Smith A.; Turner B. (2020) Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philosophical Transactions of the Royal Society B, 375(1794), 20190120.

SEEG - Sistema de Estimativas de Emissões de Gases de Efeito. (2021) Emissões Totais. SEEG/Observatório do Clima. Retrieved from: https://plataforma.seeg.eco.br/total_emission. Accessed: 12/10/2021.

SEEG - Sistema de Estimativas de Emissões de Gases de Efeito. (2021a) Emissões por setor/Agropecuária. SEEG/Observatório do Clima. Retrieved from: https://plataforma.seeg.eco.br/sectors/agropecuaria. Accessed: 12/10/2021

Specsolo (2022). Tecnologia Specsolo. Retrieved from: http://www.specsolo.com.br/antiga_pg_specsolo_scan/. Accessed: 10/5/2022.

Springmann, M., Clark, M., Mason-D'Croz, D. Wiebe, K., Bodirsky, B. L., Lassaletta, L., ... & Willett, W (2018). Options for keeping the food system within environmental limits. Nature 562 (7728), 519–525.

Steer, A.; Hanson, C. (2021) Corporate Financing of Nature Based Solutions: What Next? World Resource Institute. Retrieved from: https://www.wri.org/insights/corporate-financing-nature-based-solutions-what-next. Accessed: 8/22/2022.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M.,... & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. Science, Vol. 347, Issue 6223, 1259855.

Stiglitz, J; Stern, N.; Duan, M., Edenhofer, O., Giraud, G., Heal, G. M., ... & Winkler, H. (2017) Report of the High-Level Commission on Carbon Prices. Carbon Pricing Leadership Coalition. World Bank.

Thamo, T.; Pannell, D.J. (2016) Challenges in developing effective policy for soil carbon sequestration: perspectives on additionality, leakage, and permanence. Climate Policy, 16 (80), 973-992.

Thamo, T.; Pannell, D.J.; Pardey, P.G.; Hurley, T. M. (2020) Private incentives for sustainable agriculture: soil carbon sequestration. Working Paper 2004, UWA Agricultural and Resource Economics.

Thompson, N. M., Hughes, M. N., Nuworsu, E. K., Reeling, C. J., Armstrong, S. D., Mintert, J. R., ... & Foster, K. A. (2022). Opportunities and challenges associated with" Carbon farming" for US row-crop producers. Center for Commercial Agriculture. Available at: https://ag.purdue.edu/commercialag/home/wp-content/uploads/2021/06/202106_Thompson_CarbonMarkets.pdf. Accessed: 9/13/2022.

TSVCM (2020) Taskforce on Scaling Voluntary Carbon Markets. Consultation Document. November, 2020. 98p.

TSVCM (2021) Taskforce on Scaling Voluntary Carbon Markets. Final Report. January, 2021. 148p.

UNFCCC - United Nations Framework Convention on Climate Change (2018). Koronivia Joint Work on Agriculture. Decision 4/COP.23. Retrieved from: https://unfccc.int/decisions. Accessed: 8/26/2022.

Valdiones, A. P. et al. Desmatamento Ilegal na Amazônia e no Matopiba: falta transparência e acesso à informação. ICV (Instituto Centro de Vida), Imaflora, Lagesa (Laboratório de Gestão de Serviços Ambientais da Universidade Federal de Minas Gerais). Disponível em: https://wwfbr.awsassets.panda.org/downloads/desmatamento_ilegal_na_amazonia_e_no_matopiba___estudo_completo.pdf. Accessed: 01/19/2022.

van den Bergh, J.; Botzen, W. (2020) Low-carbon transition is improbable without carbon pricing. Van Den Bergh, J., & Botzen, W. (2020). Low-carbon transition is improbable without carbon pricing. Proceedings of the National Academy of Sciences, 117(38), 23219-23220.

Verra (2022). Verified Carbon Standard. Methodologies. Retrieved from: https://verra.org/methodologies/

Verra (2020). Verified Carbon Standard. Methodologies. VM0042 Methodology for Improved Agricultural Land Management, v1.0. Retrieved from: https://verra.org/methodology/vm0042-methodology-for-improved-agricultural-land-management-v1-0/. Accessed: 10/05/2022.

Villas-Boas, P. R., Franco, M. A., Martin-Neto, L., Gollany, H. T., & Milori, D. M. (2020a). Applications of laser-induced breakdown spectroscopy for soil analysis, part I: Review of fundamentals and chemical and physical properties. European Journal of Soil Science, 71(5), 789-804.

Villas-Boas, P. R., Franco, M. A., Martin-Neto, L., Gollany, H. T., & Milori, D. M. (2020b). Applications of laser-induced breakdown spectroscopy for soil characterization, part II: Review of elemental analysis and soil classification. European Journal of Soil Science, 71(5), 805-818.

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S.,… Murray, C. J. L. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. The Lancet, Vol. 393, Issue 10170, 447–492.

World Bank (2022). Carbon Pricing Leadership Report 2021/22. World Bank, Washington, DC. Retrieved from: https://static1.squarespace.com/static/54ff9c5ce4b0a53decccfb4c/t/6290ddafb9a58932868f4797/1653661106052/Carbon+Pricing+Leadership+Report+2021-22.pdf. Accessed: 9/02/2022.

World Bank (2022) State and Trends of Carbon Pricing 2022. Retrieved from: https://openknowledge.worldbank.org/handle/10986/37455 Accessed: 9/02/2022.

World Bank (2021) State and Trends of Carbon Pricing 2021. Retrieved from: https://openknowledge.worldbank.org/handle/10986/35620. Accessed: 4/03/2022.

Wunder, S. (2008). How do we deal with leakage. In Moving ahead with REDD: issues, options and implications (Vol. 1, pp. 65-75). Retrieved from: https://projects.ncsu.edu/project/amazonia/Wunder_CH7.pdf. Accessed: 10/05/2022.

Zanatta, J. A.; Bordon, B.; Holler, B.W. A.; Rachwal, M. F. G; Rossi, L. M. B.; Higa, R. C. V. (2020). Índice de alteração do carbono no solo, em conversões de uso do solo envolvendo plantações florestais no Brasil. Documentos 342. Embrapa Florestas, Embrapa. Retrieved from: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/217027/1/Livro-Doc-342-1804-final-2.pdf. Accessed: 9/05/2022.

Editorial Board & Staff

Authors
Camila Dias de Sá, Claudia Cheron König and Niels Søndergaard

Graphic design, front cover and text formatting and infographics
Contexto Gráfico and Jamil Ghani

Cover Photo
by various @AdobeStock and Wenderson Araujo, Sistema CNA/Senar

Publisher
Agricultural Policy Dialogue Brazil-Germany (APD)

Editorial Coordination
Gleice Mere, Ingo Melchers and Carlos Alberto dos Santos

Photomontage
Jamil Ghani

Mn C Mg CO Mn C Mg CO Mn C
$ P re Si $ P Fe Si $ P
Mg CO Mn C Mg CO Mn C Mg
P Fe Si $ P Fe Si $ P Fe
C Mg CO Mn C Mg CO Mn C
$ P Fe Si $ P Fe Si $ P
Mg CO Mn C Mg CO