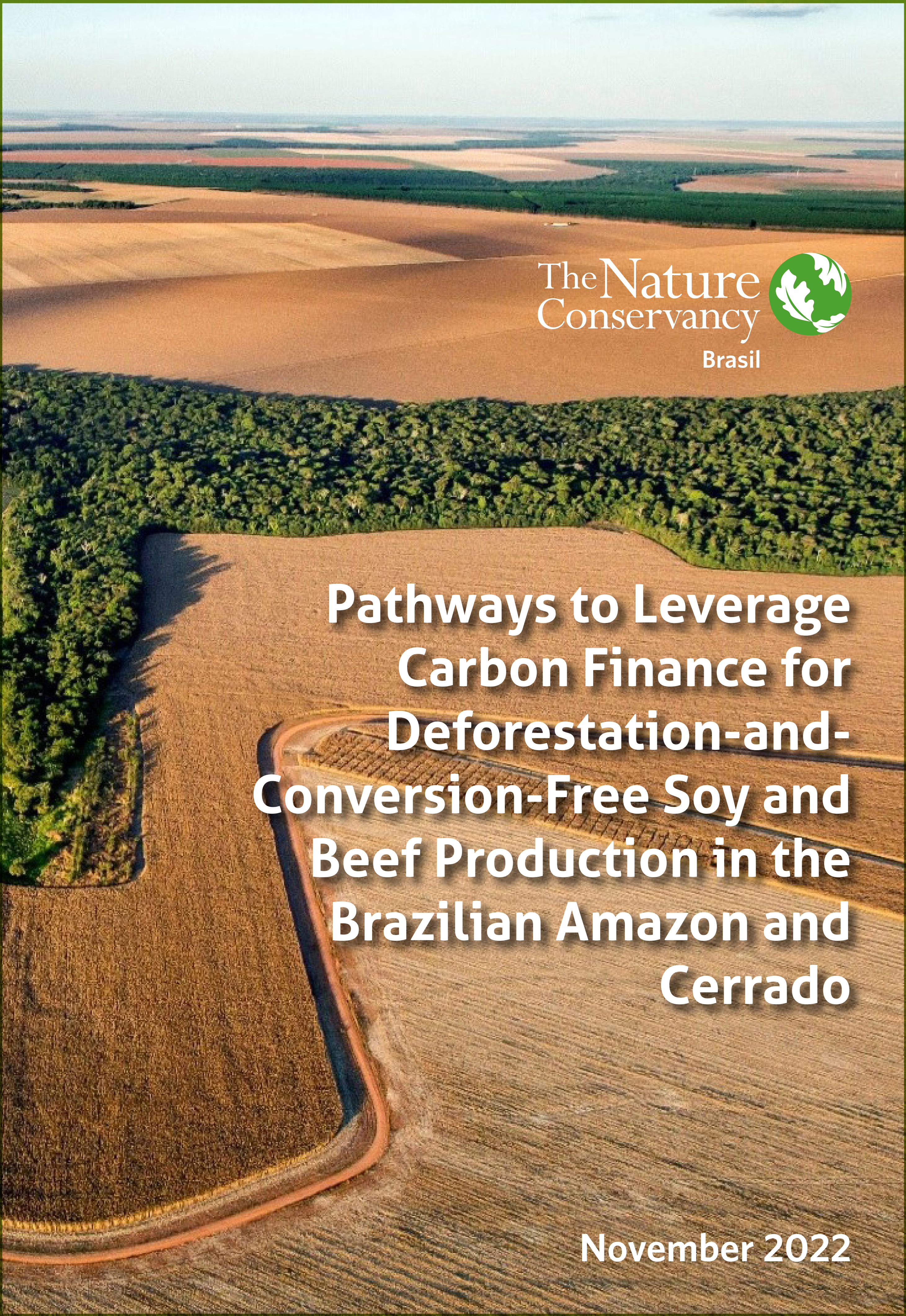


The Nature Conservancy
Brasil

Pathways to Leverage Carbon Finance for Deforestation-and-Conversion-Free Soy and Beef Production in the Brazilian Amazon and Cerrado

November 2022

Summary

AUTHORS
Fernanda Rocha
Edenise Garcia
Fernando Cesário
Julia Mangueira
Greg Fishbein
Melissa Brito
Supported by Radicle Brazil
Funded by the Gordon and Betty Moore Foundation

Executive summary

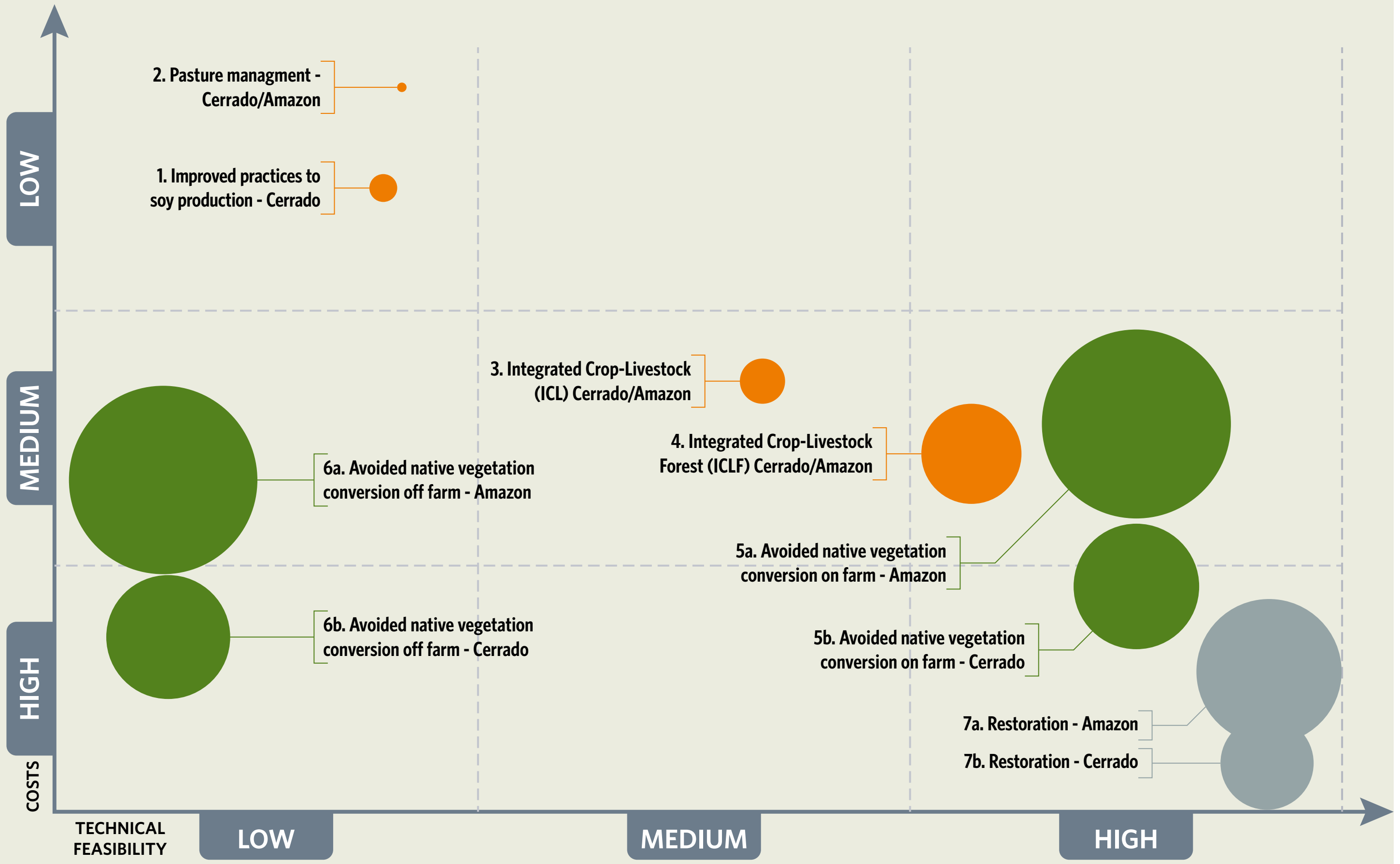
The land sector offers one of the greatest opportunities for the world to reduce greenhouse gas (GHG) emissions over the next decade and limit global warming to 1.5 degrees Centigrade – through a combination of halting deforestation and conversion of native vegetation, restoring forests and natural vegetation, and reducing emissions from agricultural and other land-use practices. Brazil offers one of the richest environments in the world to implement such approaches given the vast stores of carbon in its Amazon, Cerrado and Atlantic Forest biomes, the agricultural threats facing these critical ecosystems, and the amount of land that has already been degraded and is available for restoration.

The agriculture-related opportunities in the land-use sector can be broken down into several key sustainability strategies i.e., regenerative agriculture expansion on already-cleared pastureland, sustainable intensification of cattle ranching, protection of native vegetation beyond the legal requirement, native vegetation restoration and agroforestry. These strategies can then be connected to one or more "pathways" for generating carbon benefits, such as improvements in soil carbon, avoided conversion of native vegetation (on and off-farm), and native vegetation restoration. For example, a program to expand soy production on degraded pastureland can generate climate benefits from improving soil health, avoiding the conversion of native vegetation in the landscape (on and off the farms restored), and potentially native restoration as farmers comply with the Forest Code. Sustainable intensification of cattle ranching can create similar types of benefits, although of different magnitudes.

Various mechanisms are emerging for generating value from the carbon benefits of sustainable agriculture in order to drive deeper investments into these activities, including offsets markets, scope 3 emissions frameworks, jurisdictional programs and national-level programs to achieve NDCs. The purpose of this report is to assess, for the Brazilian Amazon and Cerrado, the different sustainable agriculture strategies, their associated carbon benefit pathways, and the emerging carbon finance mechanisms in order to clarify where the most promising opportunities are available to accelerate investment.

Figure 1 summarizes the pathways with respect to the magnitude of the carbon opportunity, the costs associated with implementation, and the methodologies and technical issues for credibly measuring carbon impact.

Figure 1: Summary of the analysis, based on quantitative and qualitative information and criteria



Key observations from this analysis include:

- **Avoiding deforestation (on and off farm) emerges as the most cost-effective means to reduce emissions at large scale.**
  - In the case of on-farm avoided conversion, i.e. the protection of surplus legal reserve, methodologies are available to monetize the value through offset markets. Various initiatives are working to implement this approach, but face challenges with respect to methodological issues, high transaction costs and the challenges of obtaining commitments from farmers to protect native vegetation for multiple decades.
  - In the case of off-farm emissions, the only recognized way to measure and monetize carbon at a landscape scale is through a jurisdictional or national program, which involves significant uncertainty with respect to allocating resources from the jurisdictional / national program to the actors implementing the sustainable agriculture strategy.
- **Restoration of forests and other native vegetation has a high mitigation potential and there are demonstrated technical approaches to monetizing the carbon benefits through offsets, however, the economics are challenging given the high upfront costs and the long timeframe it takes for biomass to grow. As a result, native vegetation restoration has been slow to gain momentum.**
- **Recovery of pasture for soy and integrated crop-livestock (ICL) systems generate tangible soil carbon benefits and have high potential to scale, however the magnitude per hectare of these benefits is small relative to the forest-oriented pathways. In addition, there are technical challenges to monetizing soil carbon including the variability and measurement issues and permanence challenges. When integrated systems contemplate the forest component (ICLF) the mitigation potential is enhanced, and co-benefits are improved.**

In light of these observations, we recommend the following efforts to accelerate investment and implementation of sustainable, climate-positive agriculture strategies:

- **Greater focus should be placed on working with jurisdictional and national climate programs to support and reward agricultural initiatives that encourage avoided conversion of natural vegetation, including regenerative agricultural expansion on pastureland and sustainable cattle intensification.**
  - Avoiding conversion at landscape scale is the most important opportunity for Brazil and currently there are no substantial mechanisms to leverage carbon benefits to encourage pasture expansion and yield improvements commensurate with the contribution they make to avoiding conversion. Connecting carbon benefits with these practices can only be done cost-effectively and at scale through a jurisdictional or national program, and it merits deeper discussion as to what mechanisms could be created within initiatives such as PCI in Mato Grosso, Para Agora or national programs.
- **Greater effort should be invested to create group carbon projects to incentivize farmers not to clear native vegetation beyond the legal requirements**.
  - This type of avoided conversion can be measured and monetized through an offset program. This approach has not been implemented extensively and we see significant opportunities to do so. Estimates indicate there are over 1 million hectares of native vegetation in the Cerrado in excess of legal reserve requirements which are suitable for soy production (MapBiomas, 2022).
- **Companies and farmers can continue to measure and monetize soil carbon benefits, but should consider including in their programs measures to avoid conversion and restore *native vegetation* in order to enhance the carbon impact and the cost-effectiveness of monetizing the benefits.**
  - Systems that integrate crops and livestock, and potentially trees, will have greater carbon benefits than crops alone.
- **Native vegetation restoration should be expanded and to make it more economical, the costs can be supported by integrating restoration into programs with strong underlying economics – such as agriculture expansion on pastureland and sustainable cattle intensification. Restoration is often required for farmers in such programs to comply with the Forest Code.**

Context and objective

Concerns about the social, environmental and economic impacts of climate change has led the public and private sectors, non-governmental organizations and society in general to discuss and engage in initiatives related to the mitigation of greenhouse gas (GHG) emissions and adaptation to the climate change effects.

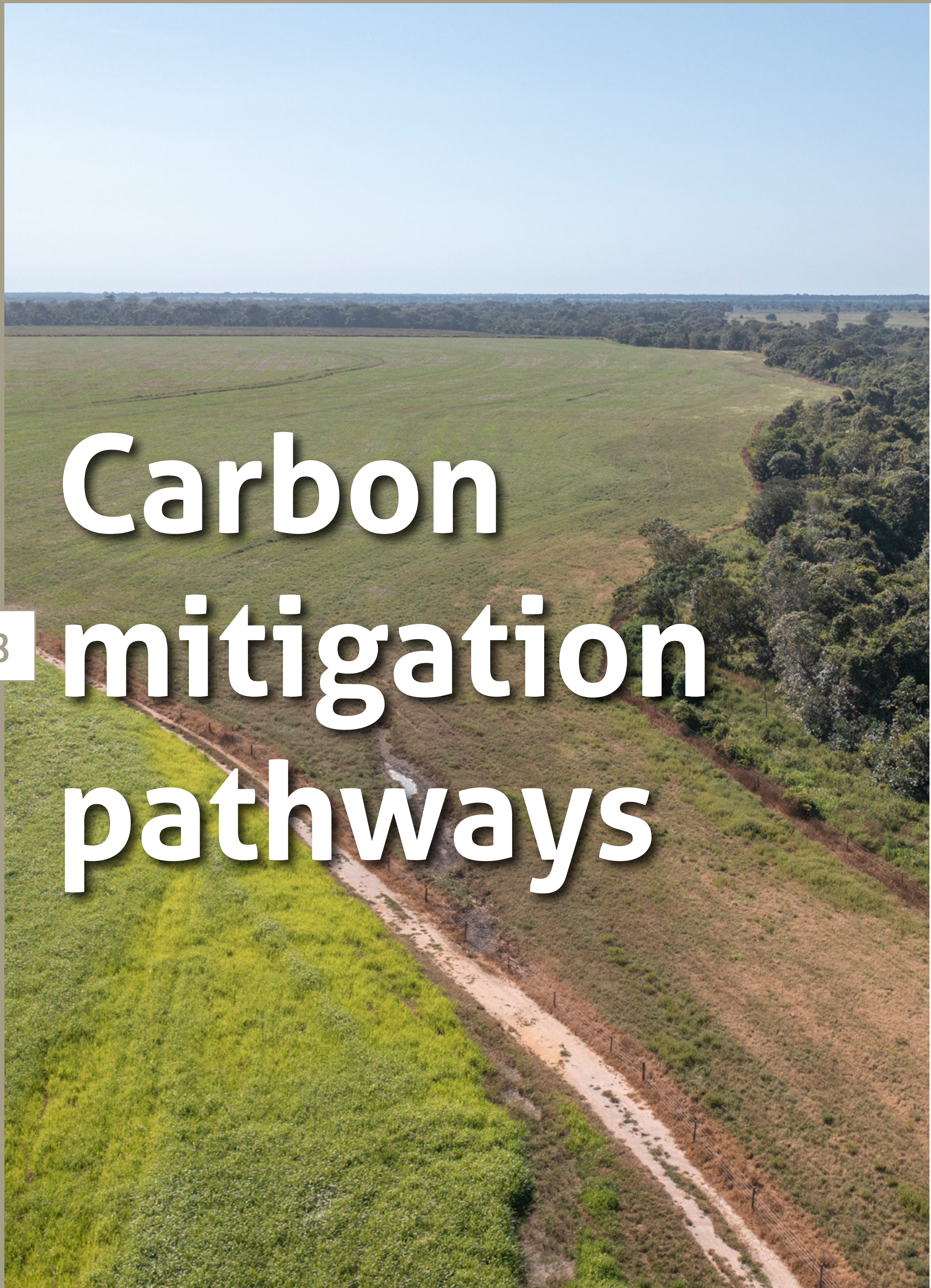
Natural Climate Solutions (NCS) – or actions that use nature to store carbon or avoid/reduce GHG emissions – are essential to achieving the goal of keeping the increase in the global average temperature below 1,5°C. NCS have the potential to mitigate approximately 11 gigatons of GHG emissions globally per year – that's one third of what's needed to stabilize the climate by 2030 (Griscom, et al., 2017).

Brazil offers one of the richest environments in the world to implement NCS, given the vast carbon stores in its Amazon, Cerrado and Atlantic Forest biomes, the threats facing these critical ecosystems, and the amount of land that has already been degraded and is available for vegetation and soil restoration. In addition, in 2021, Brazil lost 2.90 Mha of natural forest, resulting in 1.70 Gt of CO_2 emissions (GFW, 2022[1]). Deforestation due to agricultural pressure accounted for almost 97% of all deforestation validated by MapBiomas Alerta in 2021 in Brazil (MapBiomas, 2022).

Following this scenario, TNC have been implementing NCS pathways through the conservation, improved management, and restoration of ecosystems for the last 30 years in Brazil. TNC has also developed consistent environmental requirements to associate to new and existing financial products for a Deforestation-and-Conversion-Free (DCF) approach in the production of soy and beef - a necessity for companies with land-based value chains to deliver on their climate strategies and net-zero plans.

This report explores how carbon benefits related to DCF production could be measured and monetized to accelerate and expand DCF soy and cattle production adoption in the Brazilian Amazon and Cerrado. It analyses several NCS pathways with regards to their estimated carbon mitigation potential, associated costs and technical feasibility to monetizing the benefit and how payments could be made to the farmers.

1. Available in Global Forest Watch: https://www.globalforestwatch.org/



Carbon mitigation pathways

Brazil offers one of the richest environments in the world to implement NCS

The Nature Conservancy distills NCS into defined carbon mitigation pathways[2] spanning four realms – forests, grasslands, agriculture, and wetlands, and three overarching intervention types – protection, management, and restoration. Some specific combinations were selected based on representativeness to analyze the carbon mitigation pathways associated with DCF soy and cattle production in the Amazon and Cerrado. The objective of this report is to assess the most promising carbon mitigation pathways for both biomes based on the existing measurement methodologies and monetizing approaches that includes the payment type to deliver the resources to the farmers.

Pathways are evaluated with respect to the estimated magnitude of the opportunity, the implementation costs, and the methodologies and technical issues for credibly measuring and monetizing the carbon impact. Regenerative systems resulting from restoration and management pathways considered degraded areas[3] as their initial condition (baseline). converted to regenerative systems.

2. **Forests:** avoided forest conversion, climate-smart forestry, plantation management, fire management, avoided wood fuel harvest, urban canopy cover, reforestation; **Grasslands:** avoided grassland conversion, grassland restoration; **Agriculture:** trees in agricultural lands, rice management, nutrient management, biochar, cover crops, reduced tillage, legume crops, legumes in pastures, grazing optimization, grazing animal & feed management, manure management; **Wetlands:** avoided coastal wetland impacts, avoided freshwater wetland impacts, coastal wetland restoration, freshwater wetland restoration.

3. The carbon pool in well-managed soil tends to saturation (to a new equilibrium) at some point over the time of system implementation (Wiesmeier et al., 2020). For soils, the time adopted is the IPCC default of 20 years (IPCC, 2006; 2019). Also, other publications report the default period of 20 years (Smith, 2004). Likewise, the inverse path, ie the emission of GHG by soil degradation, also has a maximum default period of 20 years

The pathways included in this report are detailed below:

Table 1 - Carbon mitigation pathways.

NCS intervention type	Pathway	Description
Management	1 - Improved practices for soy production Cerrado	Degraded area converted into soybean crops under conditions of regenerative practices such as no-tillage, cover crops and rotation with other crops - practices that comprise a set of agricultural technological processes while promoting soil conservation management[4].
	2 - Improved pasture management - Cerrado / Amazon	Degraded area converted to well-managed pasture with significant yield increase, employs a primarily grass-fed system and follows recognized practices for sustainable pasture intensification. This practice includes reestablishment of production, through fertilization and soil correction, without mechanized preparation of the area and without change in forage.
	3 - Integrated crop-livestock (ICL) Cerrado / Amazon	Degraded pasture converted into integrated crop-livestock (ICL) that comprises the use of different production systems within the same area. It can be performed through intercropping, crop succession or crop rotation, with cattle ranching associated - so that all the activities are mutually beneficial.
	4 - Integrated crop-livestock-forest (ICLF) Cerrado / Amazon	Degraded area converted to integrated crop-livestock-forest (ICLF) which is a production strategy that has been growing in Brazil in recent years. It comprises different production systems: agricultural, cattle ranching and forestry systems, within the same area.
Protection	5 - Avoided native vegetation conversion on farm Cerrado / Amazon	Avoided emissions from preventing human conversion of forest to non-forest land uses such as agricultural lands. These pathways concern the preservation of forest patches on rural lands beyond what is legally required according to the biome (surplus legal reserve).
	6 - Avoided native vegetation conversion off farm Cerrado / Amazon	Avoided emissions from preventing human conversion of forest to non-forest land uses such as agricultural lands given the cattle ranching intensification and/or pasture recovery to agricultural production that contributes to alleviate the conversion pressure in the landscape. This is a carbon benefit impact that is generated outside of the rural property (off-farm).
Restoration	7 - Native vegetation restoration - Cerrado / Amazon	Increased sequestration from restoration of native vegetation, that is, transitioning non-native vegetation land uses to native vegetation land uses in places where native vegetation historically occurred. This pathway considers revegetation with native species and mixed planting of trees, mainly in permanent preservation and legal reserve areas according to the legal requirements.

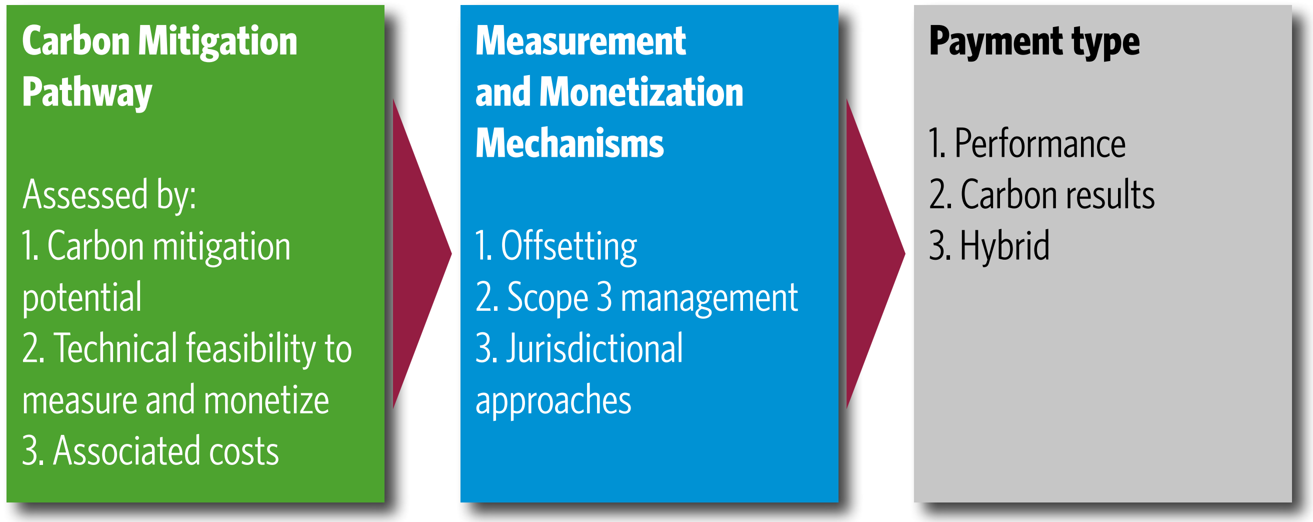
4. Eventual tillage actions during the first phase of transition towards regenerative agriculture might be needed given the high degradation level and extremely compact soil.

There is an additional relevant pathway for both biomes Amazon and Cerrado, represented by agroforestry systems (AFS). Differently from ICLF systems, AFS consists of integrated production systems based in trees and crops that optimize land use and promote biodiversity, socioeconomic and environmental sustainability. In this approach, AFS might encompass different native productive species - commercial or not - and semi-perennial crops. Due to the wide range of possible AFS arranges, and the high carbon removals potential, the AFS estimations are still in development; and were not included in this assessment.

The agriculture-related opportunities in the land-use sector can be broken down into several key sustainability strategies i.e., regenerative agriculture expansion on already-cleared pastureland, sustainable intensification of cattle ranching, protection of native vegetation beyond the legal requirement and native vegetation restoration and agroforestry. These strategies can then be connected to one or more "pathways" for generating carbon benefits, such as improvements in soil carbon, avoided conversion of native vegetation (on and off-farm), and native vegetation restoration. For example, a program to expand soy production on degraded pastureland can generate climate benefits from improving soil health, contributing to the avoidance of converting native vegetation in the landscape (on and off the farms restored), and potentially native restoration as farmers comply with the Forest Code. Sustainable intensification of cattle ranching can create similar types of benefits, although of different magnitudes.

The methodological process used in this report is represented in the Figure 2. The first step was to assess the pathways associated with the conservation strategies of pasture recovery, cattle ranching intensification and protection of native vegetation that could benefit from carbon incentives. The pathways were assessed based on their carbon mitigation potential, the technical feasibility to measure and monetize the carbon benefit and the associated costs to pursue it. After that, mechanisms to monetize carbon were identified and associated with corresponding different payment types to producers.

Figure 2: Methodological process adopted by the report



Measurement and monetization mechanisms

To leverage the implementation of the pathways above, the carbon benefit could be measured and monetized trough several existing mechanisms such as offsetting, scope 3 management and jurisdictional approaches:

Offsetting: Offsets can be used by companies as a tool to achieve their climate goals, including net zero emissions. Such a strategy should, initially, properly identify the sources and reduce emissions in its operations and supply chain, to only then acquire offsets to mitigate the residual emissions that cannot be further reduced. Brazil does not have a regulated carbon market, so the market for offsets relies on the voluntary carbon market. According to existing methodologies, soy and cattle farmers could pursue this mechanism for several carbon pathways, from GHG removals to avoided conversion.

Scope 3 management: represents the GHG emissions or removals that an organization indirectly impacts in its value chain. Among the many categories of scope 3 emissions, there is the "purchase of goods and services". That is why the food and agricultural sector have their main emissions sources allocated within scope 3. In this way, farmers (suppliers) represent scope 3 emissions of industries, because they are part of their supply chain. The same applies to financial institutions, where all financed operations are categorized as scope 3 in their GHG inventory.

Actions to reduce emissions under the scope 3 approach are legitimate when companies are capable of properly measuring, their scope 3 emissions in their GHG inventories and take effective actions to reduce emissions in their supply chain. As an example, a company that is an intensive buyer or seller of agri-based products can undertake actions at the farm level to incentivize emissions reductions in their supply chain by several means, such as those that enhance regenerative agriculture or avoid clearing of native vegetation. This way, the company can report in its inventory the emissions reductions or removals that were obtained at the farms in the supply chain.

The inventory method of scope 3 management allows companies to track the aggregate effect of their activities on total corporate GHG emissions over time. In the agricultural sector, for instance, companies can incentivize their suppliers to demonstrate soil carbon enhancement from regenerative agriculture practices and account for the associated benefit in their inventories under an inset program. At the same time, emissions from native vegetation conversion attributed to the suppliers are reported in the corporate inventory as well, so working with farmers to avoid conversion helps reduce scope 3 emissions.

This is an initiative that must come from the corporate side to the farmers in their supply chain, through various forms of support such as technical assistance to farmers to improve their production systems, direct payments for carbon removals, or lower cost financing, among others.

Jurisdictional approaches: governmental programs of integrated landscape management that bring together key relevant stakeholders to co-develop and align goals towards sustainable practices within the jurisdiction. Deforestation and forest degradation are the main areas on which the Brazilian states are focusing their jurisdictional approaches, followed by native vegetation restoration. Results of jurisdictional approaches can help Brazil comply with its Nationally Determined Contribution (NDC) submitted to the United Nations Framework Convention on Climate Change (UNFCCC), and can support local authorities and companies to meet their voluntary climate action targets.

These approaches are commonly supported by financial resources coming from international cooperation, such as Reduced Emissions from Deforestation and Forest Degradation (REDD) programs and other payment programs for environmental services, which allows transfers of resources based on results in reducing deforestation within a given jurisdiction. Recently, there have been movements in connecting jurisdictional REDD+ programs to the carbon market. The Architecture for REDD+ Transactions (ART), and its associated jurisdictional TREES standard, aims to facilitate transactions between corporate buyers and governments regarding the purchase of jurisdictional-scale credits. ART provides a standard process to transparently register, verify and issue REDD+ emission reductions credits. Once issued, these serialized credits can be sold in voluntary or compliance markets. Although ART is focused on national-level REDD+, it also allows direct subnational participation according to certain criteria such as national government approval.

National approaches: national level programs and initiatives related to a country's NDCs which, in the case of Brazil, may include various climate-smart agriculture programs led by MAPA and other agencies, Forest Code enforcement policies, finance programs such as the Amazon Fund and other initiatives.

Payment type

The successful engagement of producers in the chosen pathways raises the issue of how farmers will be compensated and incentivized to change behavior.

The approaches can have different levels of complexity, depending on what is the result or practice that needs to be presented by the farmer to gain access to that specific financial resource. This report indicates three types of payment approaches, which are based on the form of measurement of a farm practice or result.

Figure 3 – Types of payment approaches.

PERFORMANCE

The performance-based payment approach compensates farmers based on the implementation of a given activity, such as a change of practice in a farm.

CARBON RESULTS

The carbon results payment approach is objectively based on the carbon measurements related to a specific activity that is implemented. Payments are done based on demonstrated measured mitigation achieved.

HYBRID

A hybrid approach mixes both the performance and the carbon results. It can compensate farmers based on performance indicators, but also give additional financial benefits for verified carbon results.

Carbon Mitigation Pathway Assessment

Every listed pathway is evaluated considering three criteria, as follows:

» **Carbon mitigation potential**: values of emissions and removals were compiled in the literature to estimate the carbon balance of the pathway per hectare per year. The objective of this metric is to provide a single indicator of climate performance of the pathways. Estimates are presented in the Annex. Key assumptions include:

- Well-managed regenerative agricultural systems require several types of inputs to restore and maintain the system's productive capacity, and these emissions need to be netted from the carbon benefits to arrive at a net carbon impact.The main sources of GHG emissions from each pathway were estimated including nitrogen fertilizer, fuels, livestock and limestone.
- The modelling of mitigation potential considered the carbon permanence of 30 years, taking into account the eligibility criteria of the main international standards for carbon projects such as the Gold Standard and Verified Carbon Standard (VCS).
- The carbon pool in well-managed soil tends to saturation (to a new equilibrium) at some point over the time of system implementation (Wiesmeier et al., 2020). For soils, the time adopted is the IPCC default of 20 years (IPCC, 2006; 2019). Also, other publications report the default period of 20 years (Smith, 2004).
- Implementation in a minimum 2,000 hectares area spread over 10 years (200 hectares per year). According to some modeling, this is minimum area to technically and financially make carbon projects viable, considering the 30-year carbon permanence.
- The GHG emission factors from cattle and inputs were taken from the Fourth National Communication of Brazil to the United Nations Framework Convention on Climate Change (UNFCCC) (Brazil, 2020).
- The mitigation potential of each pathway was prepared based on the GHG Protocol guidelines.

» **Technical feasibility** - given by measurement, report and verification (MRV), permanence and additionality classified into high, medium, and low as follows:

Table 2: Criteria to pathways assessments regarding technical feasibility of monetizing the carbon benefit

MRV	
High	Pathways with well-established methodologies and processes for all steps (for example, higher transparency and methods to monitor projects and pathways with forest systems). Well-consolidated MRV pathways for all steps.
Medium	Pathways with methodologies and processes for some steps or carbon pools (for example, there are still gaps and major challenges regarding soil carbon monitoring[5]). Pathways with MRV suitable for some steps.
Low	Pathway that can be monitored and reported, but not verified.
Permanence	
High	Greater amount of carbon pools leads to increased project resilience and lower risks of non-permanence. Pathways with 2 C pools - soil and biomass.
Medium	The biomass carbon pool presents a lower risk of non-permanence when compared to the soil carbon pool (due to soil carbon losses through management).
Low	The soil carbon pool presents a high risk of non-permanence due to upturn losses (common practice in agricultural systems); heterogeneity of tropical soils, biogeochemistry of soil carbon due to edaphoclimatic factors. In the case of the avoided conversion off farm, the risk of non-permanence is related to the governance gaps of jurisdictional projects.
Additionality	**Evaluated using the common practice approach**
High	The pathway has no or low probability to be common practice in the country. Pathways with forest component in integrated systems.
Medium	The pathway can be common practice in some regions of the country.
Low	The pathway has higher probability to be common practice in the country or pathways without verification.

5. For example, the quantification of carbon in the soil which is still under review by Verra for VM00042.

» **Associated costs –** qualitative analyses composed of monitoring costs, cost of implementation and opportunity costs.

Table 3: Criteria to pathways assessment regarding costs

Costs	
High	Monitoring cost: Mandatory to monitor two carbon pools (biomass and soil carbon) Cost of implementation: in the case of avoided conversion on farm, high cost for offsetting projects such as registration, validation, and verifications. In the case of avoided conversion off farm, high cost due to the jurisdictional arrangement, involvement of several actors and actions. For restoration, there are costs associated with the acquisition of seedlings, inputs, labor, monitoring the area, etc. In cases of natural regeneration there are costs with seedlings and labor. Opportunity cost: the producer gives up production when protecting land they can legally convert to agriculture.
Medium	Monitoring cost: mandatory to monitor one pool (soil or biomass) Cost of implementation: the operating cost (inputs, labor, seedlings, seeds, machinery, monitoring, administration, etc.) of integrated systems is higher than the operating costs of only crop or livestock Opportunity cost: the producer does not give up production entirely to protect (the producer can manage the legal reserve with economic activities).
Low	Monitoring cost: mandatory to monitor one carbon pool (soil). Cost of implementation: crop or livestock in single systems present well-known infrastructure, logistics and technical packages, in comparison with integrated systems. They also generate positive economic returns which makes them economically feasible and low-cost to implement. For protection of native vegetation on-farm, there is low need for interventions by the farmer. For avoided conversion off-farm, there is no cost to the farmer. Opportunity cost: the producer does not give up production, for example with productive systems that enhance soil health.

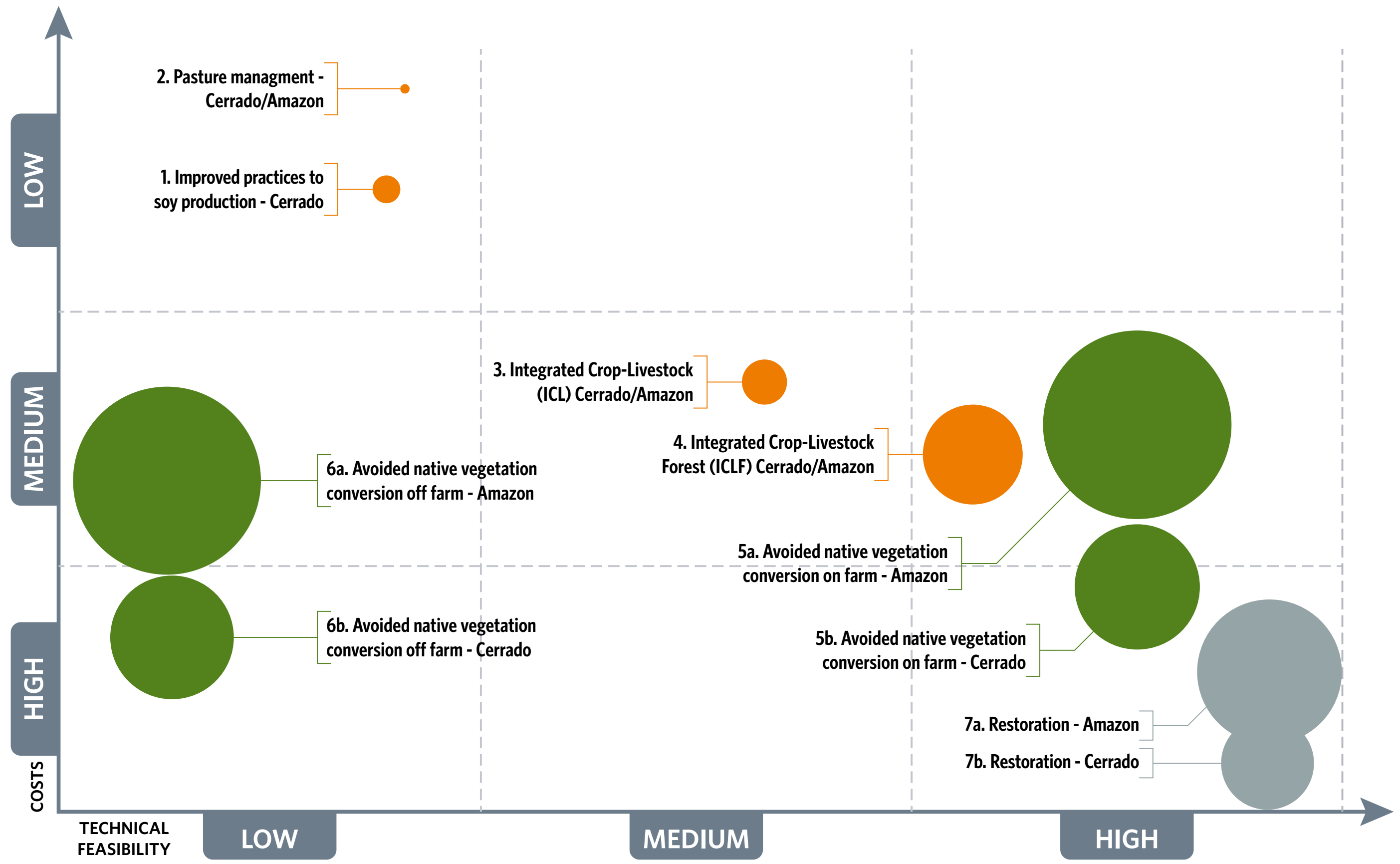
Results of the analysis

Consistent with literature, the pathways with higher potential of carbon mitigation are the avoided conversion and restoration of native vegetation. Avoided conversion emerges as the most cost-effective means to reduce emissions at large scale. The agricultural pathways present a high opportunity for implementation as well, especially considering integrated systems of production.

The bottom x-axis refers to the technical feasibility regarding MRV procedures, permanence, and additionality, and the y-axis, the associated costs. The size of the bubbles represents the magnitude of the carbon storage/sequestration potential*. The colors of the bubbles represent the conservation strategies of each pathway summarized in 3 major groups: regenerative agriculture, avoided native vegetation conversion and restoration.

*Further details are presented in Annex 1.

Figure 4: The analysis is based on qualitative and quantitative information and criteria.



Note that in Figure 4 the magnitude per hectare of avoided off-farm native vegetation conversion is the same as with the on-farm level. In practice, for every hectare of agricultural expansion on pastureland, for example, the avoided off-farm native conversion will only be a fraction of that hectare because some of that hectare would have been planted on pastureland under a business-as usual-scenario. Historical analysis indicates, for example, that approximately 70% of soy expansion in the Cerrado is over pastureland and 30% over native vegetation. Because we do not have reliable estimates of this percentage into the future for cattle in the Amazon and Cerrado or soy in the Cerrado, we included the full carbon value per hectare for the off-farm estimate.

Regenerative agriculture:

Improved practices for soy production in Cerrado (pathway 1), pasture management in Cerrado and Amazon (pathway 2) and ICL both in Cerrado and Amazon (pathway 3) have the least potential for carbon sequestration per hectare and low/medium technical feasibility as a result of the high uncertainties regarding permanence, additionality and MRV procedures. However, these are low-cost pathways so if these barriers can be overcome, they could be highly scalable, given the large amount of degraded land in the Amazon and Cerrado territory.

To make projects with a low amount of carbon per hectare viable, grouped solutions must be considered. In practice, a feasible project, would have to include a variety of solutions, from regenerative agriculture to avoided deforestation on farm and native vegetation reforestation.

In the case of MRV, more specifically for projects with soil carbon monitoring, the gaps are being widely discussed with several actors involved with the theme: private sector, research institutions, representatives of the agricultural sector, technical staff of international registries of carbon projects in the voluntary market, etc. There is a need to find solutions to enable cost-effective soil samples analysis and to reduce technical uncertainties.

The improved practices for soy production and pasture management will be more relevant for carbon projects when the technical feasibility issues are overcome, and carbon offsets can be produced in scale. The main gaps are related to soil carbon monitoring. The permanence of carbon in the soil is still a challenge, due to some soil turning practices largely used by Brazilian farmers, such as the use of harrows. This causes significant soil carbon losses. However, a potential significant impact of these pathways is to reduce pressure on forest conversion to agricultural land, once the increase in productivity and payments for carbon offsets will in theory reduce the need to convert new land.

Both pathways have the advantage of being highly scalable, as it is within the existing farmers knowledge, technical packages available in the market, and great availability of land. In addition, these pathways generate positive economic returns which makes them economically feasible and low-cost to implement.

ICL is a very effective way to sustainably produce food, regenerate land and sequester carbon, while still supplying the market with commodities such as soy and beef. It has an advantage compared to pathways 1 and 2 as it can combine crops and livestock, the main two commodities for agribusiness in Brazil in the same system. In addition, it has higher potential for carbon storage than single crops or livestock systems (but much lower than native vegetation), greater additionality (since it is not yet a common practice in some regions of the country) and well-developed technological packages that allow farmers to transition in larger scale to more regenerative practices, considering that the areas currently with soybean and corn rotation would be more easily available and apt for the transition to a ICL system. Finally, grain producers already have the technological knowledge and machinery for the transition to a ICL system.

ICL is a promising low carbon agriculture solution, as it is potentially scalable to virtually all degraded land in Brazil. It does require knowledge, technology and finance to be scaled, but doesn´t disrupt conventional systems, making it easier for farmers to adopt it.

An opportunity to be further explored is to consider these three pathways under a jurisdictional program, which would leverage the scalability of the program, also including farmers and ranchers that otherwise wouldn't have access to the carbon market, mainly because of the costs and specific requirements of offsetting projects (eligibility, additionality, permanence 30 years). However, the risks must be carefully assessed, because shifting governmental priorities would compromise the continuity of such program and jeopardize the trust and engagement of farmers in carbon markets. This change of route in the creation,

maintenance or contribution of resources to government plans and programs is very common in Brazil due to the alternation of political parties with different ideologies. However, it is urgent that the climate and agriculture agenda be a long-term priority in Brazil.

Pathway 3, integration of crops-livestock-forest ICLF is an agricultural strategy that integrates different production systems, namely agricultural, animal farming and forestry systems, within the same area. It can be performed through intercropping, crop succession or crop rotation, so that all the activities are mutually beneficial. ICLF benefits from having a second carbon pool – forest biomass (in comparison with the other regenerative agriculture pathways). That promotes a higher permanence security, as well as greater mitigation potential. Those aspects increase the possibilities for management opportunities.

Currently most of these systems implemented in Brazil uses an exotic species as the forest component. However, the usage of native species should be equally incentivized as it brings additional conservation benefits for the biome.

ICLF has a significant potential to store carbon and yet provide an agricultural income, which reduces the impact of the opportunity cost. Its technical feasibility regarding MRV, permanence and additionality are high, however, its scale of adoption is low as it is more labor intensive, needs high initial investments and has to be implemented in smaller areas. These systems are complex and, although increasing are still not common practice in Brazil, and they require specialist monitoring and training. It is not yet a traditional practice and demands a significant change for farmers with long term plans and technical assistance that is capable of understanding and promoting the diverse activities needed to implement ICLF.

Regarding the most promising carbon monetization mechanism and payment type, the regenerative agriculture pathways could benefit from the three approaches: offsetting, scope 3 and jurisdictional programs. The pathways that contemplate only soil carbon enhancement (without the native vegetation aspect), such as improved practices for soy production, ICL and pasture management, the scope 3 approach would be best.

The value generation for the Scope 3 programs is clear, as large agricultural companies that have farmers in their supply chain can claim emission reductions when financing a transition to a more sustainable agriculture. Value is generated for both sides, in the case companies use the earnings to provide financial incentives to farmers in exchange for scope 3 benefit to them. Such Scope 3 programs can be scaled once all methodological gaps for soil carbon monitoring are overcome to lead a transition to a more sustainable agriculture.

A hybrid program has a real potential to scale transition once it tackles scope 3 and jurisdictional opportunities. From the agriculture point of view, ILCF is a complex system, difficult to scale and to invest in, thus having carbon as a new revenue stream can be an incentive to these practices adoption.

Avoided native vegetation conversion

Avoided native vegetation conversion off farm is related to the conservation of forests in the Cerrado and Amazon biomes outside of the property. Expansion of agriculture over pastureland, sustainable cattle intensification and other production models that expand production without deforestation or conversion of native vegetation can contribute to avoiding native vegetation conversion by reducing the pressure for expansion over native vegetation. This pathway offers a high per-hectare carbon mitigation that can be realized quickly and at a comparatively low cost per tCO_2e, typically with many co-benefits, such as biodiversity and water conservation.

Change in land use from forest to agricultural land is the main source of emissions in Brazil. Approximately 75% of GHG emissions are related to land use change and agriculture (SEEG, 2022). Preserving forests under a jurisdictional program in large areas of the Amazon and Cerrado would have a great impact regarding carbon emissions avoidance.

Regional differences for Cerrado and Amazon biomes were considered in the analyses due to the different opportunity costs and the potential carbon stock of each biome. Thus, Pathway 6 was divided into Pathway 6a – Amazon and Pathway 6b – Cerrado, so differences between biomes could be highlighted.

Expansion of agriculture over pastureland, sustainable cattle intensification and other production models that expand production without deforestation or conversion of native vegetation can contribute to avoiding native vegetation conversion by reducing the pressure for expansion over native vegetation.

Avoided conversion off farm pathways have both medium carbon storage potential (taking into consideration what is already legally protected by the Forest Code) and high scale adoption. However, they have low technical feasibility and high costs, mainly because the opportunity cost associated. Additionally, there are barriers associated with a jurisdictional program, which involves a fair amount of uncertainty with respect to connecting a monetary benefit with the underlying conservation strategy. It is important to note that the costs are not directly related to the producer. These are costs involved in the governance of jurisdictional programs, and land opportunity costs if off-farm avoided conversion occurs in legally deforested areas.

Currently, there is no available measurement and monetization methodology for off farm avoided native vegetation conversion apart from jurisdictional level. It is important to note that, although there are protocols and guides for jurisdictional programs, there can be a lot of variety among programs, which will not always have consistent procedures for the carbon benefit measurement. Besides, there is high complexity for its implementation, due to the involvement of many different actors.

A jurisdictional approach operates at a scale larger than an individual farm, often implementing regenerative agriculture practices or sustainable intensification on degraded lands across a large, multi-farm area, as a pathway to capture carbon benefits. At a landscape level, the spillover or indirect benefit of reducing pressure to clear new areas - in other words, avoided conversion - can be measured and monetized using the performance indicators of improved practices as a proxy. Quantifying off-farm avoided conversion is highly relevant when it is done in the context of a jurisdictional program across several farms, as opposed to drawing a direct attribution from individual farm interventions and avoided conversion in disassociated frontier areas.

On the other hand, avoided native vegetation conversion on-farm for the Amazon (Pathway 5a) and for Cerrado (Pathway 5b), represents the conservation of all legal reserve surplus in the Amazon and Cerrado and it has the greater opportunity to reduce emissions considering the Brazilian reality.

Brazilian Forest Code Legislation (Lei 12.651/12) determines that just a percentage of a property can be deforested. In the Cerrado and Amazon biomes, properties can be legally deforested to a percentage of 65% and 20% of their areas, respectively. Preserving areas beyond the level that is legally required by the Brazilian Forest Code qualifies for carbon credits related to the "surplus" preserved forest under the voluntary carbon market.

Growers that have a large enough forest area that remain on their properties in excess of the legal requirements might engage in an avoided conversion offset approach. In this case, if they are prepared to permanently conserve them, they could engage in a REDD+ project. These opportunities should be evaluated on a case-by-case basis, and only when the size of the forest in excess of the legal amount would be eligible. If these forests are too small, it could be possible group farmers together to participate as a grouped project to make it cost effective to develop and verify carbon.

Offset methodologies for this kind of projects are well established, although there are still opportunities to streamline the crediting process so producers could largely adopt the pathway. Implementation costs of avoided conversion on-farm is not prohibitive, because the main direct costs are part of the cost of the management of the productive portion of the property, although there are some needed conservation actions in the area of native vegetation, such as fire management. The main challenge is the opportunity cost to the farmer of not clearing the land, although this is somewhat mitigated by 1) the substantial time and cost to obtain permits for legal clearing and 2) the increasing trend in the market not to buy soy and beef associated with deforestation and conversion of natural vegetation. Additional challenges to deploy these pathways are the need of an up-front investment to certify the carbon under a credible standard and to the producers to commit to a 30-years contract (commonly used on the voluntary carbon market).

Avoided conversion offsets, as determined by STBi, shall not be claimed by companies of the agricultural sector for their net zero goals, because it does not encompass a productive area of its value chain. However, avoided conversion pathways do contribute to scope 3 management as they avoid an increase in GHG inventories which would occur if a supplier converts native vegetation.

Furthermore, regarding permanence, with the appropriate credit value, more effective actions to guarantee carbon in the area could be taken. Actions aimed at containing natural risks (mainly burning) and external risks related to issues from different agents, such as land disputes, community engagement during the crediting period and political changes need to be taken. All these measures to ensure the success of the project require financial resources. In addition to the buffer reserve, a portion of the remuneration obtained from the sale of these credits could be used for actions to guarantee the permanence of carbon. Recommendations for this pathway include efforts to reduce project risks of discontinuance, such as rigorous due diligence on land tenure, a clear understating of the local communities and participation

and a fair share of benefits, in addition to other strategies for ensuring permanence, for example the implementation of conservation easements, the institution of private protection reserves and solid agreements with landowners. Moreover, it is sometimes too complicated for a producer to quickly set up a project, get it verified to receive the carbon credits and access the market to sell them – there is a need to establish a grouped project and aggregate farmers with the same interest.

Native vegetation restoration

The environmental benefits of restoring native vegetation, with repercussions in reducing the costs of production systems on the farm, are many. The main benefits are the generation of a favorable microclimate, protection of springs and riverbanks, protection and increase of pollinators, reduction in incidence of pests, increase in the availability of soil water and reduction in soil erosion. The presence of pollinators provides an increase in crop productivity, and they represent a vital ecosystem service for agricultural productivity (Potts et al., 2010).

Restoration projects can be applied in degraded areas that are currently occupied by low-productivity agriculture. Restoration projects in legal reserve areas and permanent preservation are distinct. In legal reserves it is possible to obtain some return through sustainable management of these areas, in addition to the possibility of inserting exotic species. This would result in a lower opportunity cost when added to the gains from management. Although both of these activities are required under Brazilian law, , considering the current enforcement and environmental liabilities in Brazil, these are both considered additional for purposes of carbon methodologies.

If the cost of implementation for restoration (planting trees) was included, then avoiding deforestation (on and off farm) would emerge as the most cost-effective means to reduce emissions at large scale. Natural regeneration as a restoration category could also deliver great impact with lower cost, however mitigation potential is lower compared with planting trees and performance risks must also be considered.

Restoration could be included in a jurisdictional program. Being part of Brazilian NDC would then be an opportunity for such programs to be subsidized and scaled by governmental bodies in a jurisdictional program, allowing farmers to fully comply with Brazilian Forestry regulations contributing at the same time with Brazilian NDC targets. The proposed monetization mechanism could accelerate the restoration of these areas, which, according to the forest code, have a period of up to 20 years to be restored, which is in fact very long in relation to the climate urgency.

Restoration could also be included in scope 3 and offset programs, however it is very unlikely to happen in large scale, as implementation and monitoring costs are high. Being part of Brazilian NDC would then be an opportunity for such programs to be subsidized and scaled by governmental bodies in a jurisdictional program, allowing farmers to fully comply with Brazilian forest regulations contributing at the same time with Brazilian NDC targets.

The restoration of legally protected areas - legal reserve and permanent preservation - may be additional considering the status of the country's environmental liabilities. Also, additionality would be linked to restoration time. The proposed monetization mechanisms could accelerate the restoration of these areas, which, according to the forest code, have a period of up to 20 years to be restored for legal reserves.

In sum, restoration carbon projects have high technical feasibility and opportunities as restoration has a high mitigation potential, high permanence of carbon and is well accepted by the carbon market, and it has several co-benefits for soil, water, biodiversity and communities as already stated. It is also additional and has well established MRV

Restoration projects can be applied in degraded areas that are currently occupied by low-productivity agriculture.

procedures. Its costs, on the other hand, are extremely high due to great effort needed for implementation and monitoring. Another barrier to overcome of this pathway, especially in the Cerrado, is the high opportunity cost of land due to the high financial returns expected from agricultural commodities.

Recommendations

Natural Climate Solutions (NCS) differ in their potential to mitigate climate change, however, protection of existing natural systems such as the Amazon and Cerrado forests is the most effective strategy. Protection-type NCSs also align with global commitments to stop deforestation, limit forest degradation and halt biodiversity loss. Natural ecosystems can store large amounts of carbon, sequester carbon and represent more stable and long-term carbon stores compared with working and restored lands. Avoiding the conversion of mature and young secondary ecosystems prevents carbon from being released into the atmosphere and maintains their ability to keep sequestering carbon" (Cook-Patton, 2021).

In view of all the assessment presented, avoided deforestation (on and off farm) emerges as the most cost-effective means to reduce emissions at large scale. On-farm avoided conversion is eligible to the carbon market approach although there are implementation challenges such as obtaining long-term commitment from farmers not to convert. On the other hand, projections for the value of the carbon credit and the advance of the carbon market are encouraging. This scenario is closely related to one of the main challenges to promote this pathway - the opportunity cost.

Off-farm avoided conversion still faces methodological barriers to be able to be measured and monetized individually for farmers. However, jurisdictional and national programs are suggested means to implementation of this pathway, where carbon benefit is assessed at a landscape scale.

Reforestation pathways present high mitigation potentials and are also contemplated under the offsets schemes, but given the needed up-front investment and long timeframe to grow the biomass it has been slow to gain momentum.

Soil carbon enhancement attributed to agricultural pathways such as integrated systems, pasture recovery for soy and cattle ranching intensification is tangible and present high scalability in both biome Cerrado and Amazon. On the other hand, there are technical issues in the measurement and monetization to make it a viable pathway to be pursued by the farmers.

In light of these observations, we recommend the following efforts to accelerate investment and implementation of sustainable, climate-positive agriculture strategies:

Greater focus should be placed on working with jurisdictional and national climate programs to support and reward agricultural initiatives that encourage avoided conversion of natural vegetation, including regenerative agricultural expansion on pastureland and sustainable cattle intensification. Avoiding conversion at landscape scale is the most important opportunity for Brazil and currently there are no substantial mechanisms to leverage carbon benefits to encourage pasture expansion and yield improvements commensurate with the contribution they make to avoiding conversion. Connecting carbon benefits with these practices can only be done cost-effectively and at scale through a jurisdictional or national program, and it merits deeper discussion as to what mechanisms could be created within initiatives such as PCI in Mato Grosso, Para Agora or national programs.

Greater effort should be invested to create group carbon projects to incentivize farmers not to clear native vegetation beyond the legal requirements. This type of avoided conversion can be measured and monetized through an offset program. This approach has not been implemented extensively and we see significant opportunities to do so. Estimates indicate there are over 1 million hectares of native vegetation in the Cerrado in excess of legal reserve requirements which are suitable for soy production (MapBiomas, 2022).

Companies and farmers can continue to measure and monetize soil carbon benefits, but should consider including in their programs measures to avoid conversion and restore *native vegetation* in order to enhance the carbon impact and the cost-effectiveness of monetizing the benefits. Systems that integrate crops and livestock, and potentially trees, will have greater carbon benefits than crops alone.

Native vegetation restoration should be expanded and to make it more economical, the costs can be supported by integrating restoration into programs with strong underlying economics – such as agriculture expansion on pastureland and sustainable cattle intensification. Restoration is often required for farmers in such programs to comply with the Forest Code.

References

ARANTES et al. Livestock intensification potential in Brazil based on agricultural census and satellite data analysis. Pesq. agropec. bras., Brasília, v.53, n.9, p.1053-1060, Sept. 2018.

ASSAD, E. D. et al. Role of the ABC Plan and Planaveg in the adaptation of crop and cattle farming to climate change. Working Paper. São Paulo, Brazil: WRI Brasil. 2020a. Available online at: https://wribrasil.org.br/pt/publicacoe

BARBOSA, F. A. et. al. Cenários para a pecuária de corte amazônica. Belo Horizonte: IGC/UFMG, 2015. Disponível em: <http://csr.ufmg.br/pecuaria/pdf/contexto.pdf>.

BRASIL. Quarta comunicação nacional e relatórios de atualização bienal do brasil à convenção-quadro das nações unidas sobre mudança do clima. Quarto inventário nacional de emissões e remoções antrópicas de gases de efeito estufa. Ministério da Ciência, Tecnologia e Inovação – MCTI. 2020. 513p. Available at: https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/sirene/publicacoes/comunicacoes-nacionais-do-brasil-a-unfccc

BRITO, B., ALMEIDA, J., GOMES, P., & SALOMÃO, R. 2021. 10 Essential Facts About Land Tenure Regularization in the Brazilian Amazon (p. 104). Belém: Imazon.

CANAL RURAL, Grupo propõe dobrar área com ILPF no Brasil até 2030. 2021. Available at: https://www.canalrural.com.br/noticias/agricultura/area-ilpf-brasil-2030/#:~:text=Sa%C3%ADmos%20de%20menos%20de%202,%2C4%20milh%C3%B5es%20de%20hectares.%E2%80%9D

COOK-PATTON, S.C. et al. Protect, manage and then restore lands for climate mitigation. Nature Climate Change. Vol 11. Pag 1027-1034. (2021). Available at: https://doi.org/10.1038/s41558-021-01198-0

EMBRAPA, EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. Integrated-Crop-Livestock-Forestry Systems. 2022. Available at: https://www.embrapa.br/en/tema-integracao-lavoura-pecuaria-floresta-ilpf/nota-tecnica

FAO, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. Sete Lagoas consensus. In: FAO. An international consultation on integrated crop-livestock systems for development, Rome: FAO, 2010. p. 1-3.

FGV. Fundação Getulio Vargas. Mercado de carbono voluntário no Brasil: Na realidade e na prática. Observatório da Bioeconômia. 2022. 17p.

GOLD STANDARD. Value Chain Interventions: Guidance for Soil Organic Carbon. 2018. Available at: https://www.goldstandard.org/sites/default/files/documents/2018_10_value_chain_interventions_soc_guidelines_draft.pdf

GREENHOUSE GAS PROTOCOL. GHG Protocol Agricultural Guidance. 2014. Available at: https://ghgprotocol.org/agriculture-guidance

GRISCOM, B.W. et al. Natural Climate Solution. 2017 Available at: Natural climate solutions (pnas.org)

GU, N.; INKOTTE, J. Emissões dos GEE's na intensificação da bovinocultura de corte para o estado do Mato Grosso alcançar as metas da PCI 2030. International Innovation Corps. 2016.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. 2019. Available at: https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC). Guidelines for National Greenhouse Gas Inventories. 2006. Available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/

INTERNATIONAL PLATFORM FOR INSETTING (IPI). A Practical Guide for Insetting. 2022. Available at: https://www.insettingplatform.com/insetting-guide/

KRUID *ET AL.* Beyond Deforestation: Carbon Emissions from Land Grabbing and Forest Degradation in the Brazilian Amazon. Frontiers in Forests and Global Change, July 2021, v.4, 10p.

LAPIG, *Dados Mapeamento da Qualidade de Pastagem Brasileira entre 2000 e 2020*. Qualidade de Pastagem (ufg.br). Acesso em julho, 2022, 2022.

LARSON, A.M. Land tenure and REDD+: The good, the bad and the ugly. Global Environmental Change. June 2013, v. 23, issue 3, p. 678-689.

LATAWIEC et al. Animal (2014), 8:8, pp 1255–1263. The Animal Consortium, 2014, doi:10.1017/S1751731114001566.

LIMA, et al. Dados de fatores de emissão de metano proveniente da fermentação entérica de gado de corte e de leite no Brasil. MAPA, 2020.

MAIA, S. M. F. et al. Contrasting approaches for estimating soil carbon changes in Amazon and Cerrado biomes. Soil and Tillage Research, v. 133, p. 75–84, 2013. Available at: https://www.sciencedirect.com/science/article/pii/S0167198713001037

MARTINS, A.L. et al. Soil Management Qualification Under No-till System in Center-Souther Brazil. World Congress of Conservation Agriculture (2017). Available at: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/167747/1/2017-063.pdf

MARTINS, S.C. et al. Inverting the carbon footprint in Brazilian agriculture: an estimate of the effects of the ABC plan. Revista Ciência, Tecnologia e Ambiente. Vol. 7, No. 1, 43-52 (2018). Available at: https://www.embrapa.br/busca-de-publicacoes/-/publicacao/1100241/inverting-the-carbon-footprint-in-brazilian-agriculture-an-estimate-of-the-effects-of-the-abc-plan

METZGER, J.P. *et al.* Por que o Brasil precisa de suas Reservas Legais. Perspectives in ecology and conservation, 2019, v. 7, pp. 104-116.

MINISTÉRIO DE MEIO AMBIENTE. The Implementation of the Warsaw Framework for REDD+ by Brazil. Nov. 2015, 215p. Available at: http://redd.mma.gov.br/images/publicacoes/wfr-brazil-2015.pdf

MORAES, A. et al. Integrated crop-livestock systems in the Brazilian subtropics. Eur. J. Agron. 2013 (IN PRESS), http://dx.doi.org/10.1016/j.eja.2013.10.004.

POLIDORO, ET AL. The impact of plans, policies, practices and technologies based on the principles of conservation agriculture in the control of soil erosion in Brazil. Authorea. April 21, 2020.

PINSKY, V.C.; KRUGLIANSKAS, I. Governing REDD+: A State-of-the-Art Review. Rev. Adm. UFSM, Santa Maria, v. 12, n.1, p. 182-197, 2019.

PORFIRIO-DA-SILVA, V.; MEDRADO, M. J. S.; NICODEMO, M. L. F.; DERETI, R. M. Arborização de pastagens com espécies florestais madeireiras: implantação e manejo. Colombo: Embrapa Florestas, 2009. 49p.

QUANTIS (2019). Quantis (2019). Accounting for Natural Climate Solutions: Guidance for Measuring GHG Emissions from Land, Forests, and Soils across the Supply Chain. Available at: https://quantis-intl.com/report/accounting-for-natural-climate-solutions-guidance/

REDE ILPF. Componente Florestal na iLPF - espaçamento entre renques, número de linhas e alinhamento. 2013.

SALTON, J. C.; HERNANI, L.; FONTES, C. Z. Sistema plantio direto: o produtor pergunta, a Embrapa responde. Brasília: Embrapa-SPI; Embrapa-CPAO, 1998. 248p.

SCIENCE BASED TARGETS INITIATIVE. Forest, Land and Agriculture Science Based Target Setting Guidance (Draft). 2022. Available at: https://sciencebasedtargets.org/resources/files/FLAG-Guidance-Public-Consultation.pdf

SEEG. Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa. 2022. Available at: https://plataforma.seeg.eco.br/total_emission

SMITH, P. How long before a change in soil organic carbon can be detected? Global Change Biology. v. 10, p. 1878-1883, 2004.

SPAROVEK, G. et al. A revisão do Código Florestal Brasileiro. Novos Estudos – CEBRAP. 2011. Available at: https://www.researchgate.net/publication/262448789_A_revisao_do_Codigo_Florestal_brasileiro

WIESMEIER, M., MAYER, S., PAUL, C., HELMING, K., DON, A., FRANKO, U., STEFFENS, M., KÖGEL-KNABNER, I. CO2 certificates for carbon sequestration in soils: methods, management practices and limitations. BonaRes Series. Germany. 2020. DOI: 10.20387/BonaRes-NE0G-CE98.

World Bank. 2022. State and Trends of Carbon Pricing 2022. State and Trends of Carbon Pricing; Washington, DC: World Bank. World Bank. https://openknowledge.worldbank.org/handle/10986/37455 License: CC BY 3.0 IGO.

WRI Brasil. Greenhouse gas protocol calculation tool for forestry in Brazil. Technical note | Janeiro de 2020. 32p. Available at: https://wribrasil.org.br/sites/default/files/ghg_protocolo-florestas-technicalnote.pdf

Annex

Carbon mitigation potential estimates

Carbon estimates that subsidized this report correspond to cumulative values of the first 10 years of implementation of each pathway. For soil saturation, a period of the 20 years was considered and for carbon projects it was considered 30 years.

Table A: Carbon mitigation estimates adopted by the report	
Pathway	**Magnitude C pool (tCO2e/ha/10yr)**
1 - Improved practices for soy production - Cerrado	3.82
2 - Pasture management - Cerrado / Amazon	0.68
3 - ICL Integration Crop-livestock - Cerrado / Amazon	25.2
4 - ICLF Integration Crop-livestock-forest - Cerrado / Amazon	108.5
5a - Avoided native vegetation conversion on farm - Amazon	496.59
5b - Avoided native vegetation conversion on farm - Cerrado	185.17
6a - Avoided native vegetation conversion off farm - Amazon	496.59
6b - Avoided native vegetation conversion off farm - Cerrado	185.17
7a - Restoration - Amazon	256
7b - Restoration - Cerrado	129.5

The following assumptions were considered for each of the pathways:
1. Improved practices for soy production

» The baseline scenario considered is degraded pasture and the regenerative system is no-till (NT). In NT system, the decomposed straw from the previous harvests is converted into natural fertilizer for the soil. Its advantages are soil carbon stock increase, a reduction in the use of chemical inputs and control of erosion, since the permanent coverage of the soil slows runoff (Salton et al., 1998).

2. Pasture management

» The emission of 1 head/ha was considered at baseline scenario (degraded land carrying capacity), transitioning to 2 heads/ha in the respective pathway scenario of sustainable intensification (Barbosa, et al., 2015; Arantes, et al., 2018; Gu; Inkotte, 2016)
Emissions from enteric fermentation and waste management were considered.

3. ICL

» An increase in carrying capacity was considered, going from 1 head/ha in degraded pastures to 2 heads/ha in the integration systems (Barbosa, et al., 2015; Arantes, et al., 2018; Gu; Inkotte, 2016).
» Emissions from enteric fermentation and waste management were considered.

4. ICLF

- Calculations of carbon removal potential in the biomass (tCO_2e/tree/year) of eucalyptus with a planting arrangement of 14 x 3 meters was considered, totaling 357 trees per hectare (Porfirio-da-Silva, et al. 2009; Rede ILPF, 2013).
- The emission of 3 head/ha was considered
- An increase in carrying capacity was considered, going from 1 head/ha in degraded pastures to 4 heads/ha in CLFI systems (Barbosa, et al., 2015; Arantes, et al., 2018; Gu; Inkotte, 2016).
- Emissions from enteric fermentation and waste management were considered.

5. Avoided native vegetation conversion on farm

- For generic values, the aboveground biomass (AGB) and belowground biomass (BGB) stocks resulted from an average of the most relevant vegetation types for each biome, according to the estimates presented on the 4th Brazil Communication to UNFCCC (2020). Only vegetation types classified with a "F", from forest, were included at the average value composition.

6. Avoided native vegetation conversion off farm

- For generic values, the above ground biomass and below ground biomass stocks resulted from an average of the most relevant vegetation types for each biome, according to the number presented on the 4th Brazil Communication to UNFCCC (2020). Only vegetation types classified with a "F", from forest, were included at the average value composition.
- The magnitude per hectare of avoided off-farm native vegetation conversion is the same as with the on-farm level. In practice, for every hectare of agricultural expansion on pastureland, for example, the avoided off-farm native conversion will only be a fraction of that hectare because some of that hectare would have been planted on pastureland under a business-as usual-scenario. Historical analysis indicates, for example, that approximately 70% of soy expansion in the Cerrado is over pastureland and 30% over native vegetation. Because we do not have reliable estimates of this percentage into the future for cattle in the Amazon and Cerrado or soy in the Cerrado, we included the full carbon value per hectare for the off-farm estimate.

7. Restoration

- The carbon removal potential in the biomass (tCO_2e/tree/year) was determined considering an average value of annual wood increase (m^3/tree/year) and wood density (g/cm^3) of about 250 native species with different growth rates (fast, moderate and slow) and sizes (high, medium and low) (WRI, 2020). This assumption was applied to Pathways 7a (with 2000 trees/ha - Amazon) and 7b (with 1000 trees/ha - Cerrado), considering an average estimate of trees/ha through different restoration techniques aiming at planting success (TNC, 2015; IPAM, 2011; Almeida 2016).
- For the GHG balances of the pathway, monitoring of the restored area was considered for 5 years after planting the seedlings. This is a safe monitoring period to ensure a good survival rate of the planted seedlings. According to TNC (2015), it is recommended that up to 30 months after planting or until the soil is completely covered by the shade of the tree canopy, maintenance should be carried out in the recovery areas. Therefore, in the present study, nitrogen and limestone applications were considered, as well as the use of fuel for such operations.

Furthermore, the following emission factor were used to the estimates:

Table B - Agricultural inputs

Agricultural inputs	Consumption Rate	Unity	Reference
Diesel	2.32	l/ha	Based on the experience of Radicle's
Ureia	0.01	ton/ha	
Limestone (dolimitic)	1		

Table 4 - Emission and Removal Sources, and respective factors

Source	Description	Emission or removal factors*	Unity	Reference
Soil	Degraded pasture to no-till	-0.7	tCO2e/ha/yr	Maia et al. (2013)
Soil	Degraded pasture to ICL	-6.23	tCO2e/ha/yr	Martins et al, 2018; Assad; Martins, 2015; GHG Protocol Agriculture
Soil	Degraded pasture to ICLF	-6.23	tCO2e/ha/yr	Martins et al, 2018; Assad; Martins, 2015; GHG Protocol Agriculture
Soil	Degraded pasture to recovered pasture	-1.78	tCO2e/ha/yr	IPCC (2019)
Biomass	Carbon removal due to tree growth.	-10.2	tCO2e/ha/yr	Assad et al. (2020b); GHG Protocol Forest
Biomass	Avoided native vegetation off farm - Amazon	496.6	tCO2e/ha	Data from the 4 Communication corresponding to forest phytophysiognomies that represent 80% of the area of the biome were used, which eliminates the phytophysiognomies that could bias the average.
Biomass	Avoided native vegetation off farm - Cerrado	185.2	tCO2e/ha	
Biomass	Carbon removal due to tree growth	Amazon: -26 Cerrado: -13	tCO2e/ha/yr	WRI (2020)
Fuel	Diesel	0.0026	tCO2e/liter	IPCC (2006)
Agricultural Inputs	Ureia	0.0031	tCO2e/t	Brasil, (2020); IPCC (1996, 2006)
	Limestone (dolimitic)	0.0005		
	Volatilization and atmospheric deposition	0.0100	kg N2O-N/kg N	
	Leaching / surface runoff	0.0075		
Agricultural waste	Soy	0.000244	kgN2O/kg	
Cattle	Enteric fermentation and waste management	1.65	tCO2e/head/yr	Brasil, (2020)

* Negative sign represents carbon removal and positive sign represents GHG emission.


The Nature Conservancy
Brasil