Received: 22 March 2023 | Revised: 26 April 2023 | Accepted: 27 April 2023 | Published online: 4 May 2023

RESEARCH ARTICLE

Green and Low-Carbon Economy
2023, Vol. 1(3) 130–137
DOI: 10.47852/bonviewGLCE3202887

BON VIEW PUBLISHING

Carbon Farming: Nature-Based Solutions in Brazil

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Abstract: Agriculture can breach the emission gap between countries' and companies' declared goals and actual achievements related to carbon neutrality. But to do so, techniques must change from the monocultural to more integrated systems that provide many eco-services, among which carbon sequestration. The Research Centre for Greenhouse Gas Innovation, which was created in 2016, in its last renewal in 2021, established the first nationwide nature-based solutions empirical data collection from the seven Brazilian biomes, on forestry, pasture, and agriculture, more specifically researching the role of agriculture for carbon sequestration and the possibilities to implement low emissions pastures. Some of the experts that take part in this center were the source of the information this paper brings, and that is the result of action research techniques, combined with content analyses assisted by Atlas TI. The main conclusions of this paper are:(a) that soil health increases the capacity to sequester carbon inside the soil at the same time that it also promotes socioeconomic development because of more productivity in the long term and also by bringing extra economic value derived from the better quality sustainability can provide; (b) the transition needed away from low-productivity pastures and in direction to carbon farming regenerative projects can contribute to meeting the emission goals; (c) there is the risk of carbon pricing increase the value of land, cause social exclusion, or influence production decisions away from food; therefore regulation, will need to play an important role; and (d) Brazil has an opportunity to promote circular sustainable bioeconomy and doing so to assume its position as an agri-environmental power.

Keywords: carbon farming, soil health, carbon sink, nature-based solutions, Brazil

Here are some highlights of the paper. The necessary transition from low-productivity pastures to more sustainable practices and even carbon farming regenerative projects can contribute to meeting the emission goals. Enhanced soil health can increase the capacity to sequester carbon, promote socioeconomic development in terms of more productivity in the long term, and also create extra economic value derived from the better quality sustainability can provide. There is the risk of carbon pricing increasing the value of land, social exclusion, or influencing production decisions away from food; therefore, regulation will need to play an important role. Brazil has an opportunity to promote a circular sustainable bioeconomy and become an agri-environmental power

1. Introduction

Agriculture plays an essential role in the fight against climate change. The way agriculture, pasture, and forestry have been practiced is not sustainable and will not support the steadily growing demand for bio inputs, food, feed, fiber, and energy in the future (United Nations Environment Programme, 2022). A considerable amount of 22% (Intergovernmental Panel on Climate Change, 2022) of the global greenhouse gases (GHG) emissions is because of Agriculture, Forestry and Other Land Use (AFOLU) which includes Land Use, Land Use Change and Forestry (LULUCF). In Brazil, monoculture, highly irrigated, and chemically kept practices have caused soil degradation, reduced the area with natural cover, and increased many GHG emissions (73% of CO_2 emission and more than 80% of N2O and CH4) (SEEG, 2022a). More than 600 million tons of Brazilian GHG are from enteric fermentation, rice cultivation, animal waste management, burning of agricultural waste, inappropriately managed soils and, over 92 million tons, from land use change and carbon losses in the soil (SEEG, 2022a).

In the Paris Agreement, countries signed themselves to ensure global warming keeps at levels well below 2°C by 2050 (United Nations, 2015). Brazil assumed the commitment in its Nationally Determined Contributions (NDCs) to reduce its GHG emissions in 2025 by 37% and in 2030 by 50%, compared with 2005 (United Nations Framework Convention on Climate Change, 2022). Due to the high AFOLU percentage in Brazilian emissions, as mentioned above, reductions in agriculture are essential to contribute to the achievement of the Brazilian NDCs. Besides that, the tropical weather and the geographic characteristics of the country enable many sustainable agricultural practices, bio inputs, and biocontrol techniques that can be deployed on a much grander scale than there is nowadays.

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Therefore, Brazil is in one of the best conditions to reverse the numbers, curtail its emissions to net zero, or even become a carbon sink regardless of the high and expensive technologies needed elsewhere. For example, Brazil is the fifth methane emitter but can reduce this rate by 36% in 2030 from 2020 by expanding existing best practices in agriculture, the energy sector, sanitation, and controlling deforestation (SEEG, 2022b). The Emission Gap Report estimates that roughly one-third of all technical methane mitigation options pay for themselves (United Nations Environment Programme, 2022). Also, the Intergovernmental Panel on Climate Change report on AFOLU shows that among all bioenergy production crops, Brazilian sugarcane is by far the smaller emitter globally (Intergovernmental Panel on Climate Change, 2022). Integrated agricultural systems (IASs), no-tillage, and degraded pasture restoration are supported by public policies and receive incentives, for example, from the National Plan for Low Carbon Emission in Agriculture (ABC Plan) (Ministry of Agriculture, Livestock and Food Supply, 2021).

Important to highlight that soil GHG emissions play a crucial role in mitigating global climate change (Intergovernmental Panel on Climate Change, 2022). According to Bossio et al. (2020), global soil carbon sequestration can reach 24 Gt CO_2eq yr^{-1}, which represents 25% of the potential of natural climate solutions and comprises 47% for agriculture and grasslands. The intensification of monocropping, when poorly managed, has caused severe soil degradation problems, and with that, significant soil organic carbon (SOC) losses to the atmosphere. On the other hand, projects restoring such degraded areas can become an effective and inexpensive way to sequester carbon from the atmosphere and create carbon credit (Oldfield et al., 2022). If integrated with sustainable pasture and agriculture techniques, they become a resourceful nature-based solution (NBS) to fight climate change.

Bearing this in mind, a group of experts in Brazil combined efforts to increase the scientific measurements necessary to estimate the contributions of IASs, the ones practicing at the same time agriculture, pasture, and forestry, therefore increasing soil health, reducing GHG emissions, and increasing SOC. This will help Brazil fulfill its NDCs in the Paris Agreement and provide scientific empirical data on each Brazilian biome. Therefore, from the end of 2021, for 5 years, this broad group of researchers will maintain: "i) constant measurements regarding the changes in the stock of SOC achieved from the adoption of integrated agricultural systems (for example, system of rotation of crops; agroforestry system; crop-livestock system; forest system); ii) empirical studies on the mechanisms of storage and stabilization of the carbon that remains in the soils, fractioning methods and techniques based on synchrotron will be used; iii) quantifications regarding emissions soil and rangeland GHG emissions (being CO_2, N2O and CH4) in order to achieve data refinement to detail national GHG inventories; iv) examination of soil biota interactions to increase soil carbon stabilization and decrease soil carbon GHG emissions in integrated agricultural systems v) application of modeling tools that assess the impacts of LULUCF scenarios and the possibilities of achieving NDCs with increased carbon sequestration in integrated agricultural systems in Brazil; vi) evaluation of the impacts of adopting integrated agricultural systems in the provision of several ecosystem services in Brazil; vii) systemic information about land management decisions and public policies to support effective NBS to mitigate climate change and in order to promote sustainable human well-being (Research Centre for Greenhouse Gas Innovation, 2021)".

The data collected in this paper's participatory research are from these experts and thus provide a Brazilian-oriented view of the role of agriculture in carbon neutrality. The research gaps in the topic of carbon farming are still very broad. Our research will tackle many aspects from the lack of empirical data to the gathering of systemic information about policies and practices. Notwithstanding, it will not intend to be conclusive, more literature review, soil and biomass collection, and emissions tracking will be developed by the research group until at least 2026.

Our study is focused on the Brazilian context, but our findings and multistakeholder approach, with data being collected by different groups of researchers, very distant from each other, but using the same methodology, are part of an initiative from Inter-American Institute for Cooperation on Agriculture, so it possibly could be adopted in other regions or countries. Apart from this introduction, the text has four parts: materials and methods, results, discussion, and conclusion.

2. Research Methodology

This research is part of a longer process tracing (Bennett & Checkel, 2014) being conducted with the NBS projects involving forestry, pasture, and agriculture, and more specifically, Project 53 (Agriculture for Carbon) and 54 (Low Emissions Pasture). These NBS branches were created in 2021 as new sections of the research center for advanced studies on energy transition for the sustainable use of natural gas, biogas, hydrogen and management, transport, storage and usage of CO_2, and the Research Centre for Greenhouse Gas Innovation (RCGI), which was created in 2016 (Research Centre for Greenhouse Gas Innovation, 2016). They will be collectively referred to herein as NBS RCGI Projects.

The data used in the analyses were collected with the techniques of action research (Thiollent, 2018) implemented during a 2-day event (17 and 18/8/22). It gathered knowledge from several experts from different regions of Brazil around the following questions: What is the role of agricultural systems in carbon neutrality? How can and have the NBS RCGI Projects contributed to achieving it? Considering ensuring scalability and viability for carbon programs in Brazil, what are the current methodological difficulties in soil collection and carbon analysis? And what are the (technological) alternatives to overcome them? What are the challenges of agriculture and pasture in generating economic value by reducing emissions from agriculture and livestock and with carbon sequestration?

During these days, the participants were involved in some focal point activities, interviews, and general meetings, all held under the Chatham House Rule (Chatham House, 2019). Therefore, participants shared their perspectives and understandings, expecting the disclosure and use only of the information received, but neither the identity nor the affiliation of the speakers nor that of any other participant directly. For this reason, the following topic does not bring the citations of the participants that contributed to the ideas gathered in Section 3.

Then, the qualitative data that the techniques enabled to bring together on the topic of the role of agriculture in carbon neutrality were analyzed with the help of the software Atlas TI to perform content analyses and visualizations. These data are described in Section 3 further ahead. Section 4 describes some quantitative data that have been collected with other types of methodologies under the scope of the broader research plan in which this paper is inserted.

3. Results

According to the participants, the first role of agricultural systems in achieving carbon neutrality is to avoid deforestation.

This is because agriculture and pasture put pressure on new areas. Another point is who will extract this carbon, in Brazil normally are the illegal loggers. But crime avoidance cannot be the only goal. Agriculture has much more to offer by being more circular and sustainable. Land use and land use change emissions reduction depend on the agricultural phase of the production chains to reach neutrality. Production can shift to more sustainable techniques that increase soil and aerial biomass carbon, use fewer chemicals, and promote the increase of quality and intensity in the production capabilities.

Another important NBS GHG topic is emissions or sequestration into aerial biomass because of the use given to the crop matters. For example, what is the end of that carbon in the eucalyptus trees? It cannot have the same impact if it is used to produce paper, is burned in fossil fuel substitution, or is highly engineered to become cellulosic ethanol that will be three times more potent to substitute the same fossil fuel. When you do these balances of greenhouse gases in the integrated systems, the amount of CO_2 that that eucalyptus extracts in 7 years is enormous, much greater than the entire emission of the agricultural phase for you to produce all that there. So theoretically, your production system is even negative.

The IAS has to be designed to offer more products, with less waste, at lower costs, because integrating agricultural systems the production is not only from crops, or pasture or forest based products but from all of them, and the residues of one production can be used as imputs to the other, saving the costs of chemical fertilizers for example. Not only planned to be exclusively food production, energy, or fiber, but all the alternatives synergically. The side products from integrated systems and the more sustainable techniques of production can support claims of additionality that eventually could be used in the carbon market. Adapting to climate change and developing resilient agricultural systems to these new conditions will demand lots of research and technology. And all this converges in what is the concept of soil conservation; if you conserve soils, you will achieve many goals and ecological services through the healthy integration of systems.

The NBS RCGI Projects (Forestry, Pasture and Agriculture for Carbon), because it is a Brazilian multi institutions project they contribute to building a structure, promoting capacity building, training human resources, anddeveloping analysis and methodologies adapted to tropical conditions. It is the first to identify the biophysical potential for carbon accumulation and the feasibility of adopting technologies at a country-base scale with different biomes and large areas.

One of the main contributions of the NBS RCGI Projects is to create an empirical data portrait of the carbon in the soil, pasture, agriculture, and forest in Brazil, how these systems can contribute to identifying gaps and publicizing the regional potential of each region and biome. The project will create the path, guide producers, train professionals, and incite change. Its researchers are among people of global excellence who will contribute to the training of professionals to base various sectors of societies' decisions and provide technical and scientific grounds to build policies.

One of the main problems of NBS is scalability. And the viability of carbon programs in Brazil, due to the country's vast proportions, highly depends on the ability to implement those solutions broadly. The methodologies used for soil collection and carbon analysis need to improve to achieve this goal. The traditional soil sampling technique is costly and time-consuming. Carbon content estimates and soil density should be used to validate other techniques based on remote sensing, spectroscopy, or other simplified methods. This can make the scale feasible both over space and over time. The basic technique has to be used as a baseline, to support and validate the other techniques. There has to be a balance between a more academic methodology that consumes time, is costly, and has great accuracy and other initiatives that have more scalability despite the accuracy. This balance is paramount in the current environment of uncertainties and heterogeneity.

Considering the economic nudges to foster sustainable agriculture, there is another hard-to-get balance. On one hand, the low price of carbon credit makes some adaptations unfeasible. On the other hand, if the price is too high, it can lead production away of food and fibers and favors leaving native vegetation instead of cultivating the soil.

Another point is that life cycle analyses and carbon inventory are very expensive. Some practices should be automatically considered more sustainable, as with sugarcane ethanol replacing gasoline. It is already broadly understood to result in a reduction. Thus, when integrated into these complex agricultural systems, livestock could be a functional unit producing food, energy, bioenergy, and fiber.

A long life pool or even an effective abatement that can be measured from a comparison with fossil fuel emissions could simplify estimates. The same logic could be applicable to the intensification methods of production. Suppose the farmer intensifies production in terms of area. In that case, it facilitates carbon accumulation in the soil and in biomass, better maintains the animals, and reduces emissions because this compact production creates more nitrogen, nutrient cycling, and feces.

One driver to intensification could be the increase in the value of land, which in Brazil is historically very cheap. Unfortunately, this measure would have the drawback of encouraging land grabbers or worsening the social disparities and exclusions, especially for small producers. Even if the value of land is not artificially increased by public policies, as the NBS system progresses, the land will appreciate in value, so intensification may be more and more present. And the notion of carbon absorption in the soil can increase the value of healthy soil areas even more.

Another market regulation alternative could be establishing lines of credit conditioned to intensification. The interest rate would be inversely proportional to the land use factor, privileging producers that are able to produce more, in the smallest functional unit, which would be one hectare. Everything related to reducing emissions is related to the pressure of agriculture for natural areas and when you produce more with less land, you have less pressure for deforestation, and it also helps with other resources balance.

Each biome has a carbon sequestration gap that it can cover. But that depends a lot on the price of the carbon credit, if it goes up to 100 dollars a ton it is expected land appreciation and also social exclusion. And the other problem of start to produce only to sequester carbon and no longer produce food. That is a reason to justify that the price of carbon cannot go up much. This problem happens to electricity if the price is high; the producer closes the factory and sells the energy that was contracted.

From all the contributions from the participants, the most relevant words mentioned were in this order: soil, deforestation, biomass, and methodologies.

Different groups with participants from different regions and different universities emphasize most of the same problems and indicate similar solutions pointing to the formation of a developing scientific consensus. Carbon is only the center of a broader gearing mechanism of co-benefits such as more and better water, biodiversity, and productivity of the soil. The creation of labels, indexes, or ratings states that these variabilities and co-benefits will support the transition to more sustainable techniques; they can facilitate the measurement of the qualities and therefore the design of mechanisms to incentivize the realization that sustainability can be, and many cases already is, a win-win situation, bringing more economic value, and productivity with better social and environmental externalities.

4. Discussions

Sustainable management practices include IAS, no-till, cover cropping, complex crop rotations, and organic amendments, among others (Amelung et al., 2020; de Oliveira et al., 2022; Koch et al., 2013). The topic of IAS often emerged during participatory research activities as the most evident sustainable strategy to enhance sustainability and land productivity. The main context intowhich the participants mentioned the importance of IAS was, because they can combine annual crops, with livestock and/or forestry, using the same area under different spatiotemporal productive arrangements. This by itself increases soil quality and crop productivity. In addition, it promotes other ecosystem services, such as water preservation, improves the quality of animal life, maintains the natural landscape, conserves biodiversity, promotes soil quality, and increases biological nutrients which reduce the need for chemical additives and promote natural barriers to the spread of pests, thus reducing the need for defensives, all this along with several other socioeconomic benefits. And, on top of all these benefits, IASs stand out as one of the most promising nature-based solutions to increase carbon sequestration, both in the soil and in the biosphere.

In other words, IASs can be used for carbon cultivation while providing essential products for people (e.g., crops, meat, fibers, bioenergy) all while generating income for rural producers and also for the agro-industrial systems. Therefore, the IAS can be a powerful NBS not only for climate change but also for dealing with food insecurity and the necessary energy transition away from dependence on hydrocarbons. In Brazil, it is estimated that 17.43 million hectares have been cultivated with some type of IAS (Polidoro et al., 2021; rede ILPF, 2022).

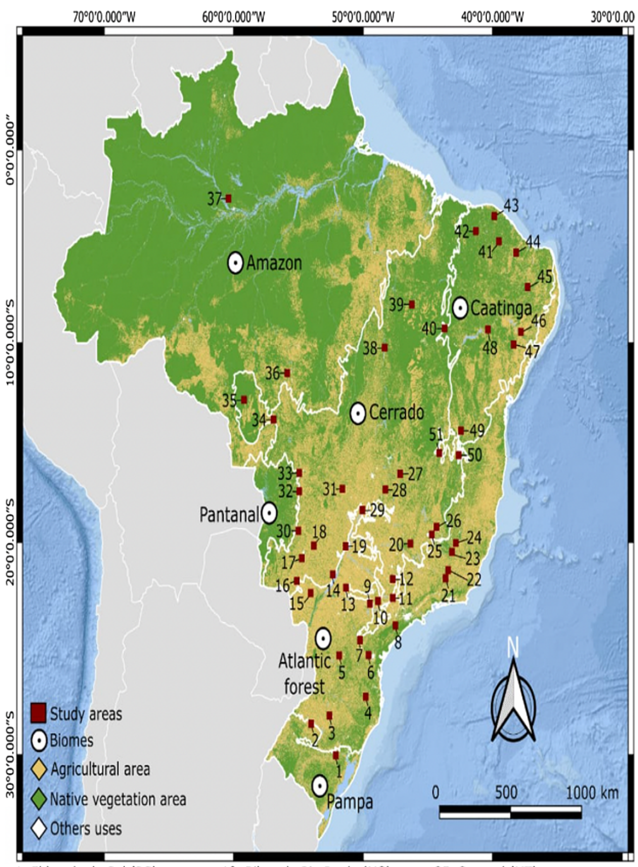
The Brazilian NDCs recognize the potential of IASs as a way to sink carbon from the atmosphere and thus mitigate global warming with a commitment to increase 5 million hectares of IASs by 2030. In this context, one of the main objectives of the NBS RCGI Projects is exactly to provide accurate measurements of the potential for carbon sequestration of IASs conducted under contrasting conditions of climate, soil, and management practices, all factors that vary a lot in Brazil. To achieve these objectives, the NBS RCGI Projects constantly review, synthesize, and revisit data available in the literature related to NBS and the main topics of the project, continuously identifying research gaps and creating a dataset for parameterization, also promoting validation of modeling and scenarios analysis.

As a consequence, NBS RCGI Projects are collecting a lot of empirical data on-site to measure soil carbon stocks, carbon stabilization mechanisms, GHG emissions from pasture, and soil carbon inputs through aboveground and belowground biomass from different species (annual crops, grasses, and trees); many biological interactions seem to impact on the carbon storage and GHG emissions, and carbon balances in IASs.

These nationwide measurements have been performed using different types of methodological approaches and spatiotemporal scales, for example, intensive field measurements at paired sites (chronosequences), long-term experiments, and specific tests conducted in the laboratory and greenhouse assessments under controlled conditions. The NBS RCGI Projects are also starting to apply modern tools to model the dynamics of GHG emissions, studying the climate change and management scenarios, and evaluating ecosystem services tradeoffs and synergies that can be associated with the adoption of IASs in Brazil. These activities will be instrumental in integrating the collected data, amplifying long-term predictions of IAS adoption in carbon sequestration, assessing the effectiveness of IAS in complying with the NDC and mitigating global warming, and investigating the effects of IAS on the benefits humans derive from ecosystems.

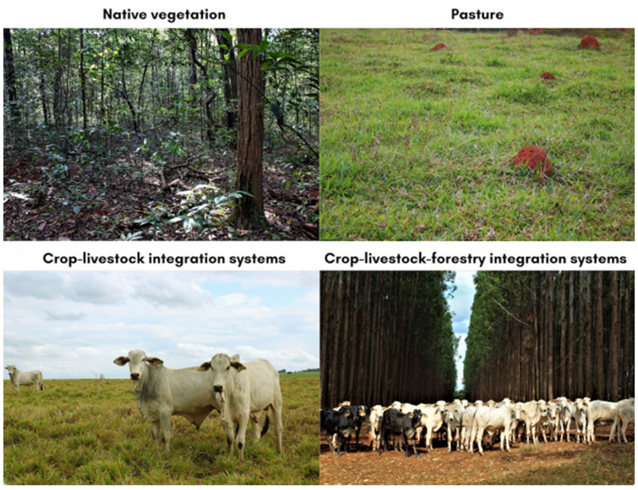
Empirical research to scientifically estimate the carbon farming potential of soil, agriculture, pasture, and forestry in Brazil is not a simple task. The NBS RCGI Projects, whose experts were the object of the participatory research described in this paper, are facing this challenge. Data are being collected from the entire Brazilian territory (over 8.5 million km^2), three climates: equatorial, tropical, and subtropical, humidity differences (rainfall levels range from 500

Figure 1
Areas where the NBS RCGI Projects are collecting data (soil, plant, and/or gasses)



1. Eldorado do Sul (RS)
2. Cruz Alta (RS)
3. Passo Fundo (RS)
4. Ituporanga (SC)
5. Guarapuava (PR)
6. Curitiba (PR)
7. Castro (PR)
8. São Paulo (SP)
9. Iaras (SP)
10. Botucatu (SP)
11. Nova Odessa (SP)
12. Pirassunuga (SP)
13. Rancharia (SP)
14. Cauiá (SP)
15. Naviraí (MS)
16. Dourados (MS)
17. Campo Grande (MS)
18. Ribas do Rio Pardo (MS)
19. Ilha Solteira (SP)
20. Bambuí (MG)
21. Juíz de Fora (MG)
22. Coronel Pacheco (MG)
23. Viçosa (MG)
24. Oratórios (MG)
25. Florestal (MG)
26. Sete Lagoas (MG)
27. Cristalina (GO)
28. Ipameri (GO)
29. Cachoeira Dourada (MG)
30. Bandeirantes (GO)
31. Rio Verde (GO)
32. Itiquira (MT)
33. Rondonópolis (MT)
34. Diamantino (MT)
35. Sapezal (MT)
36. Sinop (MT)
37. Manaus (AM)
38. Palmas (TO)
39. Tasso Fragoso (MA)
40. Bom Jesus (PI)
41. Ibaratama (CE)
42. São Luíz do Curu (CE)
43. Sobral (CE)
44. Limoeiro do Norte (CE)
45. Sumé (PB)
46. Cacimbinhas (AL)
47. Nª Senhora da Glória (SE)
48. Petrolina (PE)
49. Vitória da Conquista (BA)
50. Pedra Azul (MG)
51. Salinas (MG)

Figure 2
Example of chronosequence evaluated in the NBS Projects in Santa Brígida Farm – Ipameri/GO, Brazil



mm to 2,000 mm per year), and six biomes (Cerrado – savannah, Amazon – equatorial rainforest, Caatinga – semi-arid, Atlantic Forest – tropical rainforest, Pantanal – seasonal wetlands, and the Pampa – subtropical grasslands). Figures 1 and 2 show the sites where samples have been collected.

Figure 2 exemplifies that at each point on the map above, the scientists in site collect samples of soil, plant, and eventually gasses from various land uses, such as native vegetation (reference), pasture, livestock crop integration, and forest crop integration.

Some other characteristics of the study case country favor NBS. For example, the Brazilian regulatory framework is one of the best in the world for promoting carbon farming. Environmental laws in particular are among the most advanced in the world: landowners have to preserve the native vegetation of 20% of their lands (in the Amazon biome the obligation is to keep 80%, farming or other activities can occur in only 20% of the land), water's edge vegetation, and on the top of the mountains have to be kept intact as well. There are also protective measures for fragile ecosystems (Brazil, 2012).

Specific regulation creates and regulates special protected areas that can be: a) integral protection units to preserve nature intact and therefore very restrictive rules (Ecological Stations, Biological Reserves, National Parks, Wildlife Refuges, Natural Monuments); and b) sustainable use units, where nature conservation accommodates the sustainable use of part of the natural resources (Environmental Protection Areas, Areas of Relevant Ecological Interests, National Forests, Extractive Reserves, Fauna Reserves, Sustainable Development Reserves, Private Natural Heritage Reserves). Each of these types of specially protected areas has a set of activities that are allowed or not according to the law, but apart from nuts, latex, or fruits extraction and ecotourism, the sustainable use Units cannot be used for farming (in around 30% of the Brazilian territory) (United Nations Framework Convention on Climate Change, 2022).

And in the parts of Brazil where agriculture is possible, on average, only half of the properties (50.1%) are used; the area dedicated to the preservation of native vegetation in rural properties is mandatory georeferenced and registered in the Rural Environmental Registry (CAR) by all land owners, represents, and corresponds to a quarter of the national territory (25.6% or 218 million hectares). This is the equivalent of the area of ten European countries (Portugal, Spain, France, Italy, UK, Ireland, Germany, Austria, Belgium e Luxembourg) (Embrapa, 2017). No other country has an agribusiness sector with this amount of native vegetation available to help them achieve their carbon neutrality.

In terms of public policies to incentivize the sustainability of the AFOLU sector, the ABC Plan is in its second decade of implementation and has already channeled R$ 17 billion to implement a vast range of mitigation measures (Cerri et al., 2023), which include recovering degraded lands, projects of nitrogen fixation, increased accumulation of organic matter (carbon) in the soil, no-till farming, the integration of forest, crops and cattle breeding, agroforestry, and forest planting. By 2020, the ABC Plan had exceeded its goals by 155%, and this success is expected to be continued from 2020 to 2030, through the Sectoral Adaptation Plan for a Low Carbon Agriculture for Sustainable Development (ABC+ Plan) (Ministry of Agriculture, Livestock and Food Supply, 2021). It is a key policy among Brazilian sectoral efforts to tackle climate change.

Despite its innovative character, these policies have been accepted by different producer segments such as the big agri-business as well as by the small producers, in different ways and scales. The main measure of the first phase of the ABC Plan, for example, was the creation of lines of credit linked to sustainability and the practicalities demanded by this agricultural policy. Notwithstanding, the main supported technologies were for the recovery of degraded pasture, therefore linked to large-scale agriculture, almost ignoring family farming in constructing more sustainable agriculture in Brazil. This was one of the main limitations of the ABC Plan in its first phase and has been addressed by the second phase Plan ABC+, to reinforce the efforts to reach the marginalized family farmers or small producers, that replicates the abyssal structural social inequality in Brazil in the rural area (Agroicone et al., 2021).

A general advantage to Brazil is that it has one of the cleanest energy mixes in the world. In 2020, renewable sources accounted for 44.7% of the total demand for energy, around three times the world average (EPE, 2021). In the electricity demand mix, the share of renewables accounted for 78.1%. As for the transport mix, renewables represent 23% of the sources (EPE, 2021). The production of biofuels for the transport sector is incentivized with a specific policy, the RenovaBio, which uses market incentives and mandates buying certificates of decarbonization by all fuel distributors.

Public policies can create economic value for sustainable agriculture, and other initiatives have also been used, for example, in the finance market where environmental and social governance can be a competitive differential or in international trade where buyers demand private standards. Table 1 shows some examples of instruments that can be used to create economic value to sustainable agriculture.

In 2023, a new green bonds regulation enters into force (Brazilian Securities and Exchange Commission, 2022), enabling equity funds to invest in the carbon market. In the near future, Brazil is expected to create its regulated carbon market. And international discussions are advancing toward creating biodiversity credits (Verra, 2022). So, Table 1 will hopefully soon get longer.

Unfortunately, the complexity of creating a welcoming regulatory framework can face political and implementation challenges, as it happened during the years of the former government. Commodities prices in this period were high due to swine fever, COVID pandemic, and the war in Ukraine. And

Table 1
Examples of instruments that can be used to create economic value for sustainable agriculture in Brazil

Type	Norms	Effect
Voluntary Sustainability Standards	Private agreements between producer, standards setters, and certifiers	Premium of price Market access Better contract conditions
Public Payment for Environmental Services	Brazil has national, state, and municipal laws Internationally	Direct payment Public funding
Private Payment for Environmental Services (CPR-V)	National law and presidential decree	Producers can receive funding for keeping forest, including in the area where there is a legal obligation to maintain native vegetation (*reserva legal*)
Public Policies incentives (i.e. ABC Plan)	General national law and regulated procedures at the Bank of Brazil	Producers can finance investment in sustainable techniques/technologies with better interest rates
Private credit Green funding (fixed term investment with ESG characteristics) Letras de Crédito do Agronegócio LCA-Verde	Capital market regulation, regulation by Brazilian authority (CVM) There are tax incentives (no income tax to individuals and no investment tax rates to companies investing more than 30 days)	Commercial banks or investors can raise funds to finance agribusiness with more attractive emitting fixed income securities conditioned to ESG
Green funding (anticipation of credits) *Certificados de Recebíveis do Agronegócio CRA -Verde*	Capital market regulation, regulation by Brazilian authority (CVM) There are tax incentives (no income tax and no investment tax rates to individuals)	Securities receive the producers anticipated credits and can emit fixed income securities with more attractive terms if conditioned to ESG
Variable income asset fund (purchase of quotas of credit rights, real estate, securities, shares or quotas of companies, always within the agro-industrial production chain) FIAgro-FIDC: aimed at the agroindustry that invest in credit rights; FIAgro-FIP: equity investment funds; FIAgro-FII: focused on real estate assets and bonds	Recent national law (Lei nº 14.130/21) No income tax	Special ESG conditions can be applied like negative filters and through artificial intelligence it enables to identify whether a company has an environmental sanction or labor lawsuit
Voluntary carbon market	Each exchange has its own rules. Verra is the leading standard and marketplace. Gold standard is the second	Big producers (inventories are still too expensive for the small and medium size) can develop projects to capitalize on their sustainability

these emergencies weakened the social–environmental standards. These circumstances paved the way for political ideologies that mistake the environment as a burden to development when it should be seen as an asset. So, national legislation was ignored, command and control agencies were scattered with the lack of resources, and crimes were pardoned, or unpaid fines were not prosecuted.

In the International sphere, the diplomatic myopia of defending the sovereign right to deplete its natural resources and endanger its indigenous people tainted the reputation of Brazilian agriculture and halted the implementation of the EU's free trade agreement with Mercosur. In the 2030 range, USA and China promised to eliminate all illegal deforestation from global trade, including ensuring that agricultural products do not come from deforested areas. In 2024, Europe will demand due diligence from all importers making sure they are not linked to deforestation.

The new government is expected to enforce Brazilian law and also take a step forward to curtail greenwashing. The integration of sanitary, fiscal, and environmental traceability systems will be essential. Private standards systems and certifications, which depend on producers' declarations, have to ensure they meet the requirements of international buyers and prevent possible reputation risks of the value chain being eventually linked with products causing deforestation.

Finally, the Brazilian agro needs to deconstruct a misinterpretation of its position in the world. A significant part of the sector believes that the country is naturally the world barn; without its exports, the world would starve. The Brazilian role is much greater. It is an agri-environmental power, one of the megadiverse countries, that cannot neglect this hegemonic power. On the contrary, it has to direct its political strategies to increase the synergies among social and environmental businesses, promoting long-term transformation toward more sustainable, circular, and technological agriculture.

5. Conclusion

Agriculture must meet the increasing global demand for food, feed, fibers, and (bio)energy. At the same time, it will assume a new role: contributing to net zero pledges or, even better, negative ones. Brazil alone is a pivot player, expected almost to double its production, halving its impact to meet global demands by 2050. To achieve that, tropical agricultural systems must contribute to carbon sequestration, reduce emissions, and implement technologies and techniques to mitigate climate change effects.

Soil health is one of the main pillars for achieving these complex challenges. Healthy soils are more productive and resilient, making IAS less vulnerable to climate change in the next decades. However, it is not an easy task. NBS RCGI Projects are working on producing empirical data to inform better decisions and to transform science and technology into action, therefore coordinating high-impact technical and policy interventions that meet the needs of all actors in agricultural sectors.

It is expected to identify the best agriculture management scenarios for enhancing carbon sequestration and other co-benefits while being a valuable scientific basis for helping Brazil achieve its NDCs in the Paris Agreement. At the same time, NBS RCGI Projects also aim to create social impact both within the study country of Brazil and in different global contexts where similar NBSs can be applied to mitigate climate change and promote human well-being. The topic must integrate the strategic development plan of Brazil to become an agri-environmental power.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Acknowledgement

We gratefully acknowledge the support of the RCGI – Research Centre for Greenhouse Gas Innovation, hosted by the University of São Paulo (USP) and sponsored by FAPESP – São Paulo Research Foundation (2014/50279-4 and 2020/15230-5) and Shell Brasil, and the strategic importance of the support given by ANP (Brazil's National Oil, Natural Gas and Biofuels Agency) through the R&D levy regulation.

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How to Cite: Denny, D. M.T., Cerri, C. E.P., Cherubin, M. R., & Burnquist, H. L. (2023). Carbon Farming: Nature-Based Solutions in Brazil. *Green and Low-Carbon Economy* 1(3), 130–137, https://doi.org/10.47852/bonviewGLCE3202887