Universidade de Brasília
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O círculo virtuoso do REDD+ no Brasil: estratégias para agir, mensurar e captar financiamento climático

Brasília
2024

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Tese apresentada ao Centro de Desenvolvimento Sustentável da Universidade de Brasília como parte dos requisitos para conclusão do curso de Doutorado em Política e Gestão da Sustentabilidade.

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Brasília
2024

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O círculo virtuoso do REDD+ no Brasil: estratégias para agir, mensurar e captar financiamento climático / Roberta Cantinho. – Brasília, 2024.

175 p.

Tese – Centro de Desenvolvimento Sustentável, Universidade de Brasília, 2024.

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AGRADECIMENTOS

É, se eu dissesse que foi fácil, estaria mentindo. Conciliar a escrita da tese com demandas de trabalho, os reajustes devido à pandemia do COVID-19, a mudança de emprego seguida de uma promoção, os momentos difíceis de saúde do meu pai, o casamento e o cuidado com meu cachorro foram desafiadores.

Ao longo do percurso, aquela sede inicial de trazer uma tese transformadora se materializou em uma contribuição que traz não só o resultado da minha busca por conhecimento, mas também um pouco da minha experiência durante a passagem pelo governo federal e pelo estado do Pará. Estou muito feliz com o resultado e realmente espero poder sensibilizar e colaborar, mesmo que um pouquinho, para mudanças de paradigma quanto à governança de políticas públicas ambientais do país.

Não poderia deixar de agradecer ao meu companheiro de caminhada, Marcus Paulo, pela compreensão com a minha ausência em muitas noites e finais de semana e pela paciência com meus vários momentos de exaustão física e mental. Obrigada, de coração, por sempre estar ao meu lado.

Aos amigos e familiares, que sempre torceram por mim e tiveram orgulho de cada conquista profissional, deixo também meu agradecimento por, apesar da distância e falta de atenção em vários momentos, nunca desfazerem o laço profundo e verdadeiro existente entre nós.

Aos colegas de profissão, preciso dizer que tenho muito orgulho da ciência brasileira e da resiliência de gestores que ocupam cargos que, muitas vezes, desafiam seus próprios princípios, mas que nunca deixam de acreditar e persistir.

Aos meus orientadores, professores e colegas do Centro de Desenvolvimento Sustentável - CDS, agradeço pelas trocas, ensinamentos e parceria ao longo desses anos. O CDS me proporcionou a bagagem social que eu tanto buscava para trabalhar com política pública e desenvolvimento sustentável.

Por fim, desejo que nenhum de nós diminua seus sonhos para caberem em seus medos...

Boa leitura!

RESUMO

O conceito de Redução de Emissões por Desmatamento e Degradação Florestal (REDD+) foi introduzido durante as negociações da Convenção-Quadro das Nações Unidas sobre Mudança do Clima (UNFCCC) como uma compensação financeira para países em desenvolvimento que demonstrassem resultados de conservação florestal. Enquanto alguns trabalhos científicos avaliaram a metodologia de mensuração das emissões e remoções de gases de efeito estufa (GEE) do setor de uso da terra, mudança do uso da terra e florestas (LULUCF), outros avaliaram os impactos da implementação de políticas públicas e do mercado na dinâmica de uso da terra. Entendendo que essas são análises complementares, esta pesquisa buscou avaliar as etapas do círculo virtuoso do REDD+ no Brasil, desde a efetividade de políticas públicas que visam diminuir o desmatamento na Amazônia brasileira até a identificação de estratégias de mensuração que determinem robustez nos relatos de emissões e remoções de GEE do setor de LULUCF, criando perspectivas para a captação. A compilação de cenários de diferentes modelos, até 2050, na Amazônia brasileira, mostrou a imprescindibilidade da implementação do Código Florestal, da manutenção e expansão de áreas protegidas, da regularização fundiária e da valorização dos serviços ambientais. Esta avaliação ainda destaca que a formulação das metas da Contribuição Nacionalmente Determinada (NDC) deve ser coerente com a metodologia do Inventário Nacional de Emissões de GEE, sendo este o instrumento de monitoramento dos compromissos assumidos pelo país na UNFCCC. Com base na avaliação da governança e da metodologia de compilação do IV Inventário Nacional de Emissões de GEE do setor de LULUCF, propomos um arranjo institucional com representações de diversas organizações responsáveis por gerar os dados e as estimativas para garantir mais transparência, acurácia, completude e consistência nos relatos brasileiros. Esta institucionalização, além de promover melhor aproveitamento dos recursos públicos por meio da utilização de dados de iniciativas já existentes, como o PRODES, o TerraClass, o DETER e o Inventário Florestal Nacional, traria maior acurácia nos mapas de vegetação pretérita e estoque de carbono do solo e incluiria a contabilização de emissões de degradação por fogo e de remoções por regeneração no longo prazo. Adicionalmente, seriam contabilizadas as remoções oriundas da vegetação preservada em territórios Quilombolas e em propriedades privadas para além daquelas já contabilizadas em Unidades de Conservação e Terras Indígenas. Assim, o Inventário Nacional de Emissões de GEE serviria como base para a elaboração dos Níveis de Referência de Emissões Florestais (FREL) e, consequentemente, para projetos privados de REDD+, que vêm superestimando suas linhas de base e créditos de carbono gerados. Neste sentido, identificamos a necessidade do Brasil avançar em um sistema de registro integrado e regulamentado, tendo a Comissão Nacional para REDD+ (CONAREDD+) um papel fundamental na definição da linha de base federal para trazer mais credibilidade ao Mercado Voluntário de Carbono (MVC) no país. Manter o ‘círculo virtuoso’ do REDD+ é fundamental para o Brasil diminuir suas emissões de GEE, garantir integridade na contabilidade das metas da NDC e estar apto a captar financiamento climático, inclusive por meio de transações no âmbito do Acordo de Paris.

Palavras-chave: aninhamento; governança; mensuração; mudança do clima; uso da terra.

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The virtuous circle of REDD+ in Brazil:

strategies to act, measure, and capture climate finance

ABSTRACT

Reducing Emissions from Deforestation and Forest Degradation (REDD+) was introduced during the United Nations Framework Convention on Climate Change (UNFCCC) negotiations as a financial compensation for developing countries demonstrating forest conservation results. While some scientific works evaluated the methodology for measuring greenhouse gas (GHG) emissions and removals from the land use, land-use change, and forestry (LULUCF) sector, others evaluated the impacts of implementing public policies and the market in land use dynamics. Understanding that these are complementary analyses, this research sought to evaluate the stages of the virtuous circle of REDD+ in Brazil, from the effectiveness of public policies that aim to reduce deforestation in the Brazilian Amazon to the identification of measurement strategies that determine robustness in reporting GHG emissions and removals from the LULUCF sector, creating prospects for fundraising. The compilation of scenarios from different models until 2050 in the Brazilian Amazon showed the indispensability of implementing the Forest Code, maintaining and expanding protected areas, land regularization, and valuing environmental services. This assessment also highlights that formulating Nationally Determined Contribution (NDC) targets must be consistent with the National GHG Inventory methodology, which monitors the commitments the country assumed in the UNFCCC. Based on the assessment of the governance and methodology of the compilation of the 4th National GHG Inventory of the LULUCF sector, we propose an institutional arrangement with representations from several organizations responsible for generating the data and estimates to ensure greater transparency, accuracy, completeness, and consistency in Brazilian reports. This institutionalization, in addition to promoting better use of public resources through the use of data from existing initiatives, such as PRODES, TerraClass, DETER, and the National Forest Inventory, would improve the accuracy of maps of past vegetation and soil carbon stock and would include accounting for emissions due to degradation by fire and removals due to long-term regeneration. Additionally, removals arising from preserved vegetation in Quilombola territories and private properties would be accounted for in addition to those in Conservation Units and Indigenous Lands. Thus, the National GHG Inventory would serve as a basis for preparing the national Forest Emissions Reference Level (FREL) and, consequently, for private REDD+ projects, which have been overestimating their baselines and carbon credits generated. In this sense, we identify the need for Brazil to advance towards an integrated and regulated registration system, with the National REDD+ Committee (CONAREDD+) playing a fundamental role in defining the federal baseline to bring more credibility to the Voluntary Carbon Market (VCM) in the country. Maintaining the 'virtuous circle' of REDD+ is essential for Brazil to reduce its GHG emissions, ensure integrity in the accounting of its NDC targets, and be able to raise climate finance, including through transactions under the Paris Agreement.

Keywords: climate change; governance; land use; measurement; nesting.

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LISTA DE ABREVIATURAS E SIGLAS

ART	Arquitetura para transações de REDD+
BAU	*Business as usual*
CONAREDD+	Comissão Nacional para REDD+
COP	Conferência das Partes
DETER	Sistema de Detecção de Desmatamentos em Tempo Quase Real
GEE	Gases de Efeito Estufa
GTP	Potencial de aumento de Temperatura Global
GWP	Potencial de aquecimento global
FREL	Nível de Referência de Emissões Florestais
iNDC	Contribuição Nacionalmente Determinada pretendida
INPE	Instituto Nacional de Pesquisas Espaciais
IPCC	Painel Intergovernamental sobre Mudanças Climáticas
LULUCF	Uso da Terra, Mudança do Uso da Terra e Florestas
MCTI	Ministério da Ciência, Tecnologia e Inovação
MMA	Ministério do Meio Ambiente e Mudança do Clima
MRV	Mensuração, Relato e Verificação
MVC	Mercado Voluntário de Carbono
NDC	Contribuição Nacionalmente Determinada
Plano ABC	Plano de Agricultura de Baixa Emissão de Carbono
PLANAVEG	Plano Nacional de Recuperação da Vegetação Nativa
PNMC	Política Nacional sobre Mudança do Clima
PPCDAm	Plano de Prevenção e Controle do Desmatamento na Amazônia
PPCerrado	Plano de Ação para Prevenção e Controle do Desmatamento e das Queimadas no Bioma Cerrado
PRODES	Projeto de Monitoramento do Desmatamento da Floresta Amazônica Brasileira por Satélite
PSA	Pagamento por Serviços Ambientais
REDD+	Redução de Emissões por Desmatamento e Degradação Florestal
SBCE	Sistema Brasileiro de Comércio de Emissões
TACCC	Transparência, Acurácia, Completude, Consistência e Comparabilidade
TerraClass	Projeto de classificação de uso da terra após desmatamento do PRODES
TREES	Padrão de Excelência Ambiental para REDD+
UNFCCC	Convenção-Quadro das Nações Unidas sobre Mudança do Clima

LIST OF ABBREVIATIONS AND ACRONYMS

ABC Plan	Brazilian Agricultural Policy for Climate Low Carbon Agriculture Plan
ART	Architecture for REDD+ Transactions
BAU	Business as Usual
CAR	Rural Environmental Registry
CONAREDD+	National REDD+ Committee
COP	Conference of Parties
GHG	Greenhouse gas
GTP	Global Temperature Potential
GWP	Global Warming Potential
DETER	Near Real-Time Deforestation Detection System
FREL	Forest Reference Emission Level
iNDC	Intended Nationally Determined Contribution
INPE	National Institute for Space Research
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land-Use Change, and Forestry
MCTI	Ministry of Science, Technology, and Innovation
MMA	Ministry of Environment and Climate Change
MRV	Measurement, Reporting, and Verification
NDC	Nationally Determined Contribution
NFI	National Forest Inventory
PES	Payment for Environmental Service
PLANAVEG	National Plan for the Recovery of Native Vegetation
PNMC	National Policy on Climate Change
PPCDAm	Action Plan for the Prevention and Control of Deforestation in the Legal Amazon
PPCerrado	Action Plan for the Prevention and Control of Deforestation and Fires in the Cerrado
PRODES	Project for Monitoring Deforestation in the Legal Amazon by Satellite
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SBCE	Brazilian Emissions Trading System
TACCC	Transparency, Accuracy, Completeness, Consistency, and Comparability
UNFCCC	United Nations Framework Convention on Climate Change
VCM	Voluntary Carbon Market

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SUMÁRIO

1. INTRODUÇÃO

Como Parte da Convenção-Quadro das Nações Unidas sobre Mudança do Clima (UNFCCC), o Brasil reconhece que as atividades humanas estão aumentando as concentrações atmosféricas de gases de efeito estufa (GEE) e intensificando o efeito estufa natural (United Nations, 1992; Brasil, 1988). Para contribuir com o objetivo de mitigação da mudança do clima do Acordo de Paris, ratificado entre as Partes da UNFCCC (UNFCCC, 2015; Brasil, 2017a), o Brasil submeteu a quarta atualização de sua Contribuição Nacionalmente Determinada (NDC) em 2023, revisitando as metas anteriormente estabelecidas, e assumindo o compromisso de reduzir suas emissões de GEE até 2025 e 2030 com relação às suas emissões de 2005 e atingir a neutralidade em 2050 (UNFCCC, 2023a).

Os Inventários de Emissões de GEE são o principal instrumento para monitorar os avanços das Partes com relação às suas NDCs (Brasil, 2020a; UNFCCC, 2015, 2019). Nesse sentido, arranjos de Mensuração, Relato e Verificação (MRV) são essenciais para construir confiança entre os países e garantir que as metas sejam monitoradas de forma transparente, acurada, completa, consistente e comparável (TACCC; IPCC, 2006; Granziera *et al*., 2023).

A mensuração de emissões e remoções de GEE dos Inventários Nacionais precisa ser cientificamente robusta e institucionalmente legítima (Veloso, 2019). Para isso, é necessário estabelecer uma boa governança, distribuindo funções entre as instituições do governo e aprimorando a interação entre esses diferentes atores, que precisariam estar munidos dos recursos necessários para desempenhar suas funções, fortalecendo suas capacidades estatais (Calmon e Costa, 2013; Gomide e Pires, 2024; Grindle, 2004; Painter e Pierre, 2005; Von Lüpke et al., 2023).

O setor de Uso da Terra, Mudança do Uso da Terra e Florestas (LULUCF) apresenta grande complexidade na compilação de dados de atividade e fatores de emissões e remoções, devido, principalmente, à identificação de atividades antrópicas e incertezas associadas (Brasil, 2020a; Grassi *et al*., 2023; McGlyn *et al*., 2022).

Um relato que contemple as fontes e sumidouros dos diferentes componentes do setor de LULUCF provê ao país parte dos subsídios necessários para receber pagamentos por resultados de Redução de Emissões por Desmatamento e Degradação Florestal (REDD+) (Brasil, 2020b; UNFCCC, 2014). A integração, ou aninhamento (do inglês *nesting*)[1], entre programas jurisdicionais de REDD+ e projetos locais do Mercado Voluntário de Carbono (MVC) é essencial para garantir integridade na contabilidade nacional e para atender a requisitos de certificações internacionais como o Padrão de Excelência Ambiental de REDD+ (TREES) da Arquitetura para Transações de REDD+ (ART) (ART, 2021a, 2021b). Além disso, um relato de emissões e remoções de GEE completo é crucial para viabilizar a participação do Brasil em futuras transferências internacionais de mitigação (ITMO)[2], previstas no Artigo 6.2 do Acordo de Paris (UNFCCC, 2015).

No entanto, nas últimas décadas, observou-se uma vasta extensão do desmatamento nos diferentes biomas brasileiros, colocando em risco o alcance das metas da NDC e as possibilidades de captação de financiamento climático. Desde a década de 70, o bioma Amazônia foi um dos que mais emitiu GEE devido às suas altas taxas históricas de desmatamento e à sua alta biomassa florestal (MCTI, 2020).

Estudos de modelagem de uso e cobertura da terra buscaram compreender os fatores que influenciam essa dinâmica, considerando, inclusive, cenários econômicos e políticos (Aguiar *et al*., 2016; Rochedo *et al.,* 2018; Silva Bezerra *et al*., 2022; Soares-Filho *et al*., 2006; Soterroni *et al*., 2023; Verburg, 2016).

Diversos trabalhos científicos avaliaram aspectos ligados à metodologia de mensuração das emissões e remoções de GEE (Grassi et al., 2023; McGlyn et al., 2022; Veloso, 2019), enquanto outros avaliaram os impactos da implementação de políticas públicas e do mercado na dinâmica de uso da terra (Aguiar *et al*., 2016; Rochedo *et al.,* 2018; Silva Bezerra *et al*., 2022; Soares-Filho *et al*., 2006; Soterroni *et al*., 2023).

Contudo, é importante destacar que esses são aspectos complementares e que contribuem para melhor compreender as perspectivas da implementação do REDD+ do Brasil. Assim, esta pesquisa buscou avaliar as etapas do que estamos chamando de 'círculo virtuoso do REDD+', que envolve desde o direcionamento de ações para reduzir o desmatamento e a degradação florestal, até a mensuração, de forma completa e integrada, das diferentes atividades que emitem e removem GEE, para, então, o Brasil acessar diferentes fontes de financiamento climático. A

[1] O aninhamento permite a contabilização de iniciativas de REDD+ em várias escalas, garantindo transparência e prevenção da dupla contagem (World Bank Group, 2021).

[2] O ITMO possibilita que um país vendas seus créditos excedentes para países que ainda precisam atingir seus objetivos dentro do Acordo, em troca de investimentos, acesso a tecnologias e apoio com capacitação técnica.

avaliação foi focada no bioma Amazônia, diante de sua representatividade nas emissões de GEE do país e, conseqüentemente, potencial de geração de resultados de REDD+.

A pergunta que norteou essa pesquisa foi: que ações precisariam ser tomadas para o Brasil reduzir o desmatamento na Amazônia brasileira e aumentar a transparência, completude e sustentabilidade do monitoramento das emissões e remoções de GEE do setor de LULUCF para a manutenção do círculo virtuoso de REDD+? A hipótese da pesquisa é a de que a implementação do Código Florestal garante a redução do desmatamento na Amazônia e a utilização de dados oficiais, lastreados em ciência, garante a transparência na mensuração e relato de emissões e remoções de GEE do setor de LULUCF.

2. OBJETIVOS

Objetivo Geral

Avaliar as etapas do círculo virtuoso do REDD+ no Brasil, desde a efetividade de políticas públicas que visam diminuir o desmatamento na Amazônia brasileira, até a identificação de estratégias de mensuração que determinem robustez nos relatos de emissões e remoções de GEE do setor de LULUCF, criando perspectivas para a captação.

Objetivos específicos

Para atingir o objetivo geral da pesquisa, os objetivos específicos foram assim definidos:

1. Avaliar as taxas de desmatamento e emissões associadas projetadas até 2050 na Amazônia brasileira, a partir do arcabouço político institucional que regula o setor de LULUCF;

2. Analisar a governança e a metodologia de compilação do IV Inventário Brasileiro de Emissões de GEE do setor de LULUCF;

3. Desenvolver diretrizes para aprimorar a mensuração das emissões e remoções de GEE do setor de LULUCF, com base nas avaliações realizadas;

4. Examinar o cenário atual do Brasil em relação ao registro de projetos e programas de REDD+, utilizando o estado do Pará como estudo de caso.

A seguir, apresentamos o referencial teórico que subsidiou a pesquisa.

3. REFERENCIAL TEÓRICO

3.1. CONCEITOS GERAIS DE POLÍTICA E GESTÃO

Administração Pública

A Administração Pública pode ser considerada um conjunto de órgãos estabelecidos para desempenhar os serviços do Estado, em benefício da coletividade, de forma perene, sistemática, legal e técnica (Meirelles, 1995). A estrutura político-administrativa do Brasil contempla três níveis de governo: federal, estadual, incluindo o Distrito Federal, e o municipal. Por meio da Administração Pública, os gestores públicos dos diferentes níveis buscam satisfazer as necessidades da população por meio de políticas públicas (Freitas e Silva, 2022).

Política pública

Lynn (1980) define política pública como um conjunto de ações do governo que irão produzir efeitos específicos, enquanto Dye (1984) as define como “o que o governo escolhe fazer ou não fazer”. Lowi (1964) afirma que a política pública é uma regra formulada por alguma autoridade governamental que expressa uma intenção de influenciar, alterar ou regular o comportamento individual ou coletivo através do uso de sanções positivas ou negativas. Segundo Procopiuck (2003), política pública refere-se “à mobilização político-administrativa para articular e alocar recursos e esforços para tentar solucionar dado problema coletivo”. Assim, as políticas públicas englobam um conjunto articulado e estruturado de ações e incentivos, buscando alterar uma realidade em resposta a demandas e interesses das partes envolvidas (Martins, 2007).

O ciclo da política pública é representado pelas macroetapas de formulação, implementação e controle de impactos (Frey, 2000). Howlett *et al*. (2013) divide o ciclo em cinco estágios: i) formação de agenda, ii) formulação da política, iii) tomada de decisão política, iv) implementação da política e v) avaliação da política. No entanto, Secchi (2010) destaca que nem sempre é possível fazer distinção de todas as fases de uma política pública.

Uma política pública precisa possuir uma rotina de acompanhamento de suas ações. Esse monitoramento envolve a coleta de informações sobre insumos, produtos, atividades e circunstâncias relevantes para a implementação da política. Esse é um processo contínuo e fornece informações necessárias para eventuais aperfeiçoamentos. Isso implica no desenvolvimento de uma rotina para monitorar suas ações, avaliar seus resultados e utilizá-los para promover aperfeiçoamentos (Brasil, 2014a; IPEA, 2018a).

O atingimento de resultados nas políticas exige, cada vez mais, que as organizações públicas trabalhem em conjunto, ou haverá uma fragmentação dos objetivos e sobreposição de programas. Assim, coordenação e coerência são elementos essenciais para garantir qualidade nos serviços prestados pelo governo. A coordenação nas políticas públicas diz respeito a fazer com que os diversos sistemas institucionais e gerenciais que formulam políticas trabalhem juntos, enquanto coerência envolve a promoção de ações que se reforcem mutuamente. Deve-se buscar o estabelecimento de relações institucionais e articulação entre as esferas de governo em todas as fases do ciclo de políticas públicas (Brasil, 2014a).

Institucionalização e arranjos de implementação

> Institucionalização de uma política pública se refere a aspectos, formais ou informais, da existência da política, relacionados a capacidades organizacionais, normatização, padrões, procedimentos, competências e recursos que possibilitam o alcance dos objetivos e resultados da política pública (Brasil, 2014a).

Espera-se que uma política pública seja jurídica e oficialmente formalizada, por meio do estabelecimento de normas, padrões e procedimentos que definam como se darão as tomadas de decisão, a divisão de competências e as atribuições dos atores envolvidos (Procopiuck, 2013). A partir dessa definição clara das funções das organizações e das responsabilidades dos envolvidos, é possível estabelecer uma boa governança. Algumas políticas públicas estabelecem marcos regulatórios[3], onde destacam as competências dos atores envolvidos, enquanto outras constituem fóruns para discussões e deliberações de propostas. É preciso evitar excesso de normas e formalidades que poderiam dificultar o desempenho, participação e coordenação dessas políticas (Calmon e Costa, 2013).

[3] Conjunto de leis, regulamentos e normas que regem um determinado setor ou atividade, estabelecendo direitos, obrigações e limites de atuação.

Uma abordagem sobre os arranjos de implementação permite analisar e avaliar políticas públicas específicas, sendo essencial para melhorar a eficácia das políticas governamentais. Para isso, é necessário mapear os arranjos de implementação e as capacidades acionadas por esses arranjos – recursos humanos, financeiros e tecnológicos disponíveis, bem como as competências e habilidades dos atores estatais envolvidos (Gomide e Pires, 2024).

Estudos vêm avaliando arranjos institucionais em diferentes níveis. Von Lüpke *et al*. (2023) avaliaram arranjos institucionais para a política climática de uma perspectiva global, enquanto Baeiro (2022) avaliou o arranjo institucional do setor florestal brasileiro, Souza (2020) da gestão de unidades de conservação em nível estadual e Fiore *et al*. (2020) do Pagamento por Serviços Ambientais (PSA) em nível municipal. Lotta e Vaz (2015) compilaram aprendizados de arranjos institucionais complexos no Brasil.

Governança e gestão

> Governança consiste na distribuição de poder entre instituições de governo; a legitimidade e autoridade das instituições de governo; as regras e normas que determinam quem detém poder e como as decisões sobre o exercício da autoridade são tomadas; relações de responsabilização entre representantes e agências do Estado, e entre esses representantes e agências e os cidadãos; a habilidade do governo em fazer políticas, gerir os assuntos administrativos e fiscais do Estado, e prover bens e serviços; e o impacto das instituições e políticas sobre o bem-estar público (Grindle, 2004, tradução nossa).

O conceito de governança foi tratado inicialmente com enfoque no setor corporativo no clássico '*The modern corporation and private property'* de Berle e Means (1932). Desde então, a governança corporativa passou a ser estudada desde vários enfoques, inexistindo um modelo único e universal, emergindo em debates de políticas públicas (Aguilera e Jachson, 2010).

O desenvolvimento do tema no âmbito da Administração Pública esteve fortemente associado ao movimento do Banco Mundial, em especial com a publicação do relatório '*Sub-SaharanAfrica: From Crisis to Sustainable Growth'* (The World Bank, 1989), que identificou a "crise de governança" como uma das principais barreiras para a superação da pobreza na África Subsaariana.

No relatório *'Governance and Development'* (The World Bank, 1992), o conceito de governança passa a ser tratado como a forma com a qual o poder é exercido na administração dos recursos econômicos e sociais do país, em busca do desenvolvimento. Essa aprimoração de conceito trouxe aspectos da governança relacionados à forma de regime político, ao processo pelo qual a autoridade é exercida na gestão dos recursos econômicos e sociais do país e à capacidade dos governos de planejar, formular e implementar políticas e exercer suas funções.

Assim, a governança não se limita à capacidade estatal de formular, implementar e avaliar políticas públicas, mas também ao aprimoramento da interação entre diversos atores, de forma a articular seus interesses e garantir transparência e *accountability*[4] da atuação governamental (Diniz, 2001; Procopiuck, 2013). Desse modo, a cooperação entre atores é uma questão central para o sucesso ou fracasso de políticas públicas. É importante haver coordenação dessas políticas horizontalmente, envolvendo atores da mesma esfera de governo e nível hierárquico, mas também verticalmente (em multiníveis), com atores de outras esferas de governo e níveis hierárquicos da Administração Pública (Martins, 2003). Há, por consequência, dificuldade por parte dos governos de desenvolver políticas consistentes e coerentes, visto que exigem negociações complexas e extensas (Howlett *et al*., 2013).

Grindle (2004, 2007) traz o conceito de "Governança suficientemente boa", sugerindo que as lacunas de governança demandam tempo para serem sanadas e que a construção e capacitação institucionais podem ser revertidas e precisam considerar as circunstâncias de cada país, sendo indispensável a definição de quesitos mínimos.

Em linhas gerais, a governança condiciona a gestão: uma gestão arbitrária, opaca e fechada seria desprovida de boa governança, enquanto uma gestão democrática, transparente e aberta à participação estaria em maior conformidade com os princípios de governança do Estado e de sua relação com a sociedade (Brasil, 2014a). A gestão refere-se ao funcionamento da rotina de programas e de organizações no contexto de estratégias, políticas, processos e procedimentos constituídos pelo órgão. Assim, está relacionada à eficácia (cumprimento de ações

[4] *Accountability* envolve transparência, responsabilização, comunicação e prestação sistemática de contas. É um elemento essencial no processo de governar uma sociedade e no processo de detecção e correção de erros (Brasil, 2014b). Caracteriza-se pela prestação de contas (IPEA, 2018a).

prioritárias) e à eficiência (realização de ações com melhor custo-benefício) (World Bank Group, 2013).

Governabilidade

> A governabilidade diz respeito às condições sistêmicas e institucionais sob as quais se dá o exercício do poder, tais como as características do sistema político, a forma de governo, as relações entre os Poderes e o sistema de intermediação de interesses (Santos, 1997).

Araújo (2002) aponta que as variáveis de governabilidade e governança estão fortemente relacionadas, sendo complementares e com vínculo instável, dinâmico e indissolúvel, e sua separação se daria apenas para fins didáticos analíticos.

Santos (1997) ainda menciona que a diferenciação entre os conceitos de governança e governabilidade não se faz relevante no contexto atual, ponderando que o primeiro conceito incorpora princípios democráticos, voltados à articulação e cooperação entre atores sociais e políticos. Nesse sentido, a autora recomenda uma análise mais ampla referente à "capacidade governativa" (ou capacidade estatal, conforme descrito a seguir), que engloba elementos sistêmicos e operacionais contidos nos conceitos de governabilidade de governança, além de destacar a interação da capacidade operacional e financeira do Estado com as instâncias da política democrática.

Capacidade Estatal

> A capacidade estatal refere-se às habilidades, competências e recursos burocrático-institucionais de um Estado para implementar políticas públicas e desempenhar de modo eficaz suas funções, como manter a ordem pública, garantir direitos e prover bens e serviços públicos (Gomide e Marenco, 2024).

O conceito de capacidade estatal foi marcado por pesquisas nos campos de ciências sociais e economia política sobre o papel do Estado na busca pelo desenvolvimento (Gomide e Marenco, 2024). Para Evans (1993), a capacidade estatal não está apenas relacionada às características do aparelho do Estado, mas também com as estruturas sociais circundantes.

Segundo Painter e Pierre (2005), as "capacidades governativas" ("*governing capacities*") estão associadas às habilidades do governo de fazer escolhas e definir estratégias para alocar e gerir eficientemente os recursos necessários para a entrega de resultados e mobilizar o apoio e o consentimento da sociedade em suas ações. Wu *et al*. (2015) exploram o conceito de “capacidades para políticas públicas” (“*policy capacity*”) na mesma linha como um conjunto de competências e recursos necessários para a produção de ações públicas efetivas.

O Referencial para Avaliação de Governança em Políticas Públicas do Tribunal de Contas da União (Brasil, 2014a) trata o conceito de “Capacidade Organizacional” de forma semelhante à aqui descrita. Nesse sentido, destacam a necessidade de que as organizações possuam estruturas e processos adequados para executar as atividades previstas, garantir o bom uso dos recursos públicos, monitorar as ações descentralizadas, acompanhar os resultados e retroalimentar o processo decisório, buscando aperfeiçoar sua formulação e capacidade de implantação.

Gomide e Pires (2024) reforçam a capacidade estatal como um conceito abrangente e multidimensional, que envolve componentes políticos, institucionais, administrativos e técnicos. Segundo os autores, existem três grandes opções metodológicas para mensurar capacidades estatais: *surveys* (baseados nas percepções de especialistas, grupos de interesse, elites, entre outros); resultados das políticas (*outcomes*) e atributos. A maior parte das pesquisas nacionais e internacionais fazem uso dos outcomes, sendo que os *surveys* têm sido mais utilizados por organismos multilaterais para identificar existência de capacidades e comparar entre países.

Alguns estudos avaliaram a capacidade estatal em diferentes níveis e perspectivas (Euclydes *et al.,* 2022; Oliveira, 2015).

Os diferentes conceitos aqui abordados são apresentados em formato de diagrama causal na Figura A. 1.

3.2. AGENDA DE CLIMA INTERNACIONAL

Painel Intergovernamental sobre Mudanças Climáticas (IPCC)

A primeira conferência internacional voltada para a temática do clima global ocorreu em Genebra, em 1979, com apoio da Organização Meteorológica Mundial (WMO). Durante esta conferência, foi criado o Programa de Pesquisa do Clima Mundial (WCRP), lançado em 1980, com apoio da WMO e do Conselho

Internacional para a Ciência Unida (ICSU). Durante o encontro do WCRP em 1985, na Áustria, surgiram recomendações sobre a criação de um programa para tratar da mudança do clima, integrando não apenas a comunidade científica, mas também governos e organizações internacionais, em especial o Programa das Nações Unidas para o Meio Ambiente (PNUMA) e o ICSU (Mendes, 2014).

Somente em 1988 foi então criado o Painel Intergovernamental sobre Mudanças Climáticas (IPCC). O IPCC deveria realizar uma revisão e dar recomendações sobre: i) o estado do conhecimento da ciência do clima e da mudança do clima; ii) programas e estudos sobre o impacto social e econômico da mudança do clima, incluindo o aquecimento global; iii) possíveis estratégias para atrasar, limitar ou mitigar os impactos adversos da mudança do clima; iv) a identificação e possível fortalecimento de instrumentos legais relevantes existentes que influenciam o clima e v) elementos a serem incluídos para uma possível futura convenção internacional para o clima[5]. Para isso, o presidente do IPCC criou três grupos de trabalho: 1) avaliação científica; 2) avaliação de impactos e 3) avaliação de estratégias de resposta (Mendes, 2014).

Em seu primeiro relatório (AR1), lançado em 1990, o IPCC adicionou uma avaliação sobre como os países em desenvolvimento poderiam ser envolvidos nas ações de pesquisa, adaptação e mitigação da mudança do clima, enfatizando que "as negociações internacionais sobre uma Convenção-Quadro devem começar o mais rápido possível após a apresentação deste relatório". A proposta do IPCC era a de que os governos considerassem a possibilidade de criação de protocolos para tratar das soluções junto à Convenção-Quadro a ser criada (Mendes, 2014).

O AR1 foi apresentado durante a Segunda WCC e foi então estabelecido o Comitê Intergovernamental de Negociação para uma Convenção-Quadro sobre Mudança do Clima (INC/FCCC), com o objetivo de negociar o texto de uma Convenção-Quadro efetiva sobre Mudança do Clima[6] (Mendes, 2014). Desde então, já havia concordância sobre a contribuição dos países serem "equitativamente diferenciadas de acordo com as responsabilidades dos países e de acordo com seus

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[5] Parágrafo 10º da Resolução 43/53 de 1988. Disponível em: https://www.ipcc.ch/site/assets/uploads/2019/02/UNGA43-53.pdf. Acesso em: 22 fev. 2022.

[6] Primeiro parágrafo da Resolução 45/212, de 1990. Disponível em: https://digitallibrary.un.org/record/196769/files/A_RES_45_212-EN.pdf?ln=en. Acesso em: 22 fev. 2022.

níveis de desenvolvimento”[7]. Neste sentido, a Convenção deveria identificar e aplicar recursos aos países em desenvolvimento para que pudessem realizar ações de mitigação e adaptação, por meio de apoio por transferência de tecnologias apropriadas. O texto final da Convenção foi concluído em maio de 1992 (Mendes, 2014).

Convenção-Quadro das Nações Unidas sobre Mudança do Clima (UNFCCC)

Em 1992, no Rio de Janeiro, durante a Conferência das Nações Unidades sobre o Meio Ambiente e Desenvolvimento (Eco-92 ou Rio-92), o texto da Convenção foi aprovado, contando com a representação de 157 países, sendo que alguns países solicitaram reserva sobre alguns termos utilizados[8]. De toda forma, o texto foi considerado aprovado e todos os países que apresentaram reservas são hoje Partes da Convenção. Assim, a UNFCCC entrou em vigor em 1994, após o envio do quinquagésimo instrumento de ratificação, conforme o Artigo 23 de seu texto (Mendes, 2014). Atualmente, os 198 países ratificaram a UNFCCC. O Brasil promulgou a UNFCCC em 1998 (Brasil, 1998).

Como Parte da UNFCCC, os países reconhecem que as atividades humanas estão aumentando as concentrações atmosféricas de gases de efeito estufa (GEE), que, por sua vez, estão intensificando o efeito estufa natural e resultando em aquecimentos adicionais da Terra, podendo afetar negativamente os ecossistemas naturais e a humanidade. Ainda reconhecem que a maior parcela das emissões globais, históricas e atuais, é originária dos países desenvolvidos (ou Anexo-1 da UNFCCC) (United Nations, 1992).

Do ponto de vista conceitual, a mudança do clima, segundo a UNFCCC, pode ser direta ou indiretamente associada à atividade humana. Sendo assim, o objetivo final da UNFCCC é o de estabilizar a concentração de GEE na atmosfera em um nível que impeça uma interferência antrópica perigosa no sistema do clima. Esse nível deve ser alcançado em um prazo suficiente para que os ecossistemas se adaptem e para que a produção de alimentos não seja ameaçada, permitindo o desenvolvimento econômico sustentável (United Nations, 1992).

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[7] Página 24 da Resolução A/AC 237/6. Disponível em: https://ccsr.aori.u-tokyo.ac.jp/old/unfccc4/pdfs/unfccc.int/resource/docs/a/06.pdf. Acesso em: 22 fev. 2022.

[8] Durante a Eco-92, 154 países e a Comunidade Europeia assinaram a Convenção, totalizando 155 Partes (Mendes, 2014).

De maneira simplificada, as Partes da UNFCCC, levando em consideração “suas responsabilidades comuns, porém diferenciadas e suas prioridades de desenvolvimento, objetivos e circunstâncias específicas, nacionais e regionais” assumem o compromisso de: i) realizar seus inventários das emissões antrópicas de gases de efeito estufa (GEE); ii) avançar em programas de mitigação e adaptação; iii) desenvolver tecnologias para reduzir e prevenir emissões; iv) proteger sumidouros; v) considerar a mudança do clima nas políticas sociais, econômicas e ambientais; vi) promover a pesquisa científica em mudança do clima e vii) investir em educação, treinamento e conscientização (Mendes, 2014).

O artigo 8 da UNFCCC cria seu secretariado, que, dentre outras funções, é responsável por organizar suas conferências, compilar e apresentar seus relatórios e facilitar assistência às Partes, em especial aos países em desenvolvimento. Também são criados o Órgão Subsidiário de Assessoramento Científico e Tecnológico (SBSTA) (Artigo 8) e o Órgão Subsidiário de Implementação (SBI) (Artigo 9). O SBSTA realiza o intercâmbio entre as orientações científicas e tecnológicas, enquanto o SBI é responsável pela avaliação e revisão da implementação da UNFCCC (United Nations, 1992).

O artigo 11 estabelece o mecanismo financeiro da UNFCCC, sendo o Fundo Global para o Meio Ambiente (GEF), criado em 1991 pelo Banco Mundial, um dos principais agentes financiadores. Em 2010, foi criado o Fundo Verde para o Clima (GCF) também para operacionalização dos compromissos financeiros na UNFCCC (Mendes, 2014).

A UNFCCC cria, por meio do Artigo 7, a chamada Conferência das Partes (COP), onde são aprovadas as regras e são examinados os cumprimentos dos acordos realizados pelas Partes. As COPs acontecem anualmente[9], de forma rotativa. A COP1 aconteceu em 1995, em Berlim, Alemanha. A última, a COP28, aconteceu em 2023 em Dubai, Emirados Árabes. O Brasil sediará a COP30, em Belém, em 2030.

Protocolo de Quioto

Conforme previsto em seu Artigo 17 (United Nations, 1992), um dos protocolos no âmbito da UNFCCC que visaram estabelecer metas de redução de

[9] Com exceção de 2020, que não aconteceu por conta da pandemia do COVID-19.

emissões para os países desenvolvidos foi o Protocolo de Quioto. Criado em 1997, durante a COP3, no Japão, o Protocolo só entrou em vigor em 2005, quando atendidas as exigências de ratificação por, no mínimo, 55% dos países-membro da UNFCCC e que fossem responsáveis por, pelo menos, 55% do total de emissões de 1990 (UNFCCC, 1997). Durante seu primeiro período, entre 2008 e 2012, os 37 países industrializados e a Comunidade Européia comprometeram-se em reduzir 5% de suas emissões com relação a 1990. Em 2012, no Catar, foi assinada a “Emenda de Doha”, atualizando as metas de redução para pelo menos 18% das emissões com relação a 1990, entre 2013 e 2020 (UNFCCC, 2012).

O Protocolo trouxe a possibilidade de utilização de mecanismo de mercado para que os países desenvolvidos pudessem cumprir seus compromissos, incluindo três possibilidades: a Implementação Conjunta[10], o Comércio de Emissões[11] e o Mecanismo de Desenvolvimento Limpo[12] (MDL) (Moreira e Giometii, 2008).

O Brasil promulgou o Protocolo de Quioto em 2005 (BRASIL, 2005). A participação do Brasil no Protocolo de Quioto ocorreu por meio do MDL, por ser o único que admitia a participação voluntária de países em desenvolvimento. O MDL consiste no desenvolvimento de projetos que reduzem emissões de GEE que, por sua vez, podem ser vendidas por meio de Reduções Certificadas de Emissões (RCE) para os países desenvolvidos (IPEA, 2018b).

Acordo de Paris

Com o fim do período do Protocolo de Quioto, durante a COP21, em 2015, na França, 194 países ratificaram o Acordo de Paris, se comprometendo a apresentar metas de reduções de GEE com o objetivo principal de manter “o aumento da temperatura média global bem abaixo dos 2°C acima dos níveis pré-industriais” e prosseguir esforços “para limitar o aumento da temperatura a 1,5°C acima dos níveis pré-industriais” até 2100 (UNFCCC, 2015). Diante das insatisfações, principalmente

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[10] A implementação conjunta permite que um país Anexo-1 desenvolva projetos de redução de emissões em outro país Anexo-1, enquanto o país anfitrião se beneficia do investimento estrangeiro e da transferência de tecnologia.

[11] O comércio de emissões permite que dois países Anexo-1 façam um acordo pelo qual o país que tenha diminuído suas emissões para níveis abaixo da sua meta possa vender o excesso das suas reduções para outro que não tenha alcançado tal condição.

[12] Pelo Mecanismo de Desenvolvimento Limpo, os membros do Anexo I podem desenvolver projetos que contribuam para o desenvolvimento sustentável de países em desenvolvimento (não pertencentes ao Anexo I) de modo a ajudar na redução de suas emissões através da geração de créditos. Os projetos podem ser implementados nos setores energético, de transporte e florestal. Dentro do setor florestal, projetos de florestamento e reflorestamento são elegíveis.

dos Estados Unidos, em aceitar que as metas de reduções recaíssem somente aos países do Anexo-1, decidiu-se que os países signatários do acordo iriam estabelecer suas próprias metas por meio de Contribuições Nacionalmente Determinadas (NDC) (Viola, 2010).

As metas variaram em ambição e formato. A União Européia propôs reduzir as emissões de GEE de toda sua economia em 55% abaixo dos níveis de 1990, sem a utilização de créditos internacionais; já os Estados Unidos se comprometeram a reduzir as emissões de GEE entre 26 e 28% abaixo do nível de 2005 até o ano de 2025 (Oliveira, 2022).

Com o intuito de auxiliar os países a alcançarem suas metas, o Acordo previu, em seu Artigo 6, a viabilidade de cooperação entre os países por meio de "Resultados de Mitigação Internacionalmente Transferidos" (ITMO). O ITMO possibilita que um país venda seus créditos excedentes para países que ainda precisam atingir seus objetivos dentro do Acordo, em troca de investimentos, acesso a tecnologias e apoio com capacitação técnica. Além disso, estabelece o Mecanismo de Desenvolvimento Sustentável (MDS), semelhante ao MDL (Miguez e Andrade, 2019).

Durante a COP26, em 2021, em Glasgow, medidas foram adotadas para evitar a dupla contagem por meio da Estrutura de Transparência Aprimorada (ETF), bem como permitiu-se a transposição de créditos oriundos do MDL, desde que datados após 2013 (Oliveira, 2022). As transações de créditos de carbono no âmbito do Protocolo de Quioto e do Acordo de Paris estão atreladas ao mercado regulado de carbono.

Esses marcos históricos destacam a importância da cooperação internacional e da ciência na formulação de políticas climáticas eficazes. No entanto, desafios persistem, especialmente na implementação e no cumprimento das metas estabelecidas. A próxima seção explorará um dos mecanismos específicos desenvolvidos para abordar esses desafios, focando na conservação florestal como uma estratégia para a mitigação da mudança do clima, sendo uma oportunidade para países como o Brasil, que possuem vastas áreas florestais, contribuírem para a redução global de emissões de GEE enquanto promovem o desenvolvimento sustentável.

3.3. REDUÇÃO DE EMISSÕES POR DESMATAMENTO E DEGRADAÇÃO FLORESTAL (REDD+)

Pagamento por resultados de REDD+

O conceito de Redução de Emissões por Desmatamento Florestal (RED) nasceu de uma parceria entre pesquisadores brasileiros e americanos, com o intuito de compensar financeiramente países em desenvolvimento por reduzir as emissões de GEE associadas ao desmatamento. A proposta foi construída como forma de impulsionar os países em desenvolvimento a contribuírem com as metas do Protocolo de Quioto, tendo em vista suas altas taxas de desmatamento e que o MDL considerava apenas projetos de reflorestamento. Essa proposta foi apresentada durante a COP9, na Itália, em 2003, conhecida como "Redução Compensada de Emissões" (Santilli *et al*., 2000).

Em 2005, durante a COP11, no Canadá, a "Coalizão de Nações Tropicais", liderada por Papua Nova Guiné e Costa Rica, incluiu o argumento de que os países tropicais são responsáveis por estabilizar o clima por meio de suas florestas e os custos para mantê-las deveriam ser divididos entre todos (Pinto *et al*., 2010).

Durante a COP13, em 2007, na Indonésia, a Decisão 2/CP13, como parte do "Caminho de Bali", o REDD, que passa a incluir a Degradação Florestal, foi incluído como um mecanismo a ser iniciado em 2012, quando terminasse o Protocolo de Quioto (UNFCCC, 2008). Seu conceito foi também ampliado para a inclusão da conservação florestal, manejo sustentável de florestas e aumento dos estoques de carbono florestais, ficando conhecido como REDD+. Para incentivar as ações de REDD+, o Banco Mundial lançou a Parceria de Carbono Florestal (FCPF[13]), fundo que aprovou propostas de diversos países, como Bolívia, Colômbia, Costa Rica, República Democrática do Congo, Gabão, Panamá, entre outros. No Brasil, em 2008, foi lançado o Fundo Amazônia, com o objetivo de arrecadar recursos por meio de doações voluntárias para o financiamento de ações que promovessem resultados de REDD+ (Pinto *et al*., 2010). O Fundo Verde para o Clima (GCF) também é uma das fontes de pagamento por resultados de REDD+.

Em 2009, durante a COP15, na Dinamarca, por meio do Acordo de Copenhague, os países desenvolvidos assumiram o compromisso de contribuir com

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[13] O FCPF é uma parceria global de governos, empresas, sociedade civil e povos indígenas focada em atividades de REDD+. Mais informações em: https://www.forestcarbonpartnership.org/.

US$ 10 bilhões ao ano, entre 2010 e 2012, e com US$ 100 bilhões ao ano a partir de 2020, para a mitigação e adaptação dos países mais vulneráveis frente aos efeitos da mudança do clima (UNFCCC, 2010). No entanto, estudos avaliaram a dificuldade de acompanhar a efetivação desse financiamento (Roberts *et al*., 2021) e mostraram que os países desenvolvidos relatam que forneceram apenas 83,3 dos seus 100 bilhões de dólares comprometidos em financiamento anual para o clima, sendo que apenas US$ 21 a US$ 24,5 bilhões podem ser considerados suporte real (OXFAM, 2023).

Em 2010, durante a COP16, no México, foram estabelecidas as sete “Salvaguardas de Cancun para REDD+”. As salvaguardas estabelecem que as iniciativas de REDD+ devem promover e apoiar:

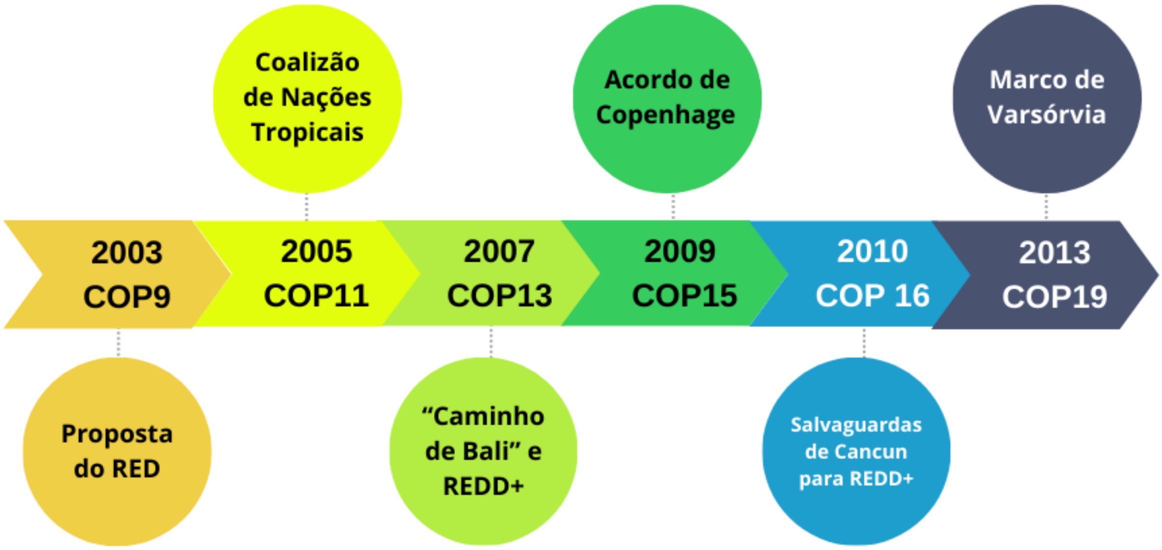
A. Ações complementares e consistentes com os objetivos de programas florestais e convenções e acordos internacionais relevantes;
B. Estruturas de governança florestais nacionais transparentes e eficazes, considerando a legislação e a soberania nacionais;
C. Respeito pelos conhecimentos e direitos dos povos indígenas e comunidades locais, levando-se em consideração as obrigações internacionais relevantes, as circunstâncias e as leis nacionais e a Declaração das Nações Unidas sobre os Direitos dos Povos Indígenas;
D. A participação plena e efetiva das partes interessadas relevantes, em particular povos indígenas e comunidades locais;
E. Ações consistentes com a conservação das florestas naturais e biodiversidade;
F. Ações para evitar os riscos de reversões de resultados de REDD+;
G. Ações para reduzir o deslocamento de emissões para outras áreas (UNFCCC, 2011).

O Marco de Varsóvia para REDD+, criado durante a COP19, em 2013, na Polônia, definiu um conjunto de sete decisões relacionadas a aspectos institucionais e de financiamento para pagamentos por resultados de REDD+ (Figura 1). Os países precisariam:

1. Desenvolver uma estratégia nacional de REDD+;
2. Submeter seus níveis de referência de emissões florestais (FREL)14 para avaliação de especialistas internacionais selecionados pela UNFCCC – processo chamado de Consulta e Análise Internacional (ICA);
3. Possuir um sistema nacional robusto e transparente que viabilize a mensuração e o relato sobre as atividades de REDD+;
4. Possuir um sistema de informação sobre a implementação das salvaguardas de REDD+.

O FREL e os resultados obtidos precisam ser relatados por meio de um Anexo Técnico ao Relatório de Atualização Bienal (BUR) e, após ICA, os resultados passam a ser verificados por meio de um Portal de REDD+ (UNFCCC, 2014). O Artigo 5 do Acordo de Paris incentiva os países a implementarem e apoiarem o REDD+ (UNFCCC, 2015).

> As Partes são encorajadas a tomar medidas para implementar e apoiar abordagens políticas e incentivos positivos para as atividades relacionadas à redução das emissões a partir do desmatamento e da degradação florestal, e o papel da conservação, do manejo sustentável de florestas e do reforço dos estoques de carbono das florestas (UNFCCC, 2015, Art. 5.2, tradução nossa).



Fonte: elaborado pela autora.

Figura 1. Principais marcos da construção do REDD+.

[14] O FREL é o nível a partir do qual os resultados das atividades de REDD+ são mensurados.

O Brasil apresentou sua Estratégia Nacional para REDD+ (ENREDD+) em 2016 (MMA, 2016). A Comissão Nacional para REDD+ (CONAREDD+; Brasil, 2023) foi recriada para coordenar, acompanhar, monitorar e revisar a implementação da ENREDD+. O Ministério do Meio Ambiente e Mudança do Clima (MMA) tem a função de Secretaria Executiva da CONAREDD+ e é também responsável por coordenar a elaboração do FREL nacional e solicitações de pagamento por resultados de REDD+ à UNFCCC.

O último FREL brasileiro à UNFCCC incluiu emissões líquidas de GEE provenientes do desmatamento para todos os biomas brasileiros, emissões líquidas de GEE provenientes da degradação no bioma Amazônia e remoções de vegetação secundária (UNFCCC, 2023b). As submissões anteriores incluíram apenas emissões brutas provenientes do desmatamento nos biomas Amazônia e Cerrado. Nenhuma das submissões brasileiras considerou o reservatório de carbono do solo nas estimativas.

O Brasil recebeu quase 1,5 bilhão de dólares por resultados de REDD+ (~ 317 milhões de tCO_2eq) do Fundo Amazônia (93%) e do Programa para pioneiros em REDD+ (REM, 7%). Esses recursos foram repassados pelo Governo da Noruega (82%), pela Petrobrás (1%), pela República Federal da Alemanha (9%), pelo Governo do Reino Unido (3%) e pelo GCF (6%) (MMA, 2024).

REDD+ no Mercado Voluntário de Carbono

Além dos mecanismos de incentivo introduzidos pela UNFCCC, o Mercado Voluntário de Carbono (MVC) florestal vem atuando fortemente no Brasil, desenvolvendo projetos privados de diferentes categorias, dentre elas, os de emissões evitadas de desmatamento, tratadas como REDD+. O MVC tem atuação principalmente de atores privados, que compram créditos de forma voluntária para demonstrar responsabilidade social corporativa (Goldstein e Gonzalez, 2014). No MVC, há a comercialização de Reduções de Emissões Verificadas ou Voluntárias (VER) ou compensação de carbono (*offsets* de carbono) (Lima, 2007).

Geralmente, esses projetos são elaborados baseados em padrões que determinam as metodologias a serem utilizadas, podendo considerar ou não requisitos quanto ao respeito a salvaguardas e à obtenção de cobenefícios sociais e ambientais (Stanley e Hamilton, 2012). Os projetos são certificados e registrados por certificadoras, como a VERRA[15], a Puro.earth[16], o *American Carbon Registry* (ACR)[17], o *Gold Standard*[18] e a Cercarbono[19].

As iniciativas do MVC florestal podem ser realizadas em formato de:

1. Projeto, em uma área determinada, como propriedades privadas, parques, territórios indígenas ou outras unidades de terra;
2. Programa, em uma jurisdição, sendo esta nacional ou subnacional.

O conceito aplicado nas metodologias desses projetos é diferente daquele mencionado na UNFCCC, uma vez que não considera emissões “reduzidas” e sim “evitadas”, as quais, por sua vez, podem ser “planejadas” ou “não planejadas” (VCS, 2024).

Em 2022, foram gerados 254 $MtCO_2e$ no MVC no mundo, sendo em sua maioria certificados pelo Padrão de Carbono Verificado (VCS*)* da certificadora VERRA. Aproximadamente 45% dos créditos foram oriundos de projetos relacionados ao setor de LULUCF e, destes, 52% foram de projetos de REDD+ (Donofrio e Procton, 2023).

Coalizão LEAF

Em 2021, os governos da Noruega, do Reino Unido, dos Estados Unidos e líderes do setor privado anunciaram a Coalizão LEAF (Reduzindo Emissões por meio da aceleração do Financiamento Florestal)[20]com o intuito de fornecer recursos financeiros aos governos florestais tropicais e subtropicais (nacionais ou subnacionais) para que avançassem mais rapidamente na eliminação do desmatamento e alcançassem suas NDCs. A Coalizão LEAF busca apoiar países inteiros ou jurisdições subnacionais por meio do pagamento por créditos oriundos de resultados de programas de REDD+.

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[15] VERRA. Disponível em: https://registry.verra.org/app/search/VCS/All%20Projects. Acesso em: 22 mar. 2023.
[16] Puro.earth. Disponível em: https://registry.puro.earth/carbon-sequestration/retirements.Acesso em: 22 mar. 2023.
[17] American Carbon Registry. Disponível em: https://acr2.apx.com/myModule/rpt/myrpt.asp?r=111. Acesso em: 22 mar. 2023.
[18] Gold Standard. Disponível em: https://registry.goldstandard.org/projects?q=&page=1. Acesso em: 22 mar. 2023.
[19] Cercarbono. Disponível em: https://www.cercarbono.com/. Acesso em: 22 mar. 2023.
[20] Coalizão LEAF. Disponível em: https://www.leafcoalition.org/pt/home. Acesso em 01 maio 2022.

A Emergent é uma organização sem fins lucrativos responsável por intermediar os contratos, ou Acordos de Compra de Reduções de Emissões (ERPA), entre governos que querem vender seus créditos com compradores corporativos e governos doadores da Coalizão LEAF.

Nesse sentido, a submissão de propostas à Coalizão LEAF[21] considera quatro "naturezas de transação", sendo a primeira voltada para contribuintes soberanos, que não usarão os créditos para contabilidade em suas NDCs, e outras três voltadas para o setor privado, nas quais:

1. Os compradores do setor privado fornecem pagamentos baseados em resultados sem assumirem a titularidade dos créditos;
2. Os compradores do setor privado assumem a titularidade dos créditos, sendo que o país fornecedor pode contabilizá-los em sua NDC;
3. Os compradores do setor privado assumem a titularidade dos créditos e o país fornecedor precisa fazer ajustes correspondentes na contabilidade de sua NDC.

A maior parte da demanda corporativa da Coalizão LEAF se enquadra na terceira opção.

Para garantir a integridade das salvaguardas socioambientais, a Coalizão LEAF compra apenas créditos de carbono florestal que atendam aos critérios do Padrão de Excelência Ambiental de REDD+ (TREES) da Arquitetura para Transações de REDD+ (ART), também conhecido simplesmente como 'ART/TREES'.

ART/TREES

O ART possui um secretariado, hospedado pela Winrock International[22], que é responsável pela operacionalização do programa. O objetivo do ART é promover a integridade socioambiental e a ambição de reduções e remoções de GEE do setor de LULUCF. O padrão TREES inclui elementos técnicos, requisitos de proteção

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[21] Modelo de proposta à Coalizão LEAF. Disponível em:https://resources.leafcoalition.org/wp-content/uploads/2023/05/LEAF-Emergent_Call-for-Proposals-3rd-Window_template.docx. Acesso em 02 Maio 2024.

[22] A Winrock International fornece soluções para desafios sociais, agrícolas e ambientais no mundo. Disponível em: https://winrock.org/. Acesso em 01 mar. 2024.

ambiental, social e de governança, condições de verificação e disposições para evitar dupla contabilidade.

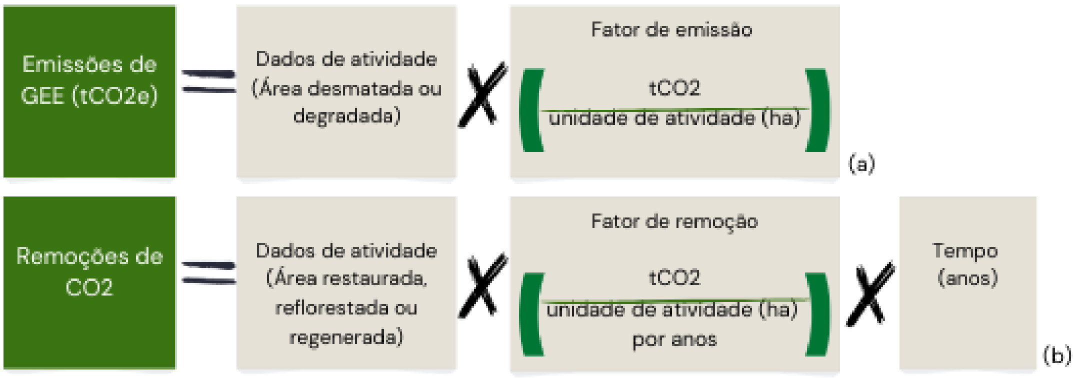
Para isso, o ART[23] fornece guias que orientam sobre como deve ser feita a contabilidade do nível de creditação (ART, 2021a) e sobre como deveriam ser respeitadas as salvaguardas ambientais, sociais e de governança (ART, 2021b).

A primeira etapa do ciclo do ART é a submissão da Nota de Conceito TREES (ART, 2021c), para então ser submetido o Documento de Registro TREES (ART, 2021d). Há, então, um processo de validação do documento pelo Conselho do ART. Em seguida, deve ser submetido um Relatório Inicial de Monitoramento TREES, que deve ser verificado pelo Órgão de Validação e Verificação (VVB) e aprovado pelo Conselho do ART para a emissão de créditos TREES. Os relatórios de monitoramento subsequentes devem ser enviados dentro do prazo de doze meses após os anos civis 1, 3 e 5 de cada período de creditação. O período de creditação do TREES é de cinco ano civis.

Governos nacionais ou subnacionais podem participar do ART, sendo que o período de creditação para governos subnacionais se encerra em 2030, quando a contabilidade deve ser em nível nacional (ART, 2021a).

Todas as atividades de REDD+ são elegíveis ao TREES, com exceção de remoções de florestas que permanecem florestas. A contabilidade das emissões segue as mesmas orientações do IPCC, ou seja, considera os diferentes compartimentos de carbono (biomassa viva acima e abaixo do solo, matéria orgânica morta – em pé, caída e serrapilheira – e matéria orgânica do solo (IPCC, 2006) (Figura 2). Os GEE considerados são dióxido de carbono (CO_2), metano (CH_4) e óxido nitroso (N_2O).

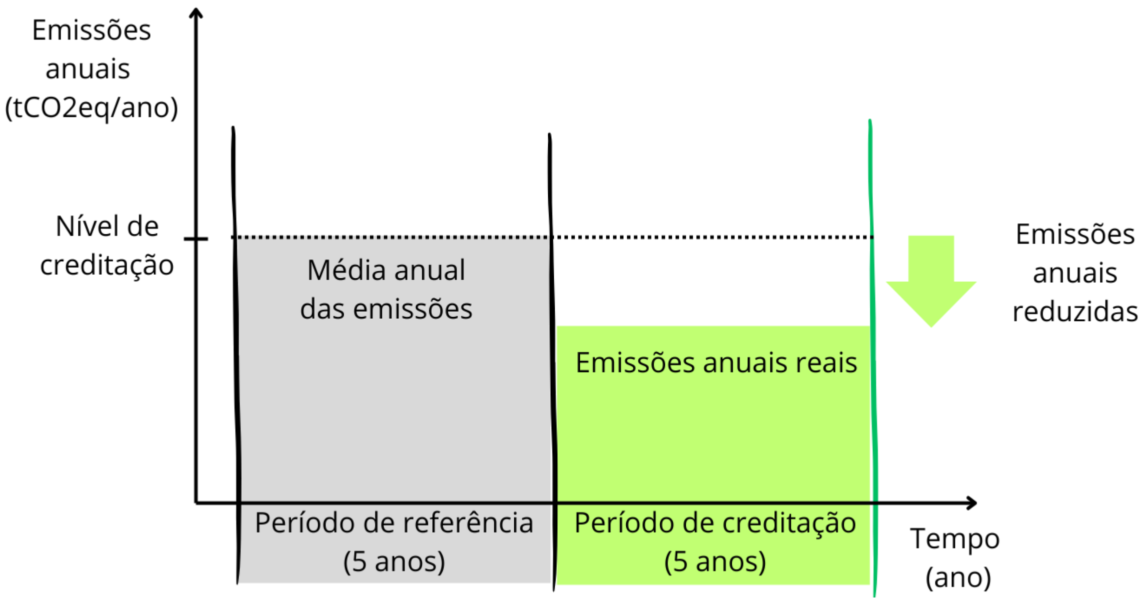
[23]ART. Disponível em: https://www.artredd.org/trees/#about-trees. Acesso em: 22 nov. 2023.



Fonte: adaptado de ART, 2021a.

Figura 2. Contabilidade de emissões de GEE (a) e remoções (b) segundo o padrão TREES.

O Nível de Creditação TREES para emissões é calculado usando uma média histórica de cinco anos de emissões de desmatamento e degradação, a partir do período diretamente anterior ao período de creditação (Figura 2). As remoções somente serão elegíveis quando as emissões do desmatamento e degradação forem reduzidas abaixo do Nível de Creditação TREES durante o mesmo ano. Remoções oriundas da conversão não florestal em floresta são elegíveis ao TREES, desde que ocorram em terras que não foram florestais por um período de cinco anos antes do início das atividades de plantio ou restauração.



Fonte: elaborado pela autora.

Figura 3. Nível de creditação e período de creditação do padrão TREES.

O TREES considera a aplicação de fatores de mitigação de risco de reversão (ou seja, novo aumento do desmatamento). O valor padrão é 25%, podendo ser aplicados descontos em função das circunstâncias da jurisdição:

- **Fator de Mitigação 1 (-5%):** Decretos executivos ou legislativos ativamente implementados e comprovadamente apoiando atividades de REDD+;
- **Fator de Mitigação 2 (-10%):** Variabilidade anual de desmatamento inferior a 15% nos 5 anos anteriores;
- **Fator de Mitigação 3 (-5%):** Demonstração de ações, planos ou estratégias de mitigação de reversão nacional (ART, 2021a).

A combinação desses fatores permite a avaliação do *Buffer* a ser deduzido dos créditos gerados (Tabela 1).

Tabela 1. Avaliação dos descontos para mitigação de riscos de reversão (*Buffer)* do padrão TREES.

Avaliação	**Desconto para mitigação de reversão *Buffer* (%)**
Fator fixo quando sem fatores de mitigação	25
Fator fixo quando houver fator de mitigação 1	20
Fator fixo quando houver fator de mitigação 2	15
Fator fixo quando houver fator de mitigação 3	20
Fator fixo quando houver fatores de mitigação 1 e 2	10
Fator fixo quando houver fatores de mitigação 1 e 3	15
Fator fixo quando houver fatores de mitigação 2 e 3	10
Fator fixo quando houver fatores de mitigação 1, 2 e 3	5

Fonte: adaptado de ART (2021a).

O TREES ainda inclui deduções de vazamento (ou seja, desmatamento em novas áreas devido à implantação do programa), que variam conforme o tamanho da área florestal nacional incluída no TREES em relação ao país. Há uma dedução de 20% caso essa área seja inferior a 25%; de 10% caso essa área represente entre 25 e 60%; de 5% caso represente entre 60 e 90%, havendo isenção de desconto quando essa área for maior que 90%. Também há de se considerar o desconto por incertezas, que devem ser calculadas pela simulação de Monte Carlo.

Por fim, os créditos TREES são estimados conforme a Figura 4, sendo que os créditos por remoção poderiam ser considerados, mas não obrigatoriamente.

TREES ERRt = GHG ERt - BUFt - LEAKt - UNCt

ONDE:	
TREES ERR t	Créditos TREES no ano t; tCO2e
BUF t	Buffer TREES no ano t; tCO2e
LLEAK t	Dedução por vazamento TREES no ano t; tCO2e
UNC t	Incertezas TREES no ano t; tCO2e
GHG ET t	Emissões evitadas no ano t; tCO2e

Fonte: adaptado de ART, 2021a.

Figura 4. Estimativa de créditos conforme o TREES.

Nesting ou aninhamento

Um dos requisitos do ART/TREES é o aninhamento (ou *nesting*, em inglês) de projetos locais em programas jurisdicionais de REDD+. O aninhamento é uma abordagem sistemática que permite a contabilização e o relato de reduções de emissões de iniciativas de REDD+ em várias escalas e o acesso a múltiplas fontes de financiamento em diferentes níveis, o que está relacionado com transparência e prevenção da dupla contagem. Um sistema de REDD+ aninhado exige arranjos institucionais; instrumentos legais; Mensuração, Relato e Verificação (MRV); repartição de benefícios; salvaguardas e gestão de riscos (World Bank Group, 2021).

Os países freqüentemente avançam em programas jurisdicionais com projetos privados gerando créditos de carbono simultaneamente, criando uma situação desafiadora principalmente com relação à contabilização de GEE. Construir um sistema aninhado requer ajustes nos programas e projetos existentes (World Bank Group, 2021).

No estudo desenvolvido pelo Banco Mundial, os autores mencionam três decisões fundamentais para o desenvolvimento de um sistema de REDD+ aninhado (World Bank Group, 2021):

1. **Grau de centralização (ou descentralização) para REDD+**: uma estrutura centralizada concentra-se no recebimento de pagamentos na escala jurisdicional, com um sistema de repartição de benefícios para distribuir benefícios de carbono (monetários ou não monetários); uma estrutura descentralizada permite a implementação de programas e projetos em uma escala menor;

2. **O papel dos atores não governamentais na implementação de REDD+ (setor privado, sociedade e organizações não governamentais)**: o governo precisa decidir a melhor forma de integrar com estas entidades;

3. **Tipos de financiamento climático a acessar**: encorajar o mercado de carbono no nível de projeto, direcionar esforços para pagamentos de não mercado no nível jurisdicional, limitar o crédito a apenas certos níveis ou também decidir que atividades de REDD+ são mais apropriadas em nível de projeto ou jurisdição.

Hamrick *et al*. (2021) mencionam que a implementação destes diferentes caminhos dependerá principalmente do volume de projetos existentes, se os créditos já foram vendidos e se as linhas de base estão alinhadas. Para garantia de aninhamento, é basilar definir a linha de base para estimar as reduções de emissões, que podem variar significativamente entre programas jurisdicionais e projetos, e quais atividades, reservatórios e gases serão considerados.

O Banco Mundial (World Bank Group, 2021) apresenta quatro possibilidades de abordagens para Sistemas Jurisdicionais de REDD+ e consideram apenas as opções '2' e '3' como sistemas aninhados:

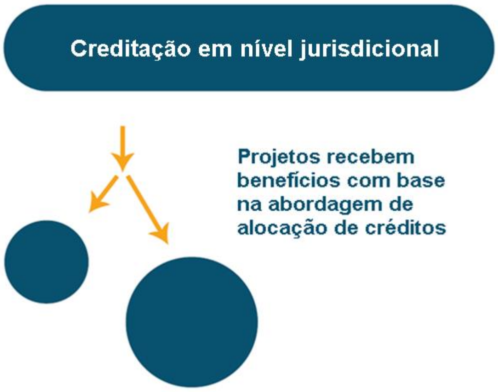
1. **Contabilização e creditação de projetos via programa jurisdicional de REDD+:** há contabilização de redução de emissões apenas em escala nacional. Os atores locais recebem pagamentos do governo como parte dos acordos de repartição de benefícios definidos pelo governo (Figura 5). O governo tem controle total sobre a contabilização e a atribuição inicial dos fundos gerados pelo programa, mas os benefícios podem ser canalizados através de meios não governamentais abaixo de um

determinado nível. Este modelo é o mais fácil de implementar nos casos em que o setor público detém controle total sobre suas terras, recursos e gestão florestal. Neste caso, o governo deseja apoiar programas jurisdicionais através de financiamento baseado em resultados de REDD+. Os mercados de carbono não são uma fonte direta de financiamento para projetos de REDD+, uma vez que o financiamento de carbono é recebido através dos acordos da repartição de benefícios do programa jurisdicional.

Fonte: adaptado de World Bank Group (2021).

Figura 5. Contabilização e creditação de projetos no programa jurisdicional de REDD+ (apenas Programa Jurisdicional).

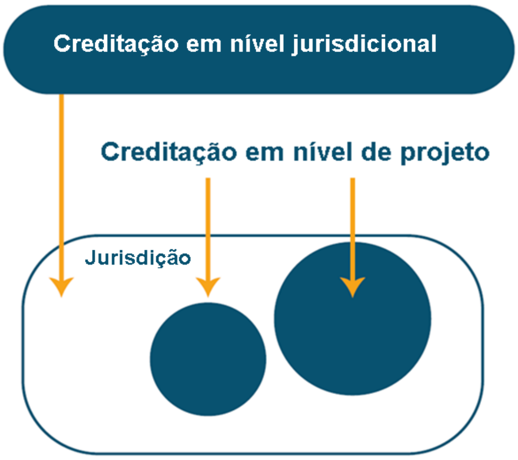
2. **Abordagem de aninhamento centralizada:** as reduções de emissões são contabilizadas em escala nacional, porém, como o governo deseja encorajar projetos através de incentivos que estão ligados ao desempenho, desenvolve com os projetos um sistema de repartição dos benefícios que recebe por meio da monetização das reduções de emissão em escala nacional. Os projetos aprovados podem receber pagamentos ou redução de emissões do governo, de acordo com seus acordos de repartição de benefícios e sistema de alocação das reduções de emissões (Figura 6). O principal objetivo dessa abordagem é incentivar projetos a contribuir para o desempenho nacional. O governo está interessado em acessar recursos de REDD+ fornecidos pelo GCF, FCPF, ou outros acordos bilaterais, ou crédito baseado no mercado em escala nacional e deseja criar incentivos para programas ou projetos subnacionais.



Fonte: adaptado de World Bank Group (2021).

Figura 6. Abordagem de aninhamento centralizada em sistemas de REDD+.

3. **Abordagem de aninhamento descentralizada:** o crédito e a monetização das reduções de emissões ocorrem tanto em escala nacional como em escala do projeto. Os projetos podem gerar e emitir diretamente redução de emissões negociáveis que não dependem do desempenho nacional (Figura 7). Dependendo do contexto, o governo pode ser obrigado a subtrair créditos do projeto dos créditos jurisdicionais. O governo regulamenta o MRV e as salvaguardas dos projetos para promover o alinhamento com as abordagens nacionais. Neste modelo, os projetos podem acessar créditos de carbono em conformidade com as regras do governo, mas sem intermediação governamental. Este modelo reconhece os direitos das comunidades e proprietários privados de monetizar os direitos de carbono e se beneficiar das reduções de emissões em suas terras. O governo deseja envolver financiamento do setor privado, incluindo investimentos diretos em REDD+, e financiamento baseado em resultados de REDD+ em escala nacional.



Fonte: adaptado de World Bank Group (2021).

Figura 7. Abordagem de aninhamento descentralizada em sistemas de REDD+.

4. **Creditação apenas por projetos (sem Programa Jurisdicional):** o crédito só ocorre em escala de projeto (Figura 8), e o governo não pretende monetizar as reduções de emissões em escala nacional. Esta abordagem aplica-se a países que não dependem de pagamentos nacionais de carbono para financiar programas governamentais. O governo pode querer regulamentar os projetos, a fim de promover a equidade na forma como os benefícios do carbono são usufruídos, aumentar a integridade ambiental dos projetos ou para garantir que as salvaguardas estão sendo aplicadas. Este modelo permite regular os projetos a fim de atingir esses objetivos e/ou alinhar o MRV dos projetos com a contabilidade nacional de GEE, o que pode ser um fator relevante frente a previstas futuras transações no âmbito do Artigo 6 do Acordo de Paris.

Fonte: adaptado de World Bank Group (2021).

Figura 8. Creditação apenas por projetos (sem Programa Jurisdicional)

O ART permite diferentes opções de aninhamento, considerando cinco diferentes cenários (Tabela 2).

Tabela 2. Cenários de aninhamento do padrão TREES.

Cenário	Descrição
1	A jurisdição chega a um acordo com os proprietários do carbono (por exemplo, povos Indígenas, comunidades locais, proprietários privados, desenvolvedores de projetos) e reparte uma parte dos créditos, receitas ou outros benefícios com o(s) proprietário(s)
2	A jurisdição chega a um acordo com os proprietários do carbono e permite atividades em escala de projeto, mas estes aplicam a linha de base do nível de creditação jurisdicional, sendo o valor total dos créditos gerados pelos projetos descontados da jurisdição
3	A jurisdição chega a um acordo com os proprietários do carbono e permite atividades em escala de projeto, utilizando a linha de base individual, sendo o valor total dos créditos gerados pelos projetos descontados da jurisdição
4	A jurisdição não chega a um acordo com os proprietários de carbono, que desenvolvem os projetos e o valor total dos créditos gerados é descontado da jurisdição
5	A jurisdição não chega a um acordo os proprietários de carbono, que optam por não participar do ART. A jurisdição propõe abordagem para alocar reduções das áreas não acordadas e os créditos são descontados da jurisdição

Fonte: elaborado pela autora a partir de ART (2021a).

Em suma, a implementação eficaz do REDD+ no Brasil, discutida ao longo deste tópico, destaca a importância de um sistema robusto de aninhamento e governança integrada para garantir a credibilidade e a sustentabilidade das iniciativas de REDD+. O atendimento a padrões internacionais, como o ART/TREES, e a participação em coalizões globais, como a Coalizão LEAF, foram identificadas como estratégias categóricas para reforçar o compromisso do país com a mitigação da mudança do clima e a conservação florestal. Além disso, esses esforços não apenas contribuem para a redução das emissões de GEE, mas também promovem cobenefícios sociais e ambientais, fortalecendo a posição do Brasil nos acordos internacionais de clima. Portanto, com uma abordagem coordenada e transparente, o Brasil pode maximizar o potencial do REDD+ e assegurar um futuro mais sustentável e resiliente para suas florestas e comunidades.

3.4. O BRASIL NOS ACORDOS INTERNACIONAIS DE CLIMA

NDC Brasileira

Em 2016, o Brasil formalizou internamente seu compromisso perante o Acordo de Paris (Brasil, 2017a). O país apresentou sua Contribuição Nacionalmente Determinada pretendida (iNDC) em 2015 (República Federativa do Brasil, 2015), incluindo metas de mitigação, adaptação e meios de implementação. Para o setor de LULUCF, a iNDC do Brasil previa metas para a redução de emissões por desmatamento e degradação florestal e para o manejo sustentável das florestas, a conservação e o aumento dos estoques de carbono florestal (REDD+).

O Brasil apresentou uma segunda atualização de sua NDC em dezembro de 2020 e uma terceira atualização em março de 2022, com metas absolutas para toda a economia (*economy-wide*) de reduzir suas emissões de GEE em 37% até 2025 e em 50% até 2030, em relação às emissões de 2005, e alcançar a neutralidade climática até 2050 (UNFCCC, 2022). Na quarta atualização da NDC brasileira, de outubro de 2023, o Brasil se comprometeu com as metas absolutas de emissões líquidas de 1,32 $GtCO_2e$[24] em 2025 e 1,20 $GtCO_2e$ em 2030, o que equivale a reduções de 48,4% e 53,1% em comparação às emissões de 2005, considerando o Potencial de Aquecimento Global[25] (GWP) do 5º Relatório do IPCC (AR-5). O Brasil

[24] CO_2e é uma medida métrica utilizada para comparar as emissões de vários GEE baseado no potencial de aquecimento global de cada gás.
[25] O Potencial de Aquecimento Global (GWP) é uma medida de quantas vezes mais calor determinada quantidade de um GEE retém na atmosfera em relação a uma mesma quantidade de CO_2, em determinado horizonte de tempo (IPCC, 2013).

mantém a meta de alcance de neutralidade de emissões até 2050 e uma perspectiva *economy-wide* (UNFCCC, 2023a).

Relatos do Brasil à UNFCCC

A Comunicação Nacional é um dos principais instrumentos que apresenta como as partes estão cumprindo seus compromissos no âmbito da UNFCCC, incluindo os Inventários de Emissões Antrópicas e Remoção de GEE não Controlados pelo Protocolo de Montreal[26] (Inventário Nacional). O Brasil, como país em desenvolvimento (não Anexo-1), comprometeu-se a publicar sua Comunicação Nacional[27] a cada quatro anos.

A Comunicação Inicial foi publicada em 2004, com estimativas de emissões GEE de 1990 a 1994 (Brasil, 2004). A Segunda Comunicação Nacional, submetida em 2010, atualizou as emissões até 2005 (Brasil, 2010), seguida pela Terceira Comunicação Nacional em 2016, com estimativas até 2010 (Brasil, 2016). A Quarta Comunicação Nacional, submetida em 2020, atualizou as estimativas até 2016 (Brasil, 2020a).

O MCTI publicou seis edições das Estimativas Anuais de Emissões de GEE, tendo sido a primeira em 2013 e a última em 2022.

O Brasil também submeteu quatro Relatórios de Atualização Bienal (BURs) à UNFCCC: o primeiro em 2014 (Brasil, 2014b), o segundo em 2017 (Brasil, 2017b), o terceiro em 2019 (Brasil, 2019) e o último em 2020 (Brasil, 2020b).

Na Tabela 3 apresentamos os anos dessas publicações e anos inventariados em cada uma delas.

A partir de 2024, o Brasil precisará submeter Relatórios Bienais de Transparência (BTR) a cada dois anos (UNFCCC, 2019).

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[26] Os gases estimados nos inventários são o dióxido de carbono (CO_2), o metano (CH_4), o óxido nitroso (N_2O), os hidrofluorcarbonos (HFC), os perfluorcarbonos (PFCs) e o hexafluoreto de enxofre (SF_6). Outros gases, como monóxido de carbono (CO), óxidos de nitrogênio (NOx) e outros compostos orgânicos voláteis não metano (NMVOC) são GEE indiretos, estimados sempre que possível.

[27] Decisão 17/CP.8: Guidelines for the preparation of national communications from Parties not included in Annex I to the Convention. Disponível em: https://unfccc.int/files/meetings/workshops/other_meetings/application/pdf/dec17-cp.pdf.Acesso em: 2 abril2022.

Tabela 3. Comunicações Nacionais, Relatórios de Atualiação Bienal (BUR) e Estimativas Anuais de gases de efeito estufa (GEE) publicadas pelo Brasil.

Publicação	Ano de publicação	Anos inventariados
Comunicação Inicial	2004	1990 a 1994
Segunda Comunicação Nacional	2010	1990 a 2005
Terceira Comunicação Nacional	2016	1990 a 2010
Quarta Comunicação Nacional	2020	1990 a 2016
1º Relatório de Atualização Bienal (BUR)	2014	1994 a 2010
2º Relatório de Atualização Bienal (BUR)	2017	1994 a 2012
3º Relatório de Atualização Bienal (BUR)	2019	1994 a 2015
4º Relatório de Atualização Bienal (BUR)	2020	1994 a 2016
1ª Edição das Estimativas Anuais de GEE	2013	1990 a 2010
2ª Edição das Estimativas Anuais de GEE	2014	1990 a 2012
3ª Edição das Estimativas Anuais de GEE	2016	1990 a 2014
4ª Edição das Estimativas Anuais de GEE	2017	1990 a 2015
5ª Edição das Estimativas Anuais de GEE	2020	1990 a 2016
6ª Edição das Estimativas Anuais de GEE	2022	1990 a 2020

Em 2005, ano de referência para as metas de redução da NDC brasileira, as emissões de GEE do setor de LULUCF representaram 62% das emissões do país (1,58 Gg CO_2e de um total de 2,56 Gg CO_2e). Em 2016, as emissões do setor de LULUCF representaram 25% (0,40 Gg CO_2e) das emissões totais do país (1,58 Gg CO_2e), considerando a métrica GWP-AR5 (Brasil, 2020a). O bioma Amazônia representou 64% das emissões do setor de LULUCF em 2016 (MCTI, 2020).

Política Nacional sobre Mudança do Clima (PNMC)

A Política Nacional sobre Mudança do Clima (PNMC) estabelece diretrizes para reduzir as emissões antrópicas de GEE, aumentar sumidouros, implementar medidas de adaptação à mudança do clima e estimular o desenvolvimento do Mercado Brasileiro de Redução de Emissões (MBRE)[28]. Entre os instrumentos da PNMC estão o Plano Nacional sobre Mudança do Clima, o Fundo Nacional sobre Mudança do Clima, os Planos de Ação para Prevenção e Controle do Desmatamento nos biomas, as Comunicações Nacionais à UNFCCC, as resoluções

[28] O Mercado Brasileiro de Redução de Emissões corresponde ao conjunto de instituições, regulamentações, sistemas de registro de projetos e centro de negociação para viabilizar negócios no mercado ambiental de forma organizada e transparente.

da Comissão Interministerial de Mudança Global do Clima, entre outros (Brasil, 2009).

Os instrumentos institucionais para a atuação da PNMC incluem o Comitê Interministerial de Mudança do Clima (CIM), a Comissão Interministerial de Mudança Global do Clima, a Rede Brasileira de Pesquisas sobre Mudanças Climáticas Globais (Rede Clima) [29] e a Comissão de Coordenação das Atividades de Meteorologia, Climatologia e Hidrologia (Brasil, 2009). O CIM monitora e promove a implementação das ações e das políticas públicas no âmbito do Poder Executivo Federal relativas à PNMC. O CIM é composto por diversos ministérios e representantes da sociedade civil, incluindo a Casa Civil da Presidência da República, que o preside (Brasil, 2024).

Por meio da PNMC, o Brasil adotou o compromisso nacional voluntário de reduzir entre 36,1% e 38,9% suas emissões projetadas até 2020, tendo sido estas dispostas por meio de decreto (Brasil, 2018).

Em resumo, o compromisso do Brasil com os acordos internacionais de clima, evidenciado pelas atualizações contínuas de sua NDC e pelos relatórios submetidos à UNFCCC, demonstra a seriedade com que o país aborda a mitigação da mudança do clima. As metas ambiciosas de redução de emissões de GEE, especialmente no setor de LULUCF, refletem a importância de políticas robustas e de uma governança eficaz. A PNMC e seus instrumentos institucionais são fundamentais para coordenar e implementar essas ações, garantindo que o Brasil não apenas cumpra seus compromissos internacionais, mas também contribua significativamente para os esforços globais de combate à mudança do clima. A continuidade e o fortalecimento dessas iniciativas são essenciais para alcançar a neutralidade climática até 2050 e promover um desenvolvimento sustentável e resiliente.

[29] A Rede Clima tem como finalidade impulsionar a geração de conhecimento e o avanço científico e tecnológico na área de mudança do clima, resultantes do intercâmbio de informações e da integração de competências de especialistas, pesquisadores, grupos de pesquisa e instituições científicas, tecnológicas e de inovação que possuam reconhecida competência nas áreas do conhecimento relevantes ao tema.

4. RESULTADOS

A pesquisa buscou avaliar as etapas centrais do REDD+, que aqui chamamos de ‘círculo virtuoso do REDD+’: i) **agir**, direcionando ações para reduzir o desmatamento e a degradação florestal na Amazônia Brasileira; ii) **mensurar**, garantindo, para além de robustez científica, legitimidade legal e institucional na mensuração de emissões e remoções do setor de LULUCF do país e iii) **captar**, a partir do cumprimento de requisitos que garantam integridade na contabilidade dos créditos de carbono gerados e possibilitem ao país acessar diferentes fontes de financiamento que pagam por resultados de REDD+, que, por sua vez, irão retroalimentar ações de combate ao desmatamento, aumento das áreas florestais e valorização de serviços ambientais (Figura 9).

Os resultados são apresentados em formato de três artigos científicos, em inglês, que serão submetidos a revistas científicas, de forma a garantir o compartilhamento das contribuições no meio acadêmico de maneira mais ampla. Os artigos refletem as etapas do ‘círculo virtuoso do REDD+’ e os objetivos específicos traçados (Tabela 4).

A metodologia utilizada envolveu revisão bibliográfica de literaturas “cinza” e científica, análises documentais, consultas a atores do governo que trabalham com a agenda climática e análises quantitativas. A metodologia é descrita de forma detalhada nos próprios artigos apresentados a seguir.

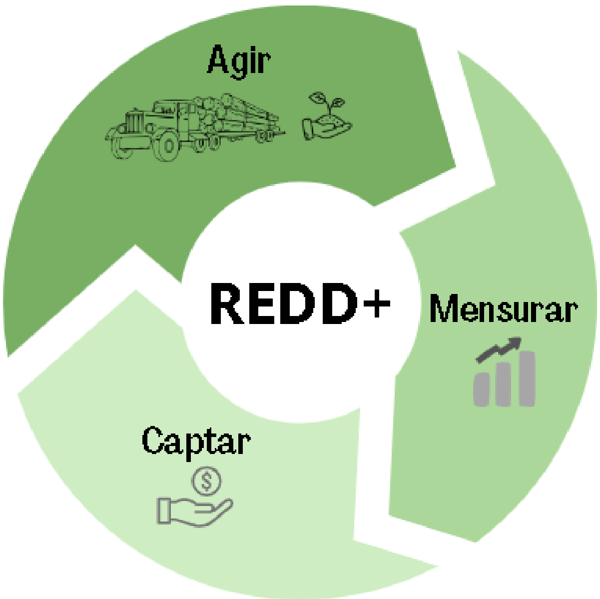


Figura 9. O ‘ciclo virtuoso’ do REDD+.
Fonte: elaborado pela autora.

Tabela 4. Estrutura de apresentação dos resultados da pesquisa.

Hipótese
A implementação do Código Florestal garante a redução do desmatamento na Amazônia e a utilização de dados oficiais, lastreados em ciência, garante a transparência na mensuração e relato de emissões e remoções de GEE do setor de LULUCF
Objetivo geral
Avaliar as etapas do círculo virtuoso do REDD+ no Brasil, desde a efetividade de políticas públicas que visam diminuir o desmatamento na Amazônia brasileira, até a identificação de estratégias de mensuração que determinem robustez nos relatos de emissões e remoções de GEE do setor de LULUCF, criando perspectivas para a captação

	Objetivo específico	Artigo científico	Ferramental	Resultados obtidos
Agir	Avaliar as taxas de desmatamento e emissões associadas projetadas até 2050 na Amazônia brasileira, a partir do arcabouço político institucional que regula o setor de LULUCF	Modeling deforestation in the Brazilian Amazon and its importance in strengthening environmental policies	- Revisão bibliográfica de literatura "cinza" e científica - Análises quantitativas - Coleta de dados ativa junto a pesquisadores	- Tabelas com síntese das metodologias dos estudos de modelagem de uso da terra - Gráficos com resultados de desmatamento e emissões de GEE associadas dos diferentes cenários para a Amazônia brasileira até 2050 - Análise do impacto da implementação de políticas públicas nas emissões de GEE e relação com metas da NDC brasileira
Mensurar	Analisar a governança e a metodologia de compilação do IV Inventário Brasileiro de Emissões de GEE do setor de LULUCF Desenvolver diretrizes para aprimorar a mensuração das emissões e remoções de GEE do setor de LULUCF, com base nas avaliações realizadas	Scientific and political advances to transparent and complete measurement of Brazilian emissions and removals in the land-use sector	- Revisão bibliográfica de literatura "cinza" e científica - Análise documental sobre políticas, programas, planos e bases de dados disponíveis - Consulta a três pontos focais do governo que trabalham na agenda de clima (optaram por não se identificar)	- Lacunas no monitoramento de emissões e remoções de GEE do setor de LULUCF nos Inventários de Emissões - Plataformas e dados disponíveis quanto aos diferentes planos, programas e políticas relacionadas ao setor de LULUCF - Desenho de proposta de arranjo institucional para geração de dados para garantir transparência, completude e sustentabilidade nos relatos brasileiros de emissões e remoções de GEE do setor de LULUCF
Captar	Examinar o cenário atual do Brasil em relação ao registro de projetos e programas de REDD+, utilizando o estado do Pará como estudo de caso	Nesting private carbon projects within jurisdictional programs to access REDD+ results payment: the case of Pará	- Revisão bibliográfica de literatura "cinza" e científica - Solicitação de dados de terceiros (PNUD) - Análises quantitativas - Análise documental de instrumentos da CONAREDD+ e SBCE	- Lições aprendidas para o Brasil quanto às experiências de aninhamento em outros países - Nível de creditação ART/TREES e créditos obtidos em 2023, considerando o impacto dos projetos privados - Papel da CONAREDD+ no aninhamento de projetos privados de REDD+ no Brasil

4.1. MODELING DEFORESTATION IN THE BRAZILIAN AMAZON AND ITS IMPORTANCE IN STRENGTHENING ENVIRONMENTAL POLICIES

Summary

The Brazilian Amazon has experienced extensive deforestation in recent decades, primarily driven by human activities such as logging, livestock, burning, and urbanization. These activities emit significant amounts of greenhouse gases (GHG) into the atmosphere and degrade ecosystems and environmental conditions. Various studies have projected land use and cover through computational models to better understand the factors influencing these changes and develop strategies for future mitigation. We compiled projections for the deforestation rate for the Brazilian Amazon from different groups by 2050. Our analysis revealed that modeling frameworks integrating the energy sector, agriculture demand, land speculation, and grabbing resulted in more realistic deforestation projections. Despite differences in modeling characteristics, all studies indicated that under a Business as Usual (BAU) scenario, Brazil will not meet its Land Use, Land-Use Change, and Forestry (LULUCF) goals as outlined in the country's Nationally Determined Contribution (NDC) under the United Nations Framework on Climate Change (UNFCCC). Moreover, although not evaluated in this study, the scenario would likely worsen when considering emissions from forest degradation and the increasing deforestation rates in the Cerrado biome. All the projections underscored the necessity of implementing the Forest Code, alongside enhancing ecosystem protection and land regularization and valuing the environmental services. In this context, we underscore that it would be fundamental to consider the National GHG Inventory database to formulate the NDC goals to guarantee coherence once this is the main instrument to monitor the country´s commitment under the UNFCCC. Failure to reduce deforestation also jeopardizes Brazil's ability to access payments for results from Reducing Emissions from Deforestation and Forest Degradation (REDD+). These payments are crucial for implementing mechanisms that value standing forests on a large scale, such as payment for environmental services (PES) and maintaining the 'virtuous' circle of conservation and sustainable development.

4.1.1. Introduction

Despite having one of the most extensive areas of forest cover in the Amazon biome, Brazil has experienced significant deforestation in recent decades (INPE, 2024). This deforestation is primarily driven by human activities such as logging, livestock, burning, and urbanization (Almeida *et al*., 2010), and the expansion of agriculture has positioned Brazil as a leading exporter of agricultural or mineral commodities (Silva Bezerra *et al*., 2022). These activities emit large amounts of greenhouse gases (GHG) into the atmosphere, leading to a decline in ecosystem and environmental conditions, such as loss of biodiversity (Barlow *et al*., 2016), soil erosion, disruption of water cycling and carbon storage (Santos *et al*., 2017), and adverse effects on local and regional climates (Da Silva Cruz *et al*., 2022).

To better understand the factors influencing these changes in land use and cover and to develop strategies for future mitigation, various studies have employed econometric models (Reis e Gúzman, 1992) and spatial analysis based on empirical data (Soares-Filho *et al*., 2006; Verburg, 2016). The availability of remote sensing data and geoprocessing platforms has significantly advanced this field in recent decades, resulting in increasingly sophisticated dynamic models (Cohenca, 2016). These modeling frameworks integrate remote sensing techniques and geographic information systems (GIS), incorporating political, environmental, and economic variables, among others, to represent the main components of a system and their interrelationships (IPBES, 2016).

Recent studies have considered political impacts (Aguiar *et al*., 2016; Silva Bezerra *et al*., 2022; Soares-Filho *et al*., 2014) and the integration of other sectors, recognizing that the same macroeconomic circumstances can generate different scenarios (Rochedo *et al*., 2018; Soterroni *et al*., 2023). There has been no comprehensive compilation of the studies that project deforestation rates and associated emissions in the Amazon, considering their varied methodologies and results.

In this context, this research aims to compile the results of studies modeling deforestation rates and associated GHG emissions in the Brazilian Amazon by 2050. By comparing these results with the Land Use, Land-Use Change, and Forestry (LULUCF) goals considered in Brazil's Nationally Determined Contributions (NDC), we aim to evaluate the likelihood of the country meeting its commitments under the Paris Agreement. This research also highlights the key actions and public policies that Brazil must strengthen to contribute to climate mitigation and access payment for Reducing Emissions from Deforestation and Forest Degradation (REDD+).

4.1.2. Methodology

4.1.2.1. Studies Selection

The first step of this study involved conducting a comprehensive literature review of scientific studies related to modeling deforestation in the Brazilian Amazon and, when available, the associated GHG emissions. We aimed to cover studies from the past twenty years to understand the evolution of modeling tools and assess whether different approaches led to different conclusions.

We selected studies based on various datasets, modeling frameworks, and public policy considerations. The selection criteria included:

- Deforestation data used for calibration;
- Modeling framework;
- Integration with the energy sector;
- Inclusion of agriculture demand;
- Consideration of land speculation and land grabbing;
- Projected years and resolution;
- Policies implementation considered to model future scenarios.

4.1.2.2. Systematization of Methodologies

We systematized the selected studies' methodologies to identify their main differences. This involved comparing each study's modeling characteristics and considered policies.

4.1.2.3. Compilation and Analysis

We compiled projections on deforestation rates and associated GHG emissions from the selected studies. These projections were then analyzed and compared with Brazilian NDC goals in the LULUCF sector expected for 2025 and 2030. In Figure 4.1.1, we illustrate the methodology summary, which provides an overview of the steps taken in this study.

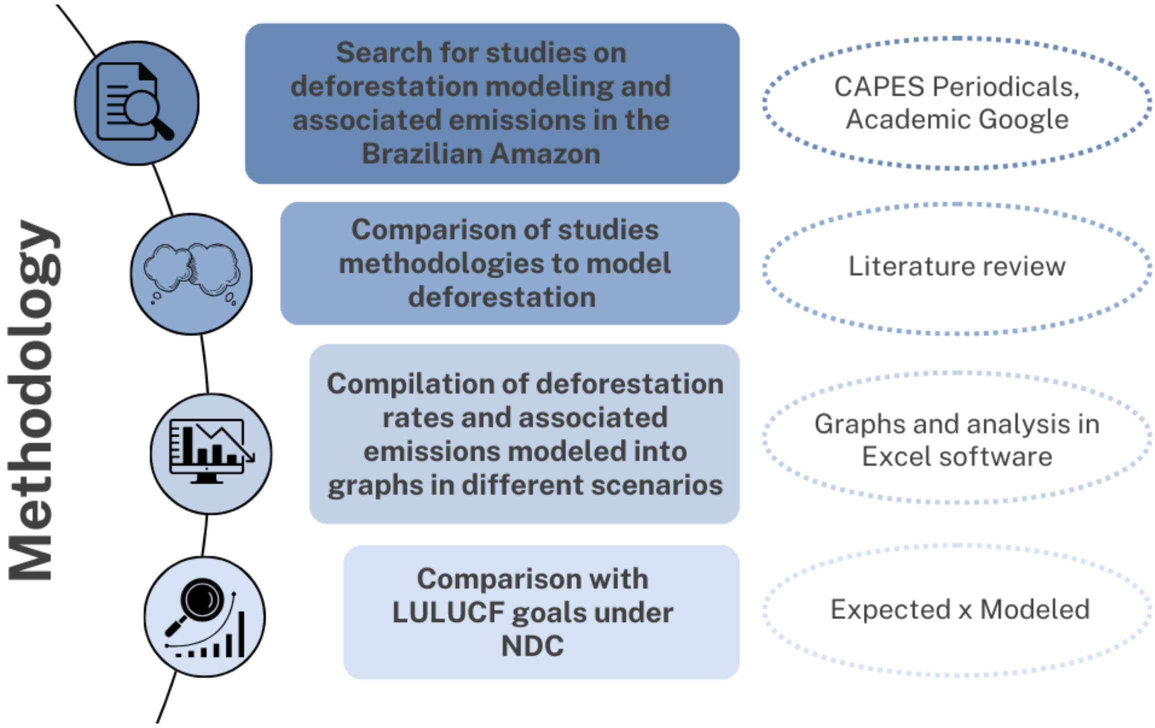


Figure 4.1.1. Methodology summary to evaluate the legal framework to reduce deforestation in the Brazilian Amazon.

4.1.3. Results and discussion

4.1.3.1. Selected Studies and Methodology Compilation

We prioritized Brazilian research groups and regional models as they better represent the national context. Nonetheless, we also considered initiatives that oriented strategic political instruments, such as REDD PAC, which subsidized the Brazilian *Intended* Nationally Determined Contribution (iNDC), and the “Options for Mitigating Greenhouse Gas Emissions in Key Sectors in Brazil” developed by the Minister of Science, Technology, and Innovation (MCTI). This approach helped us understand the perspectives of both policymakers and academics.

We focused on studies presenting results related to public policy implementation and used different models, land-use inputs, and external influencing variables to evaluate if different approaches impact the studies’ conclusions (Figure 4.1.2).

Figure 4.1.2. Brazilian Amazon land-use modeling works selected for this research.

Table 4.1.1 summarizes the selected studies' main aspects, considering datasets, platform modeling frameworks, and resolutions. Some of the studies also considered interaction with the energy sector, agriculture demand, land speculation and grabbing, and the impact of public policy implementation, such as the Forest Code, the National Plan for the Recovery of Native Vegetation (PLANAVEG), and the Low Carbon Agriculture Plan (ABC Plan).

Table 4.1.1. Main modeling characteristics and public policies considered in the studies evaluated in this research.

Parameter / Study	Soares-Filho *et al*. (2005)	Aguiar *et al*. (2016)	Rochedo *et al*. (2018)	Barbosa de Sousa *et al*. (2023)	Soterroni, A. *et al*. (2023)	REDD PAC (2015)	Mitigation Options (2017)	Silva Bezerra *et al*. (2022)
Modeling characteristics								
Deforestation data for calibration	PRODES (1997 to 2002)	PRODES (2004 to 2010)	PRODES (2016)	Mapbiomas (1985 and 2014)	Mapbiomas (2000)	MODIS land cover map of 2000	PRODES (2012)	IBGE (2000, 2010 and 2012)
Modeling framework	SimAmazonia (Dinamica EGO)	LuccME INPE-EM	Otimizagro (Dinamica EGO)	TerrSet	GLOBIOM	GLOBIOM	Otimizagro (Dinamica EGO)	LuccME
Integration with the energy sector			X		X		X	X
Agriculture demand			X		X	X	X	
Land speculation / grabbing			X				X	
Projected years	2003 to 2050	2014 to 2050	2017 to 2030	2017 and 2044	2021 to 2050	2000 to 2050	2012 to 2050	2015 to 2050
Resolution	1 km^2	625 km^2	0.25 km^2	0.0009 km^2	2,500 km^2	2,500 km^2	0.25 km^2	100 km^2
Public policies considered								
Forest Code		X	X		X	X	X	X
PLANAVEG					X		X	
ABC Plan					X		X	
Protected areas	X	X	X	X	X	X	X	X

PLANAVEG: National Plan for the Recovery of Native Vegetation; ABC Plan: Low Carbon Agriculture Plan.

Source: own production

By systematically comparing the results of these studies, we aimed to identify the impact of these differences on their conclusions.

4.1.3.2. Compilation and Analysis of Deforestation in the Amazon

Soares-Filho *et al*. (2006) simulated deforestation in the Amazon basin until 2050 under six different scenarios, considering mainly the impact of environmental inspection, the expansion of protected areas, and the asphalting process (SM1- 1; Table SM1. 1). In the Business as Usual (BAU) scenario, the east and southeast Amazon would be the most affected areas (Figure SM1. 1a), achieving deforestation rates of 39,512 km^2 by 2025 (Figure 4.1.3a). The authors consider this analysis conservative, as it did not consider additional disturbances to the forest from fire and logging nor any road projects not yet envisioned. In contrast, an optimistic scenario would reduce deforestation by 82% in the Brazilian Amazon by 2050 (Figure 4.1.3b) since it considers new asphalting extinction and extension of protected areas.

Aguiar *et al*. (2016) proposed three scenarios for the Brazilian Amazon until 2050, focusing on net CO_2 emissions (SM1- *2*; Table SM1. 2). The 'Fragmentation' scenario showed a concentration of deforestation around previously opened areas and new frontiers around some planned roads (Figure SM1. 2a), with a deforestation rate of 14,890 km^2 projected by 2050 (Figure 4.1.3a). In a 'Sustainability' scenario, deforestation projection was 50 km^2 for the same year (Figure SM1. 2c; Figure 4.1.3b), reflecting Forest Code restoration (Figure SM1. 2b), no other road building and maintenance of protected areas.

Rochedo *et al*. (2018) divided Brazil's environmental governance into three periods: i) pre-2005, a period with weak governance and high deforestation rates; ii) 2005 to 2010, when there was a decrease in deforestation associated with more robust governance, and iii) 2012 to 2017, when there were political incentives to new clearings leading to poor governance and the end of the deforestation reduction trend, mainly related to the review of the Forest Code (SM1- 3). Based on this analysis, the authors outlined three environmental governance scenarios (Table SM1. 3). In the 'Intermediate Environmental Governance' or BAU scenario, there would be an annual loss of more than 12,070 km^2 in the Amazon biome by 2025 (Figure 4.1.3a), while in a 'Strong environmental governance' scenario, the annual deforestation could be under 4,000 km^2 by 2025 (Figure 4.1.3b), which is mainly related to expansion of current deforestation command-and-control policies and Forest Code implementation. In a pessimistic scenario, deforestation could reach more than 27,000 km^2 by 2030 (Figure SM1. 3)

Barbosa de Sousa *et al*. (2023) considered that the observed conditions of changes in land use and land cover between 1985 and 2014 would remain unchanged, which could be considered a BAU scenario (SM1- 4; Table SM1. 5). We have estimated the deforestation rates considering anthropized areas (Planted Forest, Pasture, Agriculture, Urban infrastructure, and Mining) difference between 2017 and 2044 and have distributed linearly, achieving an annual deforestation rate of 13,309 km^2 (Figure 4.1.3a). The results show a reduction in Forest Formation and increased pasture areas and agricultural land (Figure SM1. 4; Table SM1. 4). Vieira *et al*. (2008) and Souza *et al*. (2013) also found that livestock was one of the main drivers of deforestation in the Brazilian Amazon and responsible for 80% of the illegal deforestation. Ometto *et al*. (2016) results also showed that over the last 40 years, the primary land use and coverage changes in the Amazon were related to conversion from forests into agricultural land.

Soterroni *et al*. (2023) explored six scenarios, considering Forest Code implementation, deforestation dynamics, native vegetation restoration, agricultural practices following current trends, energy sector infrastructures and policies, population growth, and Gross Domestic Product (GDP) (SM1- 5; Table SM1. 6). In a 'Baseline' or BAU scenario, from 2020 to 2030, deforestation in the Amazon biome would reach around 108,000 km^2, on average. Between 2030 and 2050, accumulated deforestation in the Amazon is estimated to reach 140,000 km^2. Considering a linear distribution of deforestation between these periods, the annual rates would be around 11,775 km^2 per year by 2025 and around 10,000 km^2 by 2030 (Figure 4.1.3a). In an optimistic scenario (or 'Forest Code Net Zero'), no deforestation is expected in the Amazon (Figure 4.1.3b) once it reflects, among others, zero illegal deforestation and Forest Code implementation.

Câmara *et al*. (2015) conducted the REDD+ Policy Assessment Centre project (REDD-PAC), which was considered by Brazilian decision-makers when developing the country's intended NDC (iNDC) in 2015 (SM1- 6; Table SM1. 7). In the most optimistic scenario, which considers that Forest Code is put into practice, the model projects a "zero deforestation" effect in the Amazon biome and the forest area remains in 328 Mha from 2030 onwards (Figure SM1. 5a). In a scenario where there is no amnesty for the small farms, so landowners are forced to restore the forest on previously illegally deforested land, there is a gain of 6 Mha of regrowing forest in the Amazon biome by 2050 (Figure SM1. 5b). These results show that incentives for small farmers to promote regeneration can have a substantial effect. Even if the scenario where no compensation for illegal deforestation with quotas is allowed increases forest regrowth area, this scenario could promote a mature forest reduction. When quotas are used only by crop farmers, there could be less than 9 Mha of mature forest in the Amazon biome by 2050, compared to the Forest Code Scenario (Figure SM1. 5a). The Forest Code scenario reduces the total pasture area compared to BAU (Figure SM1. 5c), stabilizing around 56 Mha in most scenarios. The authors associate it with increased pasture productivity because, by 2050, 42% of the Brazilian cattle could be herded in the Amazon biome.

Under the project **"Options for Mitigating Greenhouse Gas Emissions in Key Sectors in Brazil",** land-use conversions, deforestation trajectories, and forest regeneration were simulated under different scenarios (MCTI, 2017; SM1- 7). The scenarios included the goals of restoration of native vegetation of PLANAVEG, reducing deforestation of the PNMC, and low-carbon strategies of the ABC Plan (Table SM1. 8).

Silva Bezerra *et al*. (2022) have created three spatially explicit scenarios until 2050 based on detailed biophysical, socioeconomic, and institutional factors for each biome in Brazil (SM1- 8). The three scenarios ranged from low to high social development and high to low environmental development (Table SM1. 10). In the 'Middle of the road' and 'Strong Inequality' scenarios, forest vegetation in the Amazon biome would suffer a reduction of approximately 673,066 and 762,739 km^2, respectively, until 2050. In the 'Sustainable Development Scenario', the Amazon biome would be reduced by 217,696 km^2 of forest vegetation, approximately 2/3 less than the values observed in the other scenarios (Figure SM1. 7) since the Forest Code is implemented, protected areas are maintained, and no major federal or state roads were built after 2020.

We can see from Soares-Filho *et al*. (2006)[30] and Barbosa de Sousa *et al*. (2023) results that contemplating deforestation as an exogenous parameter (i. e., considering the deforestation historical dynamics and allocating deforestation as presumed) without considering the impact of external variables over time (such as the integration with the energy sector, agriculture demand, land speculation and grabbing, and public policies implementation) could point out projections that are not entirely realistic (Figure SM1. 8).

Except for the results from Soares-Filho *et al.* (2006), the deforestation rates under BAU are similar for 2025 and 2030 between the studies. The results for optimistic scenarios are similar for 2025 but quite different for 2030, considering the different premises assumed by each study. Soterroni *et al*. (2023) do not consider land speculation and grabbing, resulting in zero deforestation by 2030 and 2050, but these variables could have a considerable impact under the Amazon context.

The synthesized resulting projections of deforestation in the Brazilian Amazon modeled by four studies are in Table SM1. 11.

[30]We have considered results for projections of deforestation only for the Brazilian Amazon.

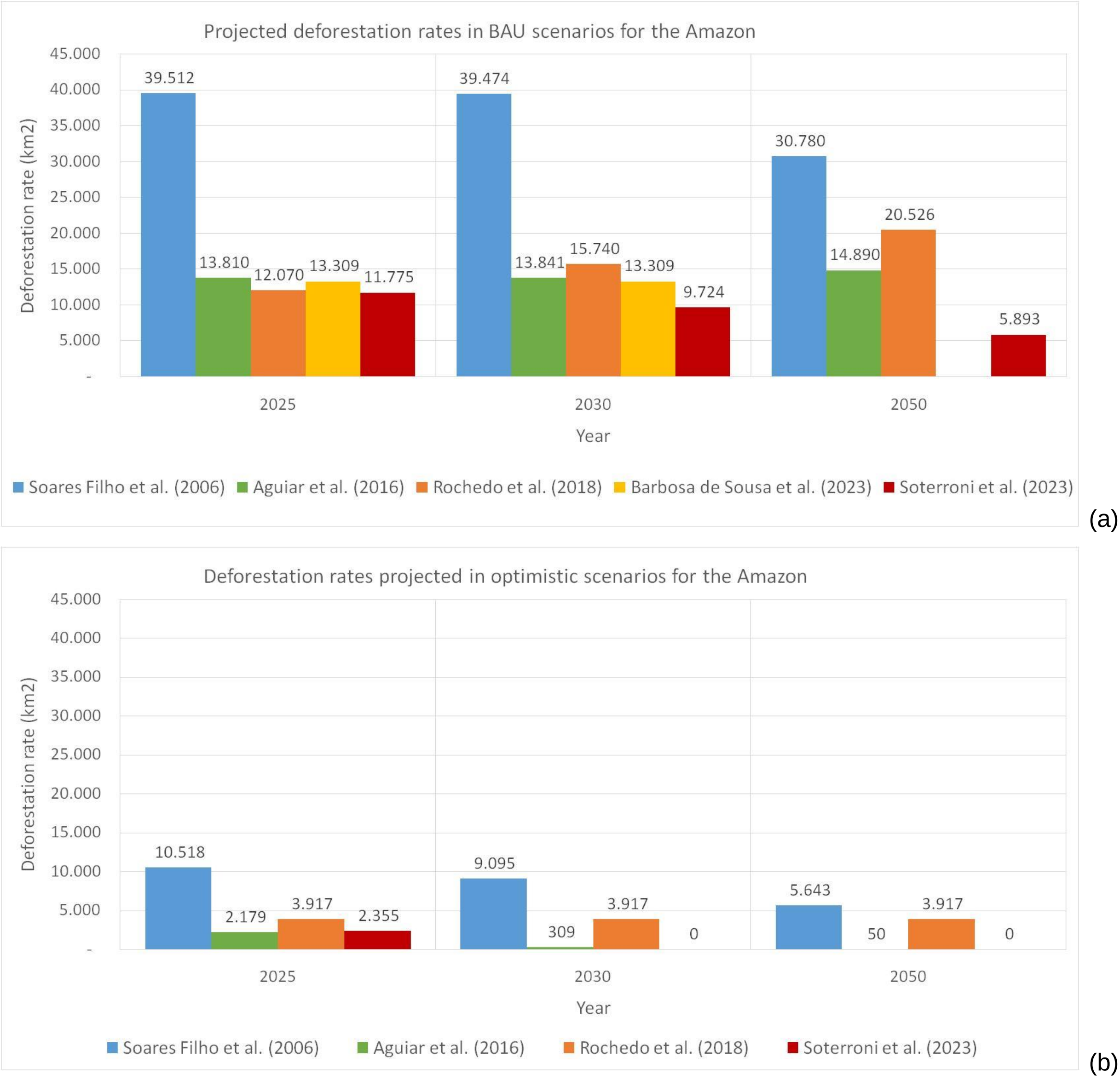


Figure 4.1.3. Projected deforestation rates in the Business as Usual (BAU) (a) and optimistic (b) scenarios in the Brazilian Amazon.

4.1.3.3. Association with GHG Emissions

We have compiled the deforestation emissions projections from the ´Fragmentation Scenario' and ´Sustainability Scenario' from Aguiar *et al.* (2016), 'Weak environmental governance' and 'Strong environmental governance´ scenarios from Rochedo *et al.* (2018), and 'Baseline' and 'Forest Code Net Zero' scenarios from Soterroni *et al.* (2023) (Table SM1. 12) so we could evaluate the projections concerning observed results from National Forest Reference Emission Level (FREL) (Figure SM1. 10) and NDC goals[31] (Figure SM1. 9).

[31] We have considered just predicted gross emissions from LULUCF sector.

As a reflection of not considering other external factors influencing deforestation, Aguiar *et al*. (2016) projections were higher than those observed and reported under National FREL and the other studies (Figure 4.1.4a;

Figure SM1. 10). As the authors also evaluated secondary vegetation dynamics and related removals, they highlight its importance in net CO_2 emissions estimates (Figure SM1. 2d), which turns the Amazon region into a carbon sink in the 'Sustainability' scenario.

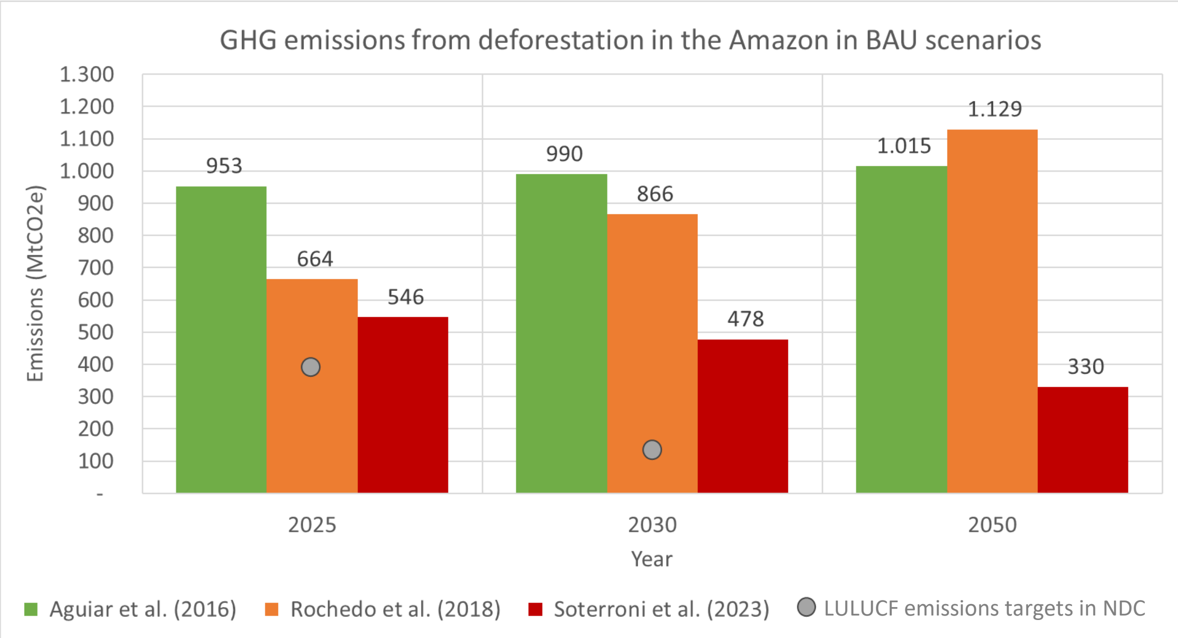
Rochedo *et al*. (2018) results help to explain how a political crisis can be a significant driver for increasing deforestation and carbon emissions in Brazil. The expansion of deforestation command-and-control policies and the implementation of the Forest Code led to a reduction of 81% of the projected deforestation in 2050 (Figure 4.1.4b).

Soterroni *et al*. (2023) GHG emissions results are lower than the others in both BAU and optimistic scenarios, so the authors reinforce how fundamental the Forest Code implementation is and stop illegal deforestation in the Amazon to neutralize emissions in 2050 (Figure 4.1.4b).

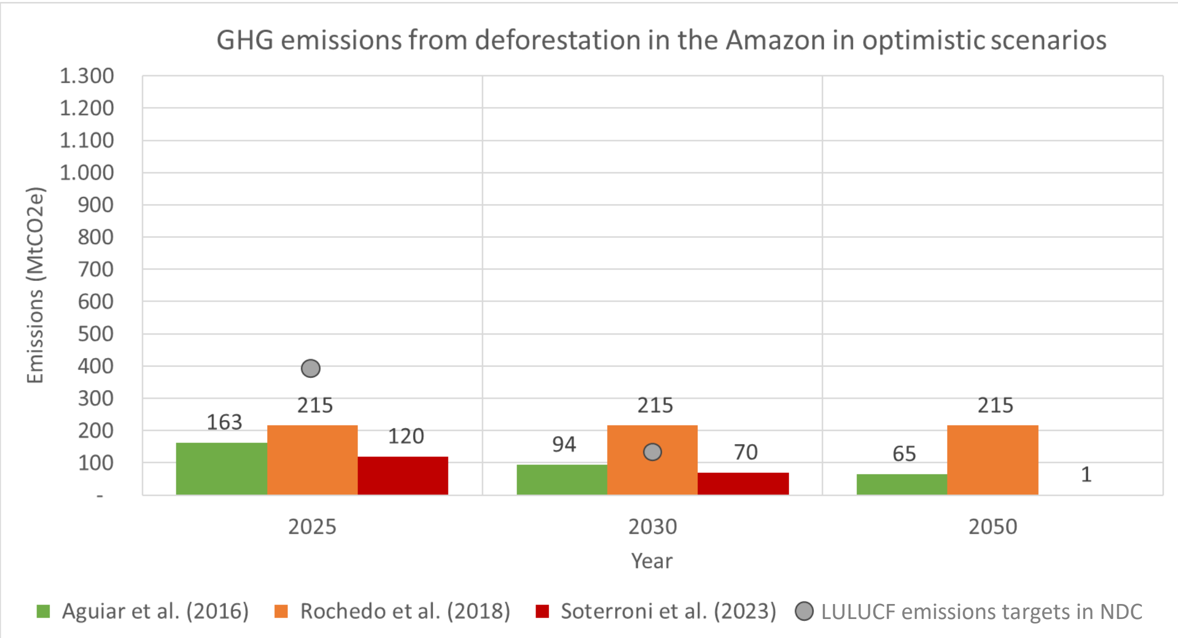
According to Soares-Filho *et al*. (2006), under the study BAU scenario, more than 32 Pg (10^9 tons) would be emitted into the atmosphere, equivalent to more than four years of current emissions per the planet. Câmara *et al*. (2015) also estimated the GHG emissions from land-use change and forestry, finding that the Amazon biome could be a net sink after 2040 (Figure SM1. 6).

MCTI (2017) highlights that reducing deforestation is the lowest-cost strategy for cutting GHG emissions in the LULUCF sector. For this reason, controlling deforestation in the Amazon has increasingly been seen as an objective linked to biodiversity conservation and a necessary action to mitigate climate change. The low-carbon scenario reduced emissions from deforestation, increased removals from regeneration and planted forest, and promoted carbon sequestration by soils – mainly related to pasture recovery.

In this context, it is worth mentioning that these intensive land-use changes also affect forest dynamics, making the Amazon forest an emitter instead of a sink (Gatti *et al*., 2021).



(a)



(b)

Figure 4.1.4. Greenhouse gas (GHG) Emissions from deforestation in Business as Usual (BAU) (a) and optimistic (b) scenarios in the Brazilian Amazon.

4.1.3.4. Assessment concerning Brazilian NDC Goals

LULUCF represented 62% of Brazilian GHG emissions in 2005 (Brazil, 2020), and 64% were from the Amazon biome (MCTI, 2020). Brazilian NDC establishes goals to achieve net emissions of 1,320 Mt CO_2e and 1,200 Mt CO_2e by 2025 and 2030, respectively (UNFCCC, 2023). According to iNDC´s calculation basis, emissions from the LULUCF sector would represent 392 Mt CO_2e and 143 Mt CO_2e by 2025 and 2030, respectively (Figure SM1. 9). Considering the representativeness of the Amazon biome in the LULUCF emissions, our analysis focused on this biome to discuss the NDC goals achievement. Nonetheless, Cerrado would be fundamental in this context, considering its deforestation increase in the last years (INPE, 2024). Furthermore, we are contemplating only gross emissions associated with deforestation, and the gross emissions from Old Growth Forest Degradation estimated by Aguiar *et al*. (2016) from 2007 to 2011 represented 47% of the clear-cut emissions, showing how significant the forest degradation might be. Also, accounting removals from secondary vegetation are crucial in these scenarios, as Aguiar *et al*. (2016) highlighted.

GHG emission results from Aguiar *et al*. (2016) in a ´Fragmentation Scenario' (953 Mt CO_2e) show that Brazil would emit more than double the projected emissions for the LULUCF sector in 2025. By 2030, the projected emissions (990 Mt CO_2e) would represent almost seven times the modeled LULUCF emissions goals under NDC (Figure 4.1.4a). On the other hand, in a ´Sustainability Scenario', Brazil could achieve its NDC goals for emissions from LULUCF by 2025 (163 Mt CO_2e) and in 2030 (94 Mt CO_2e) (Figure 4.1.4b).

Rochedo *et al*. (2018) results also show that, by 2025, in a 'Weak environmental governance' scenario, the GHG emissions from Amazon deforestation would represent almost double those expected in NDC goals (664 Mt CO_2e). By 2030, the modeled emissions would be more than six times those expected for the LULUCF sector (866 Mt CO_2e) (Figure 4.1.4a). The authors reinforce that abandoning deforestation control policies and politically supporting predatory agricultural practices make it impossible to meet Brazil´s contribution to the NDC goals, which is reflected in the 'Strong environmental governance´ scenario, where Brazil could achieve goals by 2025, but even so not in 2030 (215 Mt CO_2e) (Figure 4.1.4b).

According to projections by Soterroni *et al*. (2023), Brazil will not be achieving LULUCF emissions goals under NDC by 2025 (546 Mt CO_2e) and by 2030 (478 Mt CO_2e) (Figure 4.1.4a). Nonetheless, under the 'Forest Code Net Zero', Brazil would achieve its climate targets by 2025 (120 Mt CO_2e) and by 2030 (70 Mt CO_2e) (Figure 4.1.4b).

In this context, we highlight the policy gap between Brazil's net-zero goals and the importance of strengthening environmental policies to help the country achieve its NDC goals and effectively contribute to climate change mitigation.

4.1.3.5. Importance of Strengthening Environmental Policies

Soares-Filho *et al*. (2006) reinforce the importance of conservation units (national and state parks, among others) and protected areas (such as indigenous lands, extractive reserves, sustainable development reserves, and national forests) to deforestation control. Ecosystem protection is the most cost-effective climate mitigation measure, and not protecting these areas will rely on much higher investments in engineered solutions in the other emission sectors to achieve its net-zero goal by mid-century (MCTI, 2017; Soterroni *et al*., 2023).

However, Soares-Filho *et al*. (2006) emphasize that even a massive investment in the implementation and maintenance of a broad network of protected areas within a BAU scenario would not be enough to prevent large-scale impoverishment of the Amazonian habitats, even because forests in protected areas may still suffer the impacts of illegal logging and political and economic pressure to give way to agricultural expansion, major infrastructure, and natural resource extraction projects (Ferreira *et al*., 2024).

Although environmental protection actions contribute to decreasing the clear-cut deforestation rates, they are not enough to control the forest degradation process. Degradation of illegal logging activities and forest fires reduces the capacity of a forest to produce ecosystem services, including carbon storage (Assis *et al*., 2020; Lapola *et al*., 2023). Therefore, an extensive conservation strategy must also involve the protection of a functional array of forest remnants outside protected areas to avoid the environmental collapse of rainforest ecosystems.

The REDD PAC initiative (Câmara *et al*., 2015) highlighted that compliance with the Forest Code is essential to advance cattle productivity in the Amazon biome and avoid the impact of cattle expansion on deforestation. The authors suggest that legal reserve amnesty should be limited to small farmers, avoiding illicit break-up of large farms, considering that one of the issues of the current Brazilian Forest Code is the restoration of the legal reserves and permanent protection areas in private farms that were illegally deforested before 2008. These areas' restoration could represent ~80.000 km^2 (Soares-Filho *et al*., 2014). The study highlights that only with the implementation of the Forest Code it will be possible to achieve zero deforestation by 2030; in other words, we would not need to worry about illegal deforestation but only about legal deforestation, which differs from the results of other studies (Soares-Filho *et al*., 2014). The illegal occupation of public lands is also a barrier to reducing deforestation in the Amazon. Different studies show that deforestation in border areas becomes attractive from an economic point of view if one considers the process of taking public lands through land grabbing (falsification of titles) and cutting down the forest (Bowman *et al*., 2012; Carrero *et al*., 2022). Vacant land in the Amazon must be protected through the creation of conservation units and to intensify the land regularization process.

The Amazon region has a rural economy primarily based on exploiting natural resources (forestry, mining) and cattle-ranching, and agricultural settlements lack proper infrastructure, limiting these actors' economic opportunities. There is a lack of economic alternatives to legal deforestation in areas with low opportunity cost of land (e.g., extensive livestock farming). To reduce illegal deforestation in a socially fair way, it is necessary to continue and expand investments in promoting activities such as sustainable forest management and the extraction of non-timber products. This can be achieved through economic instruments such as providing subsidized credits, promoting the expansion of the cooperative network, and providing commercial and logistical support for selling these products (MCTI, 2017).

In this context, it is necessary to advance the implementation of Payment for Environmental Services (PES) mechanisms on a large scale, such as "Floresta+[32]" and promote actions related to PLANAVEG (MCTI, 2017; Soterroni *et al*., 2023). Forest restoration is a significant instrument of PES that brings numerous benefits in addition to mitigating GHG emissions, but it comes at a high cost. Economic instruments should be introduced to subsidize restoration by donating seedlings and materials for building fences and offering access to subsidized credit. Nonetheless, educational actions must be extended to the adult public, as the level of knowledge about environmental laws is currently insufficient (MCTI, 2017).

4.1.4. Conclusions

Our results demonstrated that the evolution of modeling frameworks, considering external aspects that influence land-use scenarios - such as the integration with the energy sector, agriculture demand, land speculation, and grabbing - and evaluating the implementation of public policies leads to more realistic

[32] Floresta+. Available on: https://www.gov.br/mma/pt-br/assuntos/servicosambientais/florestamais/projeto-florestamais-amazonia. Accessed on 23 Mar. 2024.

scenarios. Despite the inherent uncertainties of these scenarios, they can help decision-makers direct efforts to strengthen and create public policies aimed at reducing emissions from deforestation in the Brazilian Amazon, one of the country's primary sources of GHG emissions.

Brazil has enormous potential to contribute to the goals of the Paris Agreement, mainly through a reduction in deforestation and forest degradation, as well as forest regrowth. However, to achieve the goals that the country has committed to in its NDC, all the model results we evaluated showed that it is indispensable to direct efforts towards the implementation of public policies such as the Forest Code, to increase ecosystem protection, to advance in land regularization and to value the environmental services. Nonetheless, as the NDC goals were established based on a dataset that differs from those used in the National GHG Inventory, which is the instrument to monitor Brazil´s commitment under UNFCCC to report its commitment, it would be essential to consider its methodology to establish Brazilian NDC goals.

We did not evaluate emissions from forest degradation, which would further increase total emissions. Deforestation rates in the Cerrado biome have increased in recent years, making it even more challenging for Brazil to achieve its mitigation goals. Not reducing deforestation also jeopardizes Brazil’s ability to access payments for results from Reducing Emissions from Deforestation and Forest Degradation (REDD+), which would be crucial to implement mechanisms that value the standing forest on a large scale, such as payment for environmental services (PES), and maintaining the ‘virtuous circle’ of conservation and sustainable development.

Acknowledgment: We thank Aline Soterroni, Ana Paula Aguiar, Gilney Bezerra, and Pedro Rochedo for providing detailed data on the model results.

BIBLIOGRAPHIC REFERENCES

AGUIAR, A. P.; VIEIRA, I. C.; ASSIS, T. O.; DALLA-NORA, E. L.; TOLEDO, P. M.; SANTOS-JUNIOR, R. A.; BATISTELLA, M.; COELHO, A. S.; SAVAGET, E. K.; ARAGÃO, L. E.; NOBRE, C. A.; OMETTO, J. P. Land use change emission scenarios: anticipating a forest transition process in the Brazilian Amazon. **Global Change Biology**. May; 22 (5):1821-40, 2016.

ALMEIDA, A. S.; STONE, T. A.; VIEIRA, I. C. G.; DAVIDSON, E. A. Non frontier deforestation in the Eastern Amazon. **Earth Interactions**, 14, 1–15, 2010.

ASSIS, T. O.; AGUIAR, A. P.; VON RANDOW, C. et al. CO2 emissions from forest degradation in Brazilian Amazon. **Environmental Research Letter** 15 104035, 2020.

BARBOSA DE SOUZA, K.; ROSA DOS SANTOS, A.; MACEDO PEZZOPANE, J. E.; MACHADO DIAS, H.; FERRARI, J. L.; MACHADO DE OLIVEIRA PELUZIO, T.; TOLEDO, J. V.; FREIRE CARVALHO, R. D. C.; RIZZO MOREIRA, T.; FRANÇA ARAÚJO, E.; DA SILVA, R. G.; SENHORELO, A. P.; COSTA, G. A.; MARDENI, V. D. N.; KUNZ, S. H.; DOS SANTOS, E. C.. Modeling Dynamics in Land Use and Land Cover and Its Future Projection for the Amazon Biome. **Forests** 14, 1281, 2023.

BARLOW, J.; LENNOX, G.; FERREIRA, J.; BERENGUER, E.; LEES, A. C.; NALLY, R. M.; THOMSON, J. R.; FERRAZ, S. F. B.; LOUZADA, J.; OLIVEIRA, V. H. F.; PARRY, L.; SOLAR, R. R. C.; VIEIRA, I. C. G.; ARAGÃO, L. E. O.; BEGOTTI, R. A.; BRAGA, R. F.; CARDOSO, T. M.; OLIVEIRA JR., R. C.; SOUZA JR., C. M.; MOURA, N. G.; NUNES, S. S.; SIQUEIRA, J. V.; PARDINI, R.; SILVEIRA, J. M.; VAZ-DE-MELLO, F. Z.; VEIGA, R. C. S.; VENTURIERI, A.; GARDNER, T. A.. Anthropogenic disturbance in tropical forests can double biodiversity loss from deforestation. **Nature** 535, 144–147, 2016.

BOWMAN, M. S; SOARES-FILHO, B. S.; MARRY, F. D.; NEPSTAD, D. C.; RODRIGUES, H.; ALMEIDA, O. T. Persistence of cattle ranching in the Brazilian Amazon: A spatial analysis of the rationale for beef production. **Land Use Policy**, v. 29, p. 558-568, 2012.

BRAZIL. Ministry of Science, Technology, and Innovations. Secretariat for Research and Scientific Training. Fourth National Communication of Brazil to the United Nations Framework Convention on Climate Change / Secretariat for Research and Scientific Training. Brasília: **Ministry of Science, Technology, and Innovations**, 2020. 620 p.: il. ISBN: 978-65-87432-19-9.

CÂMARA, G.; SOTERRONI, A.; RAMOS, F.; CARVALHO, A.; ANDRADE, P.; SOUZA, R. C.; MOSNIER, A.; MANT, R.; BUURMAN, M.; PENA, M.; HAVLIK, PIRKER, J.; KRAXNER, F.; OBERSTEINER, M.; KAPOS, V.; AFFONSO, A.; ESPÍNDOLA, G.; BOCQUEHO, G. Modelling Land Use Change in Brazil: 2000–2050 – A report by the REDD-PAC project. São José dos Campos, Brasília, **Laxenburg, Cambridge**. INPE, IPEA, IIASA, UNEP-WCMC, 1s t edition, November 2015. Available on: http://www.redd-pac.org/reports/lucc_brazil_folder.pdf. Accessed on: 23 Mar. 2023.

CARRERO, G. C.; WALKER R. T.; SIMMONS, C. Z.; FEARNSIDE, P. M. Land grabbing in the Brazilian Amazon: Stealing public land with government approval. **Land Use Policy**, Volume 120, 106133, ISSN 0264-8377, 2022.

COHENCA, D. **Modelagem de Cenários de Ocupação no Litoral Sul de Santa Catarina utilizando Técnicas de Análise Geoespacial**. Dissertação apresentada ao Centro de Filosofia e Ciências Humanas do Programa de Pós Graduação em Geografia. Florianópolis, 2016. 149 p.

DA SILVA CRUZ, J.; BLANCO, C.J.C.; DE OLIVEIRA JÚNIOR, J.F. Modeling of Land Use and Land Cover Change Dynamics for Future Projection of the Amazon Number Curve. **Science of Total Environment**, 811, 152348, 2022.

FERREIRA, J.; ARAGÃO, L. E. O. C.; BARLOW, J et al. Brazil's environmental leadership at risk. **Science**, 346, 706–707, 2024.

GATTI, L. V.; BASSO, L. S.; MILLER, J. B.; GLOOR, M.; DOMINGUES, L. G.; CASSOL, H. L. G.; TEJADA, G.; ARAGÃO, L. E. O. C.; NOBRE, C.; PETERS, W.; MARANI, L.; ARAI, E.; SANCHES, A. H.; CORREA, S. M.; ANDERSON, L.; VON RANDON, C.; CORREIA, C. S. C.; CRISPIM, S. P.; NEVES, R. A. L. Amazonia as a carbon source linked to deforestation and climate change, **Nature**, 595, 388–393, 2021.

IPBES. Summary for policymakers of the methodological assessment of scenarios and models of biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. S. Ferrier, K. N. Ninan, P. Leadley, R. Alkemade, L.A. Acosta, H. R. Akçakaya, L. Brotons, W. Cheung, V. Christensen, K. A. Harhash, J. Kabubo-Mariara, C. Lundquist, M. Obersteiner, H. Pereira, G. Peterson, R. Pichs-Madruga, N. H. Ravindranath, C. Rondinini, B. Wintle (eds.). **Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services**, Bonn, Germany. 32 pages, 2016.

INPE. Monitoramento do Desmatamento da Floresta Amazônica Brasileira por Satélite (PRODES), 2024. Available on: http://terrabrasilis.dpi.inpe.br/app/dashboard/deforestation/biomes/legal_amazon/rates. Accessed on: 18 Jun. 2024.

LAPOLA, D. M.; PINHO, P.; BARLOW, J. et al. The drivers and impacts of Amazon forest degradation. **Science** 379, Issue 6630, 2023.

MCTI. Modelagem setorial de opções de baixo carbono para agricultura, florestas e outros usos do solo (AFOLU) / organizador Régis Rathmann. Brasília: **Ministério da Ciência, Tecnologia, Inovações e Comunicações**, ONU Meio Ambiente, 2017. 400 p.: il. Available on: https://antigo.mctic.gov.br/mctic/export/sites/institucional/ciencia/SEPED/clima/arquivos/projeto_opcoes_mitigacao/publicacoes/Setor-AFOLU.pdf. Accessed on: 29 Nov. 2022.

MCTI. Relatório De Referência: Setor Uso da Terra, Mudança do Uso da Terra e Florestas. 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. Brasília: **Ministério da Ciência, Tecnologia, Inovações e Comunicações**, 2020.

OMETTO, J.P.; SOUSA-NETO, E.R.; TEJADA, G. Land Use, Land Cover and Land Use Change in the Brazilian Amazon (1960–2013); **Springer Link**, pp. 369–383, 2016.

POPP, A.; CALVIN, K.; FUJIMORI, S.; HAVLIK, P.; HUMPEN O¨DER, F.; STEHFEST, E. et al. Land-use futures in the shared socio-economic pathways. **Global Environmental Change**. 42:331–345, 2017.

REIS, E. J; GUZMÁN, R. M. Na Econometric Model Of Amazon Deforestation. Texto para discussão no 265. **IPEA**. Brasília, 1992.

ROCHEDO, P. R. R.; SOARES-FILHO, B.; SCHAEFFER, R. *et al.* The threat of political bargaining to climate mitigation in Brazil. **Nature Climate Change** 8, 695–698, 2018.

SANTOS, T.; FILHO, V.; ROCHA, V.; MENEZES, J. Os Impactos Do Desmatamento e Queimadas de Origem Antrópica Sobre o Clima Da Amazônia Brasileira: Um Estudo de Revisão. **Revista Geográfica Acadêmica** 11, 157–181, 2017.

SILVA BEZERRA, F. G.; VON RANDOW, C.; ASSIS, T. O.; BEZERRA, K. R. A.; TEJADA, G.; CASTRO, A. A; GOMES, D. M. P.; AVANCINI, R.; AGUIAR, A. P. New land-use change scenarios for Brazil: Refining global SSPs with a regional spatially-explicit allocation model. **PLoS ONE** 17 (4): e0256052, 2022.

SOARES-FILHO, B. S.; NEPSTAD, D. C.; CURRAN, L. M.; CERQUEIRA, G. C.; GARCIA, R. A.; RAMOS, C. A.; VOLL, E.; MCDONALD, A.; LEFEBVRE, P.; SCHLESINGER, P. Modelling conservation in the Amazon basin. **Nature,** 2006.

SOARES-FILHO, B.; RAJÃO, R.; MACEDO, M.; CARNEIRO, A.; COSTA, W.; COE, M.; RODRIGUES, H.; ALENCAR, A. Cracking Brazil's forest code. **Science**, *344* (6182), 363–364, 2014.

SOTERRONI, A. C.; IMPÉRIO, M.; SCARABELLO, M. C.; SEDDON, N.; OBERSTEINER, M.; ROCHEDO, P. R. R.; SCHAEFFER, R.; ANDRADE, P. R.; RAMOS, F. M.; AZEVEDO, T. R.; OMETTO, J. P. H. B.; HAVLÍK, P.; ALENCAR, A. A. C. Nature-based solutions are critical for putting Brazil on track towards net-zero emissions by 2050. **Global Change Biology**, *29*, 7085–7101, 2023.

SOUZA, R.A.; MIZIARA, F.; MARCO JUNIOR, P. Spatial Variation of Deforestation Rates in the Brazilian Amazon: A Complex Theater for Agrarian Technology, Agrarian Structure and Governance by Surveillance. **Land Use Policy** 30, 915–924, 2013.

UNFCCC. Federative Republic of Brazil Nationally Determined Contribution (NDC) to the Paris Agreement under the UNFCCC. **UNFCCC,** 2023. Available on: https://unfccc.int/sites/default/files/NDC/2023-11/Brazil%20First%20NDC%202023%20adjustment.pdf. Accessed on: 18 Feb. 2024.

VERBURG, P. H. Simulating Feedbacks in Land Use and Land Cover Change Models. **Landscape Ecology**, 21, 1171–1183, 2016.

VIEIRA, I. C. G.; TOLEDO, P. M.; SILVA, J. M. C.; HIGUCHI, H. Deforestation and threats to the biodiversity of Amazonia. **Brazilian Journal of Biology**, 68, 949–956, 2008.

4.2. SCIENTIFIC AND POLITICAL ADVANCES TO TRANSPARENT AND COMPLETE MEASUREMENT OF BRAZILIAN EMISSIONS AND REMOVALS IN THE LAND-USE SECTOR

Summary

Measurement, Reporting, and Verification (MRV) arrangements have played a crucial role in monitoring emissions and building mutual trust among countries regarding their Nationally Determined Contributions (NDC) under the United Nations Framework Convention on Climate Change (UNFCCC). This study aimed to identify opportunities to improve institutional arrangements to support Brazil in achieving transparency, accuracy, completeness, consistency, and comparability (TACCC) in its National Greenhouse Gas (GHG) Inventories for the Land Use, Land-Use Change, and Forestry (LULUCF) sector. We identified several gaps and improvement opportunities, including developing higher-resolution maps of past vegetation and soil carbon, accounting for emissions from fire-related degradation, and considering long-term removals from regeneration and restoration. Additionally, we propose including removals from protected vegetation in Quilombola territories and private properties, in addition to those already considered within Indigenous Land and Conservation Units. To enhance the MRV of LULUCF emissions and removals, we propose an institutional framework involving representatives from various organizations, leveraging their responsibilities and expertise, and using data from official ongoing initiatives. Our proposed three-step process for compiling the LULUCF GHG Inventory includes: i) organizing the national territory database, ii) calculating emissions and removals by components, and iii) compiling the results. Establishing such institutionalization could improve governance, state capacity, and public management, ensuring better TACCC in Brazil's reports to UNFCCC, including the basis for the Forest Reference Emission Levels (FREL). Under this new arrangement, Brazil's NDC goals may need to be reviewed to account for previously unconsidered emissions from degradation and other removals. While institutionalization poses challenges, managing mechanisms and relationships between actors is crucial to ensure the continuity of actions.

4.2.1. Introduction

The National Greenhouse Gases (GHG) Inventories, part of National Communications, are the primary instrument for monitoring Parties' progress on their Nationally Determined Contribution (NDC) under the United Nations Framework Convention on Climate Change (UNFCCC) (UNFCCC, 2015). Measurement, Reporting, and Verification (MRV) arrangements play a crucial role in this process, helping to build mutual trust and confidence among countries regarding their progress towards UNFCCC objectives (Granziera *et al.*, 2023).

Under the Paris Agreement, Parties decided to enhance transparency arrangements by establishing an Enhanced Transparency Framework (ETF) to improve clarity and track progress towards achieving NDCs (UNFCCC, 2015). Establishing effective MRV arrangements involves aspects of governance to improve interaction among different actors, ensuring effective and efficient public management that guarantees compliance with priority actions (Calmon and Costa, 2013; Diniz, 2001; Grindle, 2004; Procopiuck, 2013).

State capacity is crucial for establishing these arrangements, as it involves the government's ability to define strategies for resource allocation, manage these resources efficiently, and ensure that organizations have adequate structures and processes to carry out the planned activities (Gomide and Marenco, 2024; Painter e Pierre, 2005). Institutional arrangements, which can be formal or informal, include structures, processes, mechanisms, principles, rules, and norms that influence governance in public policy (Gomide e Pires, 2024; Hochstetler, 2021).

In Brazil, the Interministerial Climate Change Committee (CIM) coordinates government actions arising from the UNFCCC (Brasil, 2024), while the Ministry of Science, Technology, and Innovation (MCTI) coordinates and elaborates the National GHG Inventories (Brasil, 2023a). The Land Use, Land-Use Change, and Forestry (LULUCF) sector is among Brazil's most significant sources of GHG emissions and requires complex arrangements to reflect the mitigation results of various environmental policies (Brazil, 2021; Mendes, 2020).

Considering the requirements of the ETF and the opportunities presented by negotiations under Article 6 of the Paris Agreement, our study aims to identify opportunities to improve institutional arrangements that could support Brazil in achieving transparency, accuracy, completeness, consistency, and comparability, (TACCC) on the National GHG Inventories reports regarding the LULUCF sector.

4.2.2. Methodology

4.2.2.1. Documentation Analysis

The first phase of this research involved a comprehensive analysis of the latest Brazilian NDC submitted under the UNFCCC and the National Policy on Climate Change (PNMC). This analysis aimed to identify relevant policies, plans, programs, and other territorial instruments that could mitigate GHG emissions from the LULUCF sector.

4.2.2.2. Identification and Evaluation of Monitoring Tools

We identified and evaluated the monitoring tools and results of the identified policies and instruments, involving:

- Consulting government focal points;
- Reviewing monitoring tools available on the respective websites and documents;
- Identifying data gaps in monitoring the progress of these instruments by the responsible institutions.

4.2.2.3. Governance and Methodology Evaluation

We evaluated the governance and methodology applied in the latest National GHG Inventory for the LULUCF sector, including:

- Analyzing the LULUCF Sector Reference Report, which details the methodology for estimating GHG removals and emissions;
- Leveraging the experience of being part of the team that compiled the 4th National GHG Inventory to identify the main challenges during its compilation.

4.2.2.4. Gap Analysis and Data Exploration

We assessed the information gaps in the LULUCF National GHG Inventory, considering the initially identified policies, plans, and instruments. We explored other potential initiatives and sources to provide the necessary data to fill these gaps, focusing on official sources.

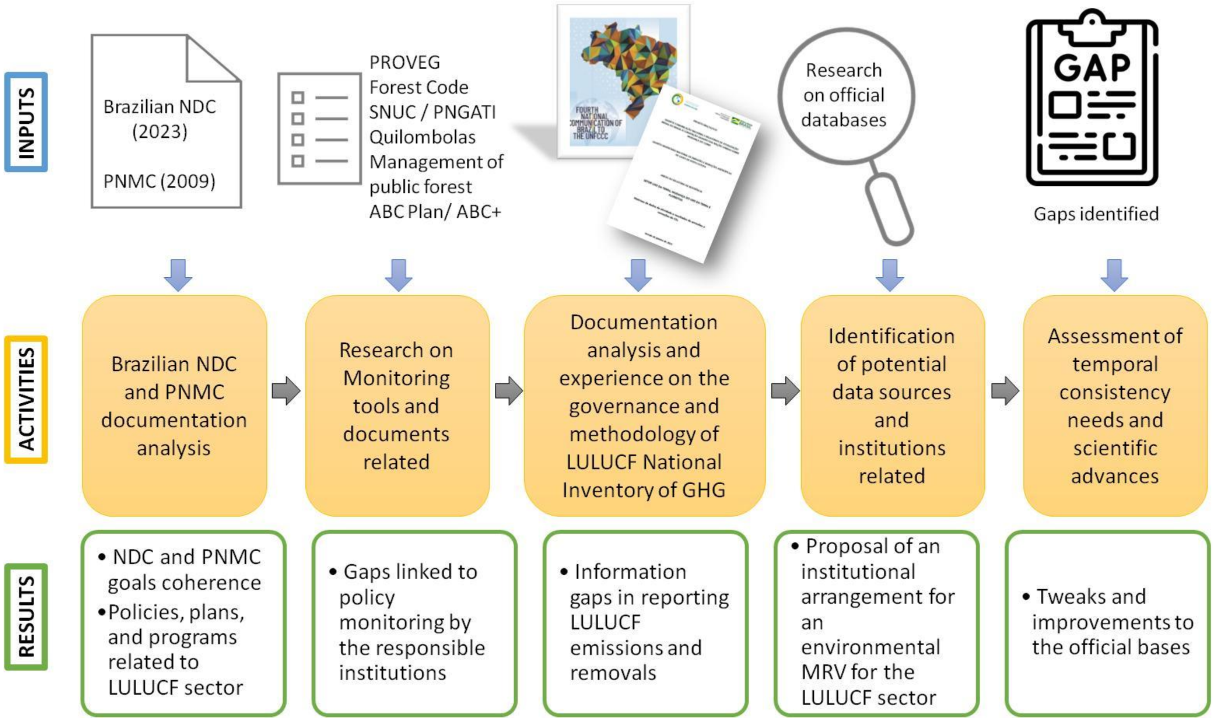
4.2.2.5. Proposal of Institutional Arrangement

Based on the identified gaps and data sources, we proposed an institutional arrangement to ensure the sustainability of the LULUCF National GHG Inventory compilation process. This proposal aimed to enhance temporal consistency and incorporate scientific advances.

4.2.2.6. Recommendations for Improvement

Considering the need for temporal consistency and scientific advances, we suggested improvements to the official databases based on the documentation analysis.

Figure 4.2.1 presents the methodological flow of this study, illustrating the sequential steps taken from documentation analysis to the proposal of an institutional arrangement and recommendations for improvement.



NDC: Nationally Determined Contribution; PNMC: The National Policy on Climate Change; PROVEG: National Policy for the Recovery of Native Vegetation; SNUC: National System for Conservation Units; PNGATI: National Policy for Territorial and Environmental Management of Indigenous Lands; ABC Plan and ABC+: Low Carbon Agriculture Plan; GHG: greenhouse gases; LULUCF: Land-Use, Land-Use Change, and Forestry; MRV: Measurement, Report, and Verification.

Figure 4.2.1. Flowchart with research methodology to evaluate improvements in the National Greenhouse Gas (GHG) Inventory of the Land Use, Land-Use Change, and Forestry (LULUCF) sector.

4.2.3. Results and discussion

4.2.3.1. Brazilian NDC and the National Policy on Climate Change

4.2.3.1.1. Detail of Goals

In 2023, Brazil submitted the fourth update of its NDC. The current goals are to achieve net emissions of 1.3 $GtCO_2e$ by 2025 and 1.2 $GtCO_2e$[33] by 2030, intending to achieve neutrality in 2050 (UNFCCC, 2023). However, the updated NDC

[33]Considering Global Warming Potential (GWP) of the 5th Assessment Report (AR5).

does not mention the mitigation actions planned for the LULUCF sector pointed out in the Brazilian intended NDC (iNDC), such as:

- Strengthen compliance with the Forest Code at federal, state, and municipal levels;
- Achieve zero illegal deforestation in the Brazilian Amazon by 2030;
- Restore and reforest 12 million hectares of forests by 2030;
- Expanding sustainable management systems for native forests;
- Additional restoration of 15 million hectares of degraded pastures and the increase of 5 million hectares of crop-livestock-forest integration systems (ILPF) by 2030 (FEDERATIVE REPUBLIC OF BRAZIL, 2015).

The National Policy on Climate Change (PNMC) formalized Brazil's voluntary goals to reduce GHG emissions between 36.1% and 38.9% of projected emissions by 2020 (Brasil, 2009). Decree nº 9.578/2018 (Brasil, 2018) regulates PNMC and mentions the National Climate Change Plan as one of its instruments, integrating action plans for deforestation prevention and control in various biomes and sectoral plans for mitigation and adaptation to climate change.

PNMC regulation predicts an 80% reduction in annual deforestation rates in the Legal Amazon, about the average verified between 1996 and 2005, and a reduction of 40% of the annual deforestation rates in the Cerrado biome concerning the average between 1999 and 2008 (Brasil, 2018).

4.2.3.1.2. Coherence Assessment

The omission of specific mitigation actions in the NDC leads to a lack of transparency regarding Brazil’s commitments to emissions reductions. The National Climate Change Plan and the PNMC have not been updated since 2008 and 2009, respectively (Brazil, 2008; 2009). Decree nº 9.578/2018 (Brasil, 2018) revoked Decree nº 7.390/2010 (Brasil, 2010), which included detailed calculations for 2020 projections, leading to a lack of transparency in the new decree.

Total projections for 2020 were 3.2 $GtCO_2e$, with 1.4 $GtCO_2e$ from the LULUCF sector, based on the Second National GHG Inventory estimates (Brasil, 2010). These projections have not been updated according to the latest National GHG Inventory (Brasil, 2018). Additionally, these estimates do not consider carbon removals or other mitigation actions provided in the ABC Plan, as it only accounts for gross emissions by deforestation.

For the Amazon biome, the deforestation projection was 19,535 km^2 for 2020. An 80% reduction in deforestation would bring the rate to 3,907 km^2 in 2020 (Brasil, 2010). However, the Project for Monitoring Deforestation in the Legal Amazon by Satellite (PRODES) data showed that deforestation was 10,851 km^2 in 2020, the highest in the last 12 years (INPE, 2024). For the Cerrado biome, the projection was 15,700 km^2, and a 40% reduction would represent 9,420 km^2 in 2020. The deforestation rate was around 7,900 km^2 in 2020 (INPE, 2024), but it increased to 11,000 km^2 in 2024.

4.2.3.2. Assessment of Government Instruments

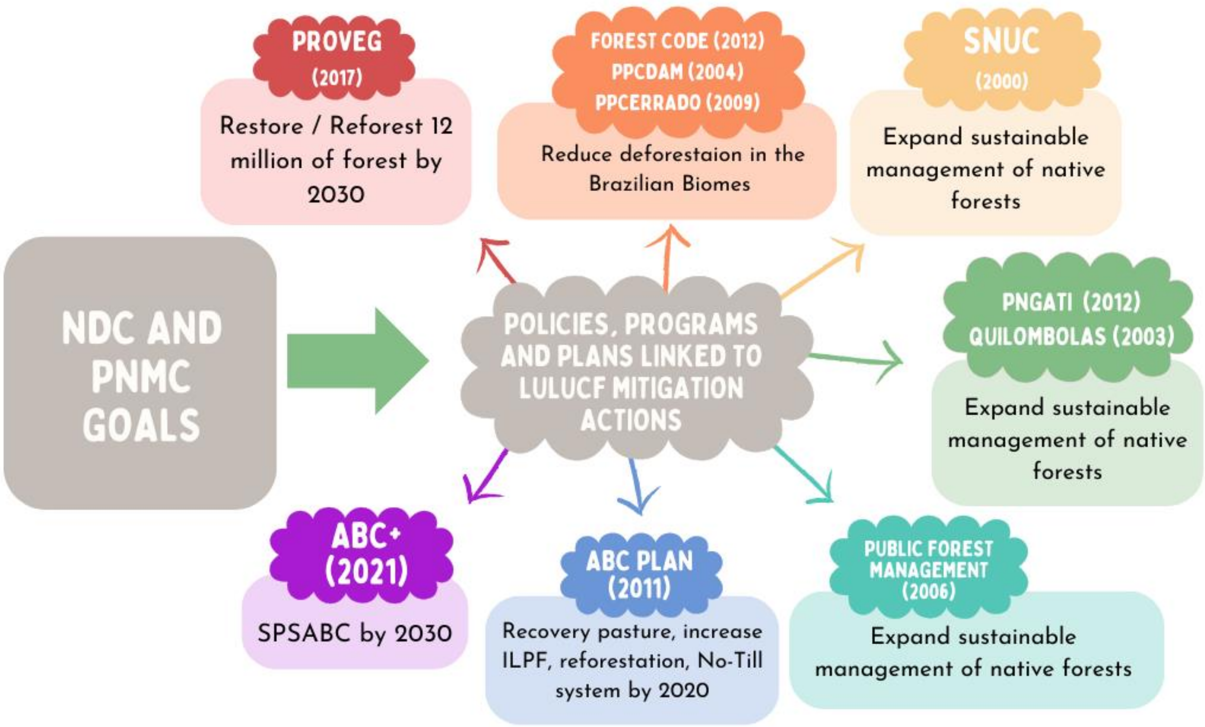
4.2.3.2.1. Progress and Data Challenges on Monitoring Tools

We identified the policies, plans, and programs related to the LULUCF sector to achieve NDC goals (Figure 4.2.2). The **National Policy for the Recovery of Native Vegetation (PROVEG)** aims to recover forests and endorse the environmental regularization of rural properties in at least 12 million hectares by 2030 through the National Plan for the Recovery of Native Vegetation (PLANAVEG) (Brasil, 2017a; 2017b) (SM2- 1). However, no platform or document presents the plan results, reflecting the exclusion of the National Committee for Native Recovery (CONAVEG) in 2019 (Brasil, 2019a).

The **Forest Code** created the Rural Environmental Registry (CAR) to integrate environmental information from rural properties, providing a database for control, monitoring, and planning (Brasil, 2012a) (SM2- 2). By 2024, more than 6 million properties were included in the national database.

The **PPCDAm**[34] and **PPCerrado**[35] plans are in their 5th and 4th phase, respectively, with goals from 2023 to 2027 that were updated based on information provided by PRODES. The 5th phase of PPCDAm includes four axes: sustainable productive activities, environmental monitoring and control, land and territorial planning, and normative and economic instruments (BRASIL, 2023b).

[34] PPDAm previous phases were from 2004 to 2008, 2009 to 2011, 2012 to 2015 and 2016 to 2020.
[35] PPCerrado previous phases were from 2010 to 2011, 2014 to 2015.



NDC: Nationally Determined Contribution; PNMC: The National Policy on Climate Change; PROVEG/PLANAVEG: National Policy for the Recovery of Native Vegetation/National Plan for the Recovery of Native Vegetation; SNUC/PNGATI: National System for Conservation Units/ National Policy for Territorial and Environmental Management of Indigenous Lands; ABC Plan/ ABC+: Low Carbon Agriculture Plan; ILPF: integrated crop-livestock-forest system; SPSABC: ABC Sustainable Systems, Practices, Products and Production Processes.

Figure 4.2.2. Public policies, programs and plans linked to the LULUCF sector to achieve Brazilian NDC goals.

The MMA maintains the National Registry of Conservation Units (CNUC) with information from the **National System for Conservation Units (SNUC)** (SM2- 3). The National Foundation of Indigenous Peoples (FUNAI) organizes spatial information related to indigenous land, part of the **National Policy for Territorial and Environmental Management of Indigenous Lands (PNGATI)** (SM2- 4). We highlight the overlaps between Indigenous Territories and Conservation Units (Cantinho *et al*., 2020).

Ministry of Agrarian Development (MDA) and the National Institute of Colonization and Agrarian Reform (INCRA) are responsible for identifying and demarcating **Quilombola territories** (SM2- 5). The Brazilian Forest Service (SFB) maintains the National Forestry Information System (SNIF), which includes data on **public forests and forest concessions** (Figure SM2. 1). According to SFB, in 2020, a total area of 1,050 million hectares of public forests was under federal forest concession.

The **ABC Plan and ABC+** Platforms estimate mitigation results but lack transparency in their calculations. Embrapa published partial estimates for the ABC Plan from 2010 to 2018, highlighting the need for a methodology to integrate these results into the National GHG Inventory (SM2- 7; SM2- 8).

4.2.3.3. Analysis of the National Greenhouse Gases Inventory

4.2.3.3.1. Governance and Methodology for Estimating Emissions and Removals from the LULUCF Sector

The General Coordination of Climate Science and Sustainability (CGCL) of the MCTI coordinates the National GHG Inventories, counting on the Brazilian Climate Change Research Network (Rede Clima) for technical-scientific coordination. The 4th National GHG Inventory followed the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). The inventory used land cover and use maps for 1994, 2002, 2005 (Amazon only), 2010, and 2016, with carbon stock maps produced by biome. Data on stock/removal from biomass in pastures, croplands, secondary vegetation, and protected natural vegetation were obtained from scientific literature and IPCC default values (Brazil, 2021).

Beyond estimating emissions and removals related to land-use changes, the inventory considered CO_2 removals from protected natural vegetation within Conservation Units and Indigenous Lands. Emissions related to degradation considered only selective logging in the Amazon (SM2- 9).

4.2.3.3.2. Information Gaps

The 4th National GHG Inventory faced several information gaps, including:

- Incomplete map of past natural vegetation at a 1:250,000 scale;
- Significant time gaps between land-use maps, leading to the need for annualization of emissions and removals and not accounting for long-term secondary vegetation removals;
- Lack of data on degradation by fire and changes in carbon soil stocks;
- Incomplete accounting of restoration of degraded pastures and removals from protected vegetation within Quilombola territories and private properties.

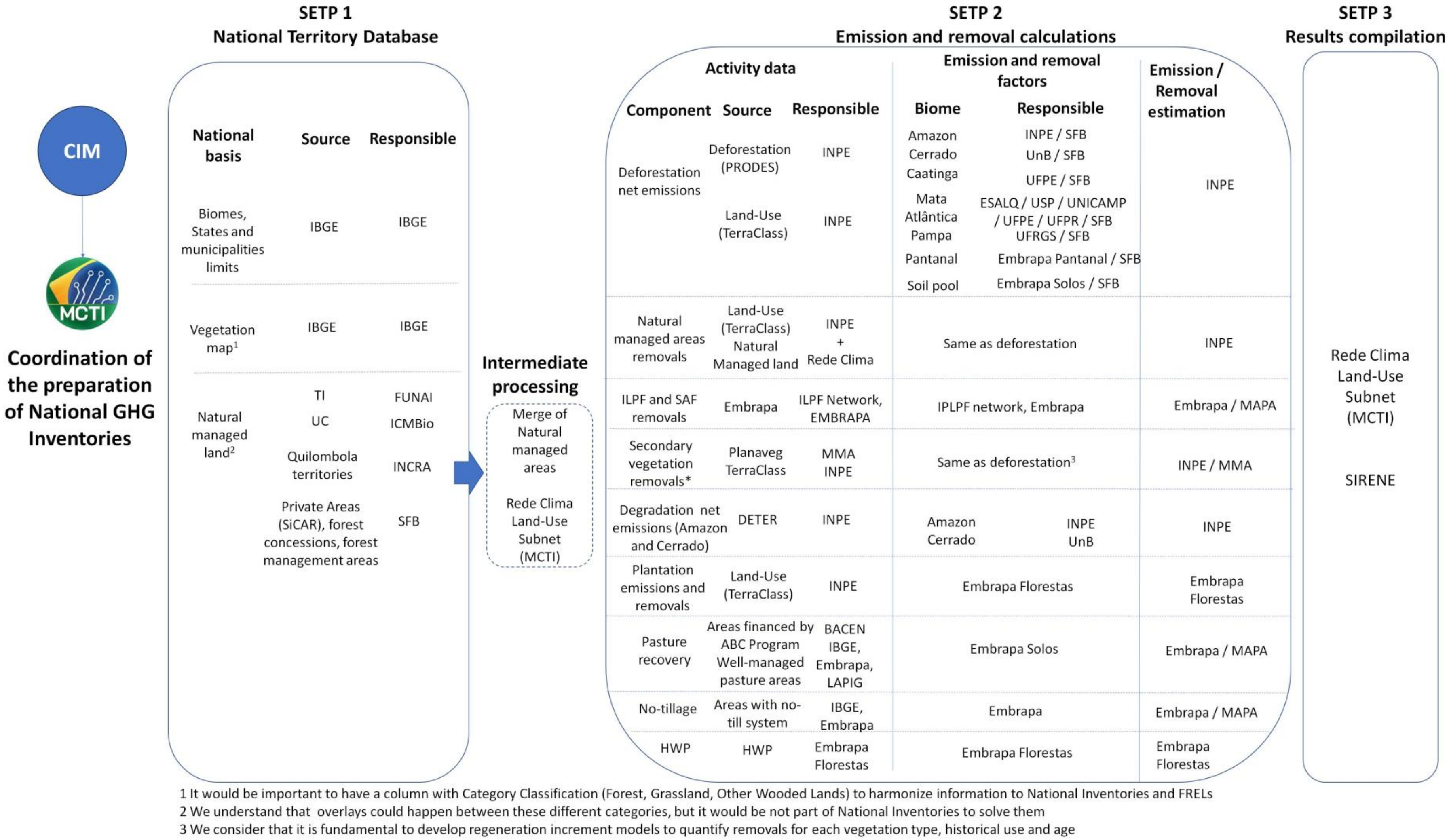
4.2.3.4. Identification of Initiatives and Data Sources

4.2.3.4.1. Potential Data Sources

Beyond the information related to policies, programs, and plans described previously, potential data sources to improve GHG emissions measurement include the Amazon and Other Biomes Monitoring Program (PAMZ+), which comprises PRODES, DETER, and TerraClass (SM2- 10). The National Forest Inventory (NFI) produces information on Brazilian forest resources (SM2- 11). We have compiled the quantitative goals related to each policy, program, and plan related to LULUCF and the potential activity data, emission, and removal factor in Table SM2. 5

4.2.3.4.2. Proposals for Improving Data Collection

We propose using official databases from PRODES, DETER, and TerraClass to estimate emissions from deforestation and degradation. This would improve data completeness and reduce costs. We also suggest a three-step process for compiling the National GHG Inventory: organizing the national territory database, calculating emissions and removals, and compiling the results (Figure 4.2.3).



Source: own production.

Figure 4.2.3. Flowchart for compiling Brazilian National GHG Inventories.

4.2.3.5. Institutional Arrangement and Governance Proposal

4.2.3.5.1. Suggested Structure

We suggest an institutional arrangement coordinated by MCTI and approved by CIM, involving representatives from various organizations responsible for providing data and estimates, guaranteeing that National GHG Inventories are scientifically robust and institutionally and legally legitimate (Veloso, 2019) (Figure 4.2.3; Table SM2. 6). This institutionalization may face challenges due to the different strategies, instruments, and competing powers of the organizations involved (Lotta and Vaz, 2015).

4.2.3.5.2. Expected benefits

Establishing this institutional arrangement would improve the engagement of different institutions, enhance data quality, and ensure better transparency and accuracy in Brazil's reports to the UNFCCC – including the harmonization with the National Forest Reference Emissions Level (FREL). It would also facilitate including mitigation actions from PLANAVEG, the ABC Plan and ABC+ in the National GHG Inventory. This arrangement would enhance governance, state capacity, and public management (Diniz, 2001; Gomide & Pires, 2024; Painter e Pierre, 2005; Procopiuck, 2013).

4.2.3.6. Suggestions for Adjustments and Improvements

4.2.3.6.1. Adjustments to Official Bases

We recommend developing a complete map of past vegetation at a 1:250,000 scale, improving the soil carbon map, and aligning the NFI carbon stock estimation with IPCC guidelines. PRODES, DETER, and TerraClass should be expanded to cover all biomes and provide biannual data since 1990, providing the necessary database to estimate removals from PLANAVEG (Table SM2. 7).

4.2.3.6.2. Impact on Mitigation Targets

Improving data quality and completeness would enhance the accuracy of GHG estimates and support Brazil in monitoring its NDC goals. Including emissions from degradation by fure and removals from PLANAVEG, the ABC Plan, ABC+, Quilombola territories, and private areas would provide a more comprehensive picture of Brazil's GHG emissions and mitigation efforts.

The degradation process could represent 47% of the deforestation emissions or even more (Aguiar *et al*., 2016; Lapola *et al*., 2023); ABC Plan could represent removals of around 194 million of $MgCO_2eq$ between 2010 and 2020, and ABC+ expects removals of one million $MgCO_2e$.

4.2.4. Conclusions

This study identified several opportunities for improvement in the LULUCF sector estimates of National GHG Inventories. The primary areas for enhancement include the development of detailed maps, the inclusion of long-term removals, the consideration of Quilombola territories and private properties, and the use of official databases.

Firstly, there is a need to develop a map of past vegetation and a soil carbon map with better resolution. Additionally, it is crucial to account for emissions related to fire degradation, especially in the Cerrado biome. Including long-term carbon removals from regeneration and restoration is also essential, as it incorporates the results of plans such as ABC, ABC+, and PLANAVEG into GHG estimates.

Another significant point is the importance of considering Quilombola territories and private properties under the CAR. This inclusion can provide a more comprehensive and accurate view of carbon removals. Furthermore, utilizing official databases such as PRODES, TerraClass, DETER, and the NFI can improve data completeness and reduce the costs associated with inventory compiling.

To promote significant advances in governance, state capacity, and public management of GHG estimates, we propose the establishment of an institutional arrangement coordinated by the MCTI and approved by the CIM. This arrangement should involve representatives from various organizations responsible for providing data and estimates, ensuring institutional engagement and clear attribution of responsibilities.

We suggest a three-step process for compiling the National GHG Inventory: (i) organizing the national database, compiling and organizing data from different official sources; (ii) detailed calculation of emissions and removals by components; and (iii) compiling and reviewing the results to ensure accuracy and completeness.

Improving the data's quality and completeness can enhance GHG estimates' accuracy and support Brazil in monitoring its NDC goals. Including emissions from degradation by fire and removals from plans such as ABC, ABC+, and PLANAVEG can provide a more comprehensive picture of Brazil's mitigation efforts.

However, the proposed institutionalization may face challenges due to the different strategies, instruments, and competing powers of the organizations involved. It will be necessary to manage mechanisms and relationships between actors to ensure the continuity of actions.

In summary, implementing the proposed improvements can lead to greater TACCC in Brazil's GHG estimates, facilitating access to comprehensive information for other UNFCCC reports, such as FREL.

BIBLIOGRAPHIC REFERENCES

AGUIAR, A. P.; VIEIRA, I. C.; ASSIS, T. O.; DALLA-NORA, E. L.; TOLEDO, P. M.; SANTOS-JUNIOR, R. A.; BATISTELLA, M.; COELHO, A. S.; SAVAGET, E. K.; ARAGÃO, L. E.; NOBRE, C. A.; OMETTO, J. P. Land use change emission scenarios: anticipating a forest transition process in the Brazilian Amazon. **Global Change Biology,** May 22 (5):1821-40, 2016.

BRASIL. Constituição da República Federativa do Brasil. **Diário Oficial da União:** Brasília, DF, 1988.

BRASIL. Lei nº 9.985, de 18 de julho de 2000. Regulamenta o art. 225, § 1o, incisos I, II, III e VII da Constituição Federal, institui o Sistema Nacional de Unidades de Conservação da Natureza e dá outras providências. **Diário Oficial da União**: Brasília, DF, 19 de julho de 2000.

BRASIL. Decreto nº 4.887, de 20 de novembro de 2003. Regulamenta o procedimento para identificação, reconhecimento, delimitação, demarcação e titulação das terras ocupadas por remanescentes das comunidades dos quilombos de que trata o art. 68 do Ato das Disposições Constitucionais Transitórias. **Diário Oficial da União**: Brasília, DF, 21 de novembro de 2003.

BRASIL. Lei nº 11.284, de 2 de março de 2006. Dispõe sobre a gestão de florestas públicas para a produção sustentável; institui, na estrutura do Ministério do Meio Ambiente, o Serviço Florestal Brasileiro - SFB; cria o Fundo Nacional de Desenvolvimento Florestal - FNDF; altera as Leis nºs 10.683, de 28 de maio de 2003, 5.868, de 12 de dezembro de 1972, 9.605, de 12 de fevereiro de 1998, 4.771, de 15 de setembro de 1965, 6.938, de 31 de agosto de 1981, e 6.015, de 31 de dezembro de 1973; e dá outras providências. **Diário Oficial da União**: Brasília, DF, 03 de março de 2006.

BRASIL. Lei nº 12.187, de 29 de dezembro de 2009. Institui a Política Nacional sobre Mudança do Clima - PNMC e dá outras providências. **Diário Oficial da União**: seção 1, Brasília, DF, p 109, 29 dez. 2009.

BRASIL. Decreto nº 7.390, de 9 de dezembro de 2010. Regulamenta os arts. 6o, 11 e 12 da Lei no 12.187, de 29 de dezembro de 2009, que institui a Política Nacional sobre Mudança do Clima - PNMC, e dá outras providências. **Diário Oficial da União**: Seção 1, p. 4. 10 de dezembro de 2010.

BRASIL. Lei nº 12.651, de 25 de maio de 2012. Dispõe sobre a proteção da vegetação nativa; altera as Leis nºs 6.938, de 31 de agosto de 1981, 9.393, de 19 de dezembro de 1996, e 11.428, de 22 de dezembro de 2006; revoga as Leis nºs 4.771, de 15 de setembro de 1965, e 7.754, de 14 de abril de 1989, e a Medida Provisória nº 2.166-67, de 24 de Agosto de 2001; e dá outras providências. **Diário Oficial da União**: seção 1, Brasília, DF, p. 1, 28 de maio de 2012a.

BRASIL. Decreto nº 7.747, de 5 de junho de 2012. Institui a Política Nacional de Gestão Territorial e Ambiental de Terras Indígenas – PNGATI, e dá outras providências. **Diário Oficial da União**: seção 1, Brasília, DF, 06 de junho de 2012b.

BRASIL. Plano setorial de mitigação e de adaptação às mudanças climáticas para a consolidação de uma economia de baixa emissão de carbono na agricultura: Plano ABC (Agricultura de Baixa Emissão de Carbono) / **Ministério da Agricultura, Pecuária e Abastecimento, Ministério do Desenvolvimento Agrário, coordenação da Casa Civil da Presidência da República.** Brasília: 2012c, 173 p. ISBN 978-85-7991-062-0.

BRASIL. Decreto nº 8.972, de 23 de janeiro de 2017. Institui a Política Nacional de Recuperação da Vegetação Nativa. **Diário Oficial da União**: seção 1, Brasília, DF, p. 7., 24 de janeiro de 2017a.

BRASIL. Portaria Interministerial 230 de 14 de novembro de 2017. Estabelece o Plano Nacional de Recuperação da Vegetação Nativa - PLANAVEG. **Diário Oficial da União**: seção 1, Brasília, DF, 16 de novembro de 2017b.

BRASIL. Ministério do Meio Ambiente. Planaveg: Plano Nacional de Recuperação da Vegetação Nativa / Ministério do Meio Ambiente, Ministério da Agricultura, Pecuária e Abastecimento, Ministério da Educação. **Ministério do Meio Ambiente**, 73 p., Brasília, DF, 2017c.

BRASIL. Decreto nº 9.172, de 17 de outubro de 2017. Institui o Sistema de Registro Nacional de Emissões - Sirene, dispõe sobre os instrumentos da Política Nacional sobre Mudança do Clima a que se refere o inciso XIII do caput do art. 6º da Lei nº 12.187, de 29 de dezembro de 2009, e altera o Decreto nº 7.390, de 9 de dezembro de 2010, que regulamenta a referida Política. **Diário Oficial da União** de 18 de outubro de 2017d.

BRASIL. Decreto nº 9.578, de 22 de novembro de 2018. Consolida atos normativos editados pelo Poder Executivo federal que dispõem sobre o Fundo Nacional sobre Mudança do Clima, de que trata a Lei nº 12.114, de 9 de dezembro de 2009, e a Política Nacional sobre Mudança do Clima, de que trata a Lei nº 12.187, de 29 de dezembro de 2009. **Diário Oficial da União**: seção 1, Brasília, DF, n. 225, p. 47, 23 de novembro de 2018.

BRASIL. Decreto nº 9.759 de 11 de abril de 2019. Extingue e estabelece diretrizes, regras e limitações para colegiados da administração pública federal. **Diário Oficial da União**, Brasília, DF, 2019a.

BRASIL. Decreto nº 10.088, de 5 de novembro de 2019. Consolida atos normativos editados pelo Poder Executivo Federal que dispõem sobre a promulgação de convenções e recomendações da Organização Internacional do Trabalho - OIT ratificadas pela República Federativa do Brasil. **Diário Oficial da União** de 6 de novembro de 2019, retificado em 4 de dezembro de 2019 - Edição extra e retificado em 13 de dezembro de 2019b.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. Plano Setorial para Adaptação à Mudança do Clima e Baixa Emissão de Carbono na Agropecuária 2020-2030 : Plano Operacional / Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Inovação, Desenvolvimento Rural e Irrigação. – Brasília: **Ministério da Agricultura, Pecuária e Abastecimento**, 2021. 133p. ISBN: 978-65-86803-63-1. Available on: https://www.gov.br/agricultura/pt-br/assuntos/sustentabilidade/agricultura-de-baixa-emissao-de-carbono/publicacoes/final-isbn-plano-setorial-para-adaptacao-a-mudanca-do-clima-e-baixa-emissao-de-carbono-na-agropecuaria-compactado.pdf/@@download/file. Accessed on 20 Feb. 2023.

BRASIL. DECRETO Nº 11.550, DE 5 DE JUNHO DE 2023. Dispõe sobre o Comitê Interministerial sobre Mudança do Clima. **Diário Oficial da União**, 2023a.

BRASIL. Ministério do Meio Ambiente e Mudança do Clima. Plano de Ação para a Prevenção e Controle do Desmatamento na Amazônia Legal (PPCDAm) : 5ª fase (2023 a 2027). **Subcomissão Executiva do PPCDAm**. Brasília, DF: MMA, 2023b.

BRASIL. DECRETO Nº 12.040, DE 5 DE JUNHO DE 2024. Altera o Decreto nº 11.550, de 5 de junho de 2023, que dispõe sobre o Comitê Interministerial sobre Mudança do Clima. **Diário Oficial da União**, Brasília, 2024.

BRAZIL. National Plan on Climate Change. **Government of Brazil**, Brasília, 2008. Available on: https://antigo.mma.gov.br/estruturas/smcq_climaticas/_arquivos/executive_summary_pnmc.pdf. Accessed on: 18 Feb. 2021.

BRAZIL. Ministry of Science, Technology, and Innovations. Secretariat for Research and Scientific Training. Fourth National Communication of Brazil to the United Nations Framework Convention on Climate Change / Secretariat for Research and Scientific Training. Brasília: **Ministry of Science, Technology, and Innovations**, 2021. 620 p.: il. ISBN: 978-65-87432-19-9.

BRAZIL. Ministry of Agriculture, Livestock and Food Supply. ABC+ Brazilian Agricultural Policy for Climate Adaptation and Low Carbon Emission 2020-2030. Brasília: **Ministry of Agriculture, Livestock and Food Supply**, 40p. il, 2022. Available on: https://www.gov.br/agricultura/pt-br/assuntos/sustentabilidade/agricultura-de-baixa-emissao-de-carbono/publicacoes/abc-sumario-executivo-2022-ingles.pdf. Accessed on: 20 Feb. 2023.

CALMON, P.; COSTA, A. T. M. Redes e Governança das Políticas Públicas. **Centro de Estudos Avançados de Governo e de Administração Pública** (CEAG/UnB), 2013.

CANTINHO, R. Z.; LINARES, J. A. H., VIEIRA, J. L. V. C.; ASSIS, M. L. R.; BUSTAMANTE, M. M. C. Áreas protegidas no Brasil: evolução, uso e cobertura da terra e impacto no Inventário de Emissões. **Revista Floresta**, Edição 51 - Volume 1, janeiro, 2021.

DINIZ, E. Globalização, reforma do estado e teoria democrática contemporânea. São Paulo: **São Paulo em Perspectiva**,15(4), 2001.

EMBRAPA. Mitigação das emissões de gases de efeitos estufa pela adoção das tecnologias do Plano ABC: estimativas parciais. MANZATTO, C. V.; ARAUJO, L. S. de; ASSAD, E. D.; SAMPAIO, F. G.; SOTTA, E. D.; VICENTE, L. E.; PEREIRA, S. E. M.; LOEBMANN, D. G. dos S. W.; VICENTE, A. K. **Embrapa Meio Ambiente**, Jaguariúna, 2020. Available on: https://www.gov.br/agricultura/pt-br/assuntos/sustentabilidade/agricultura-de-baixa-emissao-de-carbono/publicacoes/mitigacao-das-emissoes-de-gases-de-efeitos-estufa-pela-adocao-das-tecnologias-do-plano-abc-estimativas-parciais.pdf/@@download/file. Accessed on: 15 Jan. 2023.

GOMIDE, A. ; MARENCO, A. Capacidades estatais: avanços e tendências / organizado por Alexandre Gomide e André Marenco. – Brasília, **Cadernos ENAP**, 133, 2024. 99 p.

GOMIDE, A.; PIRES, R. Capacidades estatais em ação:a abordagem dos arranjos de implementação de políticas públicas. In: ENAP. Capacidades estatais: avanços e tendências / organizado por Alexandre Gomide e André Marenco. **Cadernos ENAP**, 133, 99 p., Brasília, 2024.

FEDERATIVE REPUBLIC OF BRAZIL. Intended Nationally Determined Contribution towards achieving the objective of the United Nations Framework Convention on Climate Change**. The Paris Agreement and NDCs**, 2015. Available on: https://antigo.mma.gov.br/images/arquivo/80108/BRAZIL%20iNDC%20english%20FINAL.pdf. Accessed on: 18 Feb. 2019.

GRANZIERA, B.; HAMRICK, K.; VERDIECK, J. Article 6 Explainer: Questions and answers about the COP27 Decisions on carbon markets and what they mean for NDCs, nature, and the voluntary carbon markets. **The Nature Conservancy**, 2023. Available on:

https://www.nature.org/content/dam/tnc/nature/en/documents/TNC_Article_6_Explainer_260523.pdf. Accessed on: 04 Sep. 2023.

GRINDLE, M. Good Enough Governance: Poverty Reduction and Reform in Developing Countries. **Governance: An International Journal of Policy, administration, and Institutions** 17(4): 525-548, 2004.

HOCHSTETLER, K. Climate institutions in Brazil: three decades of building and dismantling climate capacity, **Environmental Politics**, 30:sup1, 49-70, 2021. DOI:10.1080/09644016.2021.1957614.

INCRA. Instituto Nacional de Colonização e Reforma Agrária. regularização de Território Quilombola: Perguntas & Respostas. Diretoria de Ordenamento da Estrutura Fundiária. **Coordenação Geral de Regularização de Territórios Quilombolas**, Brasília, 2017. Available on: https://www.gov.br/incra/pt-br/assuntos/governanca-fundiaria/perguntas_respostas.pdf. Accessed on 20 Feb. 2023.

INPE. Metodologia Utilizada nos Projetos PRODES e DETER. **Coordenação-Geral de Observação da Terra**, 2019. Available on http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/prodes/pdfs/Metodologia_Prodes_Deter_revisada.pdf. accessed on October 10, 2023.

INPE. Monitoramento do Desmatamento da Floresta Amazônica Brasileira por Satélite - **PRODES**, 2024. Available on: http://terrabrasilis.dpi.inpe.br/app/dashboard/deforestation/biomes/legal_amazon/rates. Accessed on: 19 Jan. 2024.

IPCC – Intergovernmental Panel on Climate Change. Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Vol. 4. Agriculture, Forestry and Other Land Use. Ch. 4. Forestland. EGGLESTON, H. S.; BUENDIA, L.; MIWA, K.; NGARA, T.; TANABE, K. (eds.). Japan: **IGES**, 2006.

LAPOLA, D. M.; PINHO, P.; BARLOW, J. et al. The drivers and impacts of Amazon forest degradation. **Science** 379, Issue 6630, 2023.

LOTTA, G. S.; VAZ, J. C. Arranjos institucionais de políticas públicas: aprendizados a partir de casos de arranjos institucionais complexos no Brasil. **Revista do Serviço Público,** Brasília 66 (2) 171-194 abr/jun 2015.

MAPA. Portaria interministerial nº 984, de 8 de outubro de 2013. Institui o Plano Setorial para Consolidação de uma Economia de Baixa Emissão de Carbono na Agricultura - Plano ABC Nacional. **Diário Oficial da União**: seção 1, n. 196, p. 2, 09 de outubro de 2013.

MAPA.Relatório de Gestão de Florestas Publicas 2019. **Serviço Florestal Brasileiro**, 2019 . Available on: https://www.gov.br/agricultura/pt-br/assuntos/servico-florestal-brasileiro/acesso-a-informacao/gestao-de-florestas-publicas-1/relatorios-gestao-de-florestas-publicas/relatorio_gestao_florestas_publicas_2019.pdf. Accessed on 03 Aug. 2023.

MCTI. 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. Relatório De Referência: Setor Uso da Terra, Mudança do Uso da Terra e Florestas. Brasília: **Ministério da Ciência, Tecnologia e Inovação**, 2020.

MENDES, H. V. Viabilidade dos Compromissos Brasileiros de Redução de Emissões de Gases de Efeito Estufa: uma análise dos períodos pré e pós-2020. 157p. **Dissertação de Mestrado – Centro de Desenvolvimento Sustentável, Universidade de Brasília**, Brasília, DF, 2020.

OMETTO, J. P.; GORGENS, E. B.; PEREIRA, F. R. S.; ASSIS, M. L. R.; CANTINHO, R.; LONGO, M. JACON, A.; KELLER, M. a biomass map of the Brazilian amazon from multisource remote sensing. **Nature: Scientific data**, 10:668, 2023.

PAINTER, M.; PIERRE, J. Unpacking Policy Capacity: issues and themes. In: PAINTER, Martin; PIERRE, Jon. Challenges to State Policy Capacity. New York: **Palgrave Macmillan**, p. 1-18, 2005.

PROCOPIUCK, M. Políticas Públicas e fundamentos da administração pública: análise e avaliação, governança e rede de políticas públicas, administração judiciária. São Paulo: **Atlas**, 2013.

SOARES-FILHO, B., RAJÃO, R., MACEDO, M., CARNEIRO, A., COSTA, W., COE, M., ALENCAR, A. Cracking Brazil’s Forest Code. **Science**, 344 (6182), 363–364, 2014.

UNFCCC. Paris Agreement. **United Nations**, 2015. Available on: https://unfccc.int/sites/default/files/english_paris_agreement.pdf. Accessed on: 10 Sep. 2021.

UNFCCC. Federative Republic of Brazil Nationally Determined Contribution (NDC) to the Paris Agreement under the UNFCCC. **UNFCCC,** 2023. Available on: https://unfccc.int/sites/default/files/NDC/2023-11/Brazil%20First%20NDC%202023%20adjustment.pdf. Accessed on 12 Feb. 2024.

VELOSO, L. V. S. Evolução dos inventários nacionais de gases de efeito estufa para o setor de uso da terra, mudança de uso da terra e florestas. **Dissertação (mestrado) – Universidade Federal de Minas Gerais**, Departamento de Cartografia, 2019.

VON LÜPKE, H.; LEOPOLD, L.; TOSUN, J. Institutional coordination arrangements as elements of policy design spaces: insights from climate policy. **Policy Science** 56, 49–68, 2023.

4.3. NESTING PRIVATE CARBON PROJECTS WITHIN JURISDICTIONAL PROGRAMS TO ACCESS REDD+ RESULTS PAYMENT: THE CASE OF PARÁ

Summary

The Lowering Emissions by Accelerating Forest Finance Coalition (LEAF Coalition) has encouraged countries and states to develop or enhance their Reducing Emissions from Deforestation and Forest Degradation (REDD+) programs to meet The REDD+ Environmental Excellence Standard (TREES) from the Architecture for REDD+ Transactions (ART), known as “ART/TREES”. Pará, an Amazon state, is developing its REDD+ Jurisdictional System following ART/TREES requirements to access LEAF Coalition funding. One of the significant challenges for Pará is the nesting of REDD+ projects within its Jurisdictional System. Nesting involves aligning the measurement of greenhouse gas (GHG) emission reductions and removals from REDD+ activities across multiple scales to avoid double counting. By evaluating the experiences of other countries, the legal instruments of the National REDD+ Committee (CONAREDD+), and the development of the Brazilian Emissions Trading System (SBCE), we identified several challenges in the successful implementation of REDD+ nesting. These challenges include conceptual, scientific/methodological, economic, and political-legal issues. We assessed Pará´s crediting level from 2018 to 2022, which amounted to 244 $MtCO_2e$, and determined the necessary credit deductions (55%) following ART/TREES guidelines. In 2023, Pará could generate 18 $MtCO_2e$ after discounting for REDD+ projects (35% of the credits), potentially accessing over US$180 million from LEAF Coalition. Considering the differences in baselines between local and jurisdictional initiatives, we conclude that empowering CONAREDD+ with the legal authority and state capacity to establish a national baseline applicable to private initiatives is fundamental. Improving the estimates of emissions and removals in the National GHG Emissions Inventories is essential to providing the necessary support for the Brazilian Forest Reference Emission Level (FREL) and facilitating integration between these initiatives. This would reduce costs and enhance the credibility of the Voluntary Carbon Market (VCM) in Brazil, enabling access to project-scale voluntary markets and results-based finance.

4.3.1. Introduction

In 2021, government and private sector leaders announced the Lowering Emissions by Accelerating Forest Finance Coalition (LEAF Coalition)[36] to support large-scale Reducing Emissions from Deforestation and Forest Degradation (REDD+) programs across entire countries or subnational jurisdictions. The creation of the LEAF Coalition encouraged countries and states to build or improve their REDD+ programs to meet the REDD+ Environmental Excellence Standard (TREES) from the Architecture for REDD+ Transactions (ART), known as ‘ART/TREES’. LEAF Coalition

[36]LEAF Coalition. Available on: https://www.leafcoalition.org/pt/about. Accessed on: 23 Mar. 2023.

buyers require this standard to ensure high environmental integrity and social safeguards.

Pará, one of the Amazon states, submitted a Letter of Interest (LOI) to the LEAF Coalition[37]. To this end, the government has been developing its REDD+ Jurisdictional System following ART/TREES requirements (ART, 2021b; ART, 2021b). Pará is working on its TREES Concept Note (ART, 2021c) and TREES Registration Document (ART, 2021d), necessary for eligibility under ART/TRESS. One of the significant challenges for Pará is determining how to consider private REDD+ within its REDD+ Jurisdictional System, a condition of the ART/TREES standard.

‘Nesting’ refers to the alignment of the accounting of greenhouse gas (GHG) emission reductions and removals from REDD+ activities across multiple scales. A nested REDD+ system ensures environmental integrity and avoids double counting by aligning the Measurement, Reporting, and Verification (MRV) systems and establishing institutional arrangements for operating and maintaining this system. Ensuring integrity in this accountability is crucial for Brazil to access REDD+ finance, among other safeguards-related issues[38]. Some countries, such as Australia, Colombia, Guatemala, Peru, and the Democratic Republic of Congo, have made significant progress in nesting their REDD+ systems (World Bank Group, 2021).

In this context, this study aims to explore the experiences of other countries in establishing REDD+ nesting to derive lessons for Brazil. We also evaluate the impacts of the ongoing REDD+ projects in Pará´s credit period, following ART/TREES standards. Finally, we assess the current role of the National REDD+ Committee (CONAREDD+) and ongoing national regulations that could assist Brazil and Pará in the REDD+ nesting process to ensure integrity in accessing climate finance.

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[37] Pára LOI to the LEAF Coalition. Available on: https://resources.leafcoalition.org/wp-content/uploads/2021/12/Para_CFP-1.pdf. Accessed on 21 Mar. 2023.

[38] The safeguards establish that REDD+ initiatives must promote and support complementary actions consistent with the objectives of forestry programs and relevant international conventions and agreements; transparent and effective national forest governance structures, considering national legislation and sovereignty; respect for the knowledge and rights of indigenous peoples and local communities, taking into account relevant international obligations, national circumstances and laws and the United Nations Declaration on the Rights of Indigenous Peoples; the full and effective participation of relevant stakeholders, in particular indigenous peoples and local communities; actions consistent with the conservation of natural forests and biodiversity; actions to avoid the risks of reversals of REDD+ results; and actions to reduce the displacement of emissions to other areas (UNFCCC, 2011).

4.3.2. Methodology

4.3.2.1. Documentation Analysis

We conducted a comprehensive documentation analysis to address the challenges of nesting private REDD+ projects within Pará's jurisdictional REDD+ system. This analysis focused on how other countries have approached similar challenges to derive lessons that could apply to Brazil. Specifically, we examined documentation from Australia, Colombia, Guatemala, Peru, and the Democratic Republic of Congo. These countries were selected based on their advanced progress in establishing nested REDD+ systems. The insights gained from this analysis were contextualized to align with Brazil's national circumstances.

4.3.2.2. Crediting Level Evaluation

To assess the crediting level of the state of Pará, we analyzed emissions data from deforestation and forest degradation from 2018 to 2022. This evaluation was conducted following the ART/TREES methodology, which requires a discount on the credits issued by private projects from the jurisdictional program. To ensure harmonization with the federal methodology, we used the 2017-2021 Forest Reference Emission Level (FREL) results submitted to the United Nations Framework Convention on Climate Change (UNFCCC) as a reference.

4.3.2.3. Estimation of Credits for 2023

We estimated the potential carbon credits that Pará could generate in 2023 by considering the state's deforestation rate for that year, including the proportion related to forest degradation. The estimation process involved applying the required ART/TREES discounts, which include buffers to mitigate reversals[39], leakage[40], and uncertainties. These discounts are critical for maintaining the environmental integrity of the credits.

[39] Reversal is understood as the increase in GHG emissions from deforestation and degradation after reducing emissions from these activities in a certain period.
[40] Leakage is a reduction in carbon emissions in one area that results in increased emissions in another.

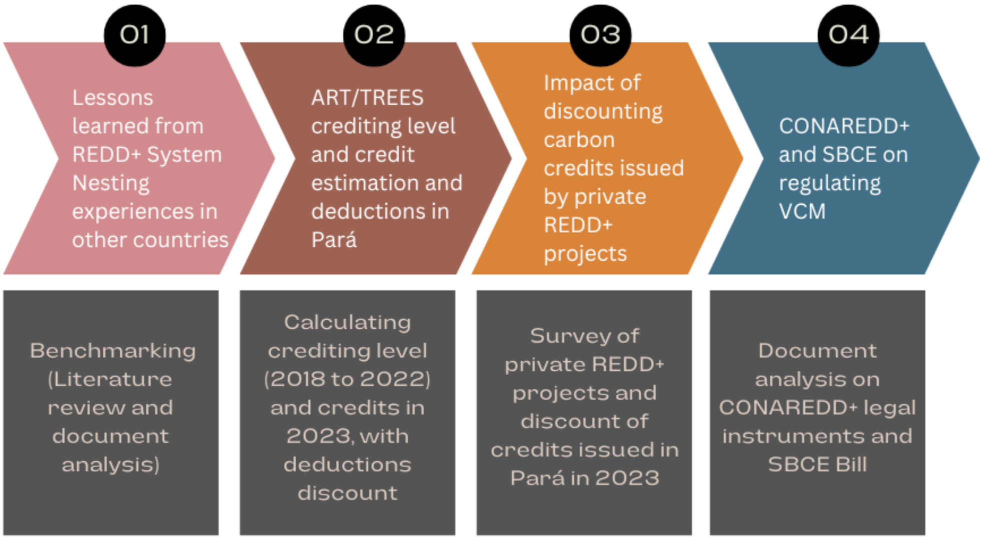
4.3.2.4. Impact Analysis of Discounting Private REDD+ Credits

To understand the impact of discounting private REDD+ carbon credits issued in 2023, we calculated the difference between the estimated credits for 2023 and the carbon credits issued from private projects. This analysis was essential to quantify the effect of integrating private project credits into the jurisdictional system and to ensure that the overall crediting level remains robust and credible.

4.3.2.5. Analysis of CONAREDD+ and SBCE Regulations

Given the discrepancies between the baselines of private projects and the national methodology, particularly regarding additionality[41], we conducted a documentation analysis on the legal instruments of the National REDD+ Committee (CONAREDD+). This analysis aimed to explore CONAREDD+'s role in regulating the Voluntary Carbon Market (VCM) and ensuring the integrity of carbon credits. Additionally, we examined the Bill related to the Brazilian Emissions Trading System (SBCE) to understand how it could regulate the VCM or reinforce CONAREDD+'s role in this context. This step was crucial for identifying regulatory frameworks supporting the nesting process and enhancing access to climate finance.

In Figure 4.3 1, we present a summary of these steps.



Where: REDD+: Reducing Emissions from Deforestation and Forest Degradation; ART/TREES: The REDD+ Environmental Excellence Standard (TREES) standard from Architecture for REDD+ Transactions (ART); CONAREDD+: National REDD+ Committee; SBCE: Brazilian Emissions Trading System

Figure 4.3 1. Methodology steps on nesting private projects in Pará evaluation.

[41] Additionality of a project means demonstrating that the project goes beyond usual practices (BAU - business as usual), that is, that the activities foreseen in the project have, as a specific purpose, the benefits of environmental and/or social service and that would not be normally carried out if the project was not implemented.

4.3.3. Results

4.3.3.1. Lessons Learned from Other Countries about the Nesting Process

4.3.3.1.1. Comparison of Integration Strategies

Costa Rica and Ecuador included all the initiatives under Jurisdictional REDD+ programs (JREDD+). Costa Rica developed its National REDD+ System under the Forest Carbon Partnership Facility (FCPF)[42], and a benefit-sharing mechanism is under development. In Ecuador, all environmental services belong to the state. Consequently, projects do not generate carbon credits (GCF, 2022). The country may receive payments for REDD+ performance, which can be transferred to beneficiaries through national forest schemes such as the SocioBosque program[43].

The Democratic Republic of Congo's (DRC) benefit-sharing arrangements for the FCPF Carbon Fund[44] provide payments for GHG performance to carbon projects, as well as the possibility for projects to receive a part of the credits that are generated by the program but are not purchased by the Carbon Fund (Democratic Republic of Congo, 2015). Programs and projects must use nationally generated data. DRC´s approach could be classified as Centralized (World Bank Group, 2021).

Colombia accessed REDD for Early Movers (REM) and Green Climate Fund (GCF)[45] (GCF, 2020) for results-based finance. It also promotes private actions to protect forests by recognizing credits from REDD+ projects under the national carbon tax (El Congreso de Colombia, 2016) and future emissions trading system (El Congreso de Colombia, 2018). In 2018, the government developed rules for projects to align their methods with the national system: programs or projects must be aligned with national FREL and registered in the 'National Registry of Greenhouse Gas Emission Reductions' (RENARE) (Republica de Colombia, 2018). A maximum

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[42] National REDD+ System in Costa Rica. Available on: https://reddcr.go.cr/en. Accessed on 23 Jan. 2024.

[43] SocioBosque Program in Ecuador. Available on: https://sociobosque.ambiente.gob.ec/. Accessed on 23 Jan. 2024.

[44] FCPF in DRC. Available on: https://www.forestcarbonpartnership.org/country/congo-democratic-republic. Accessed on: 23 Jan. 2024.

[45] REM and FCPF in Colombia. Available on:https://www.forestcarbonpartnership.org/country/colombia. Accessed on: 23 Jan. 2024.

emissions mitigation will be allocated to local projects based on the national FREL. Colombia´s approach is classified as Decentralized (World Bank Group, 2021).

Some REDD+ projects began in Guatemala before coordinating sub-national or national REDD+ systems. The government offered REDD+ projects to participate in discussions around the REDD+ program developed under the FCPF's Carbon Fund. Two existing projects were integrated into the program, and the third (the REDD+ La Costa del la Conservación project) was excluded. In 2013, Guatemala created requirements for all current and future REDD+ projects to be registered in Guatemala's National Registry of REDD+ Initiatives. These projects were supposed to follow Guatemala´s FREL. Existing projects needed to adjust and update baselines. Guatemala requires all emissions reductions to first be used to fulfill its FCPF contract (Gobierno de la Republica de Guatemala, 2019). Once Guatemala met those obligations, and if in-country projects exceeded these goals, the credits could be sold on the voluntary carbon markets.

Peru has various REDD+ projects developed by non-governmental organizations (NGOs) and private companies in partnership with indigenous communities, forest concessions, and protected areas. Many of these projects began activities before the National FREL and MRV system. Peru has taken a centralized approach to carbon rights, with a Payment for Ecosystem Services Law declaring that carbon sequestration and storage, including from REDD+ activities, are national patrimony. The 'National Registry of Mitigation Measures' (RENAMI), launched in 2020, allows the government to monitor transactions of carbon credits issued by REDD+ initiatives and manage issues of double counting from discounting these credits for the Nationally Determined Contribution (NDC).

Although Australia is not eligible for REDD+ activities due to being a developed country, it can exemplify how consistent land sector mitigation activities can be in the national accounts. All projects that sequester or remove emissions in Australia must use the state's Full Carbon Accounting Model (FullCAM) (Australian Government, 2021), which also updates Australia's GHG Inventories for the land use sector. Project accounting is aligned with national accounting – data and methodology applied to the National Inventory of Emissions of GHG are made available, reducing costs - while project crediting remains independent of any national crediting system. The private sector contributes to the emissions reduction fund through the national system of taxing national emissions, and local projects may access this fund to obtain financing. Australia’s approach to nesting demonstrates a balance between a centralized approach established through a domestic carbon offset scheme and a national accounting framework, with project-level implementation, reporting, and financing.

China chose not to participate in REDD+ standards or funds (Zhou *et al*., 2017).

In Table 4.3.1, we present a summary of integration strategies developed by countries.

Table 4.3.1. Summary of countries´ nesting strategies.

Country	Integration strategy
Costa Rica and Ecuador	Only Jurisdictional REDD+ programs.
Democratic Republic of Congo (DRC)	Programs and projects must use nationally generated data and benefit-sharing arrangements to provide payments and part of credits for GHG performance in projects.
Colombia	Programs and projects must be aligned with FREL and registered; a maximum emissions mitigation will be allocated to projects.
Guatemala	Projects must be aligned with Guatemala´s FREL and could receive credits once Guatemala meets its obligations.
Peru	Projects in protected areas must be aligned with FREL; all projects must be registered.
Australia	Project accounting is aligned with national accounting; the private sector contributes to the emissions reduction fund through the national tax system and may access this fund to obtain financing.
China	Only private projects; no JREDD+.

Source: own production.

4.3.3.1.2. Lessons learned

Colombia has recognized the role of local REDD+ initiatives in reducing deforestation, achieving emissions reductions, and stimulating climate finance flows, amongst other co-benefits. Establishing the alignment of the projects’ baselines with FREL was imperative to mitigate the overestimation of carbon credit generation in local initiatives. The limitation of credit allocation in projects helps the country to achieve its climate mitigation goals under its NDC.

Domestic carbon schemes, like those in Colombia and Australia, where projects have the right to sell carbon directly to domestic buyers, have successfully attracted private sector financing REDD+ activities due to the legal security provided by these regulated schemes. As the projects´ baselines are aligned with a national reference, it guarantees more accuracy to the credit’s estimation since studies showed that some REDD+ projects were overestimating the additionality and carbon credit generation, putting the reputation of VCM at risk (West et al., 2023).

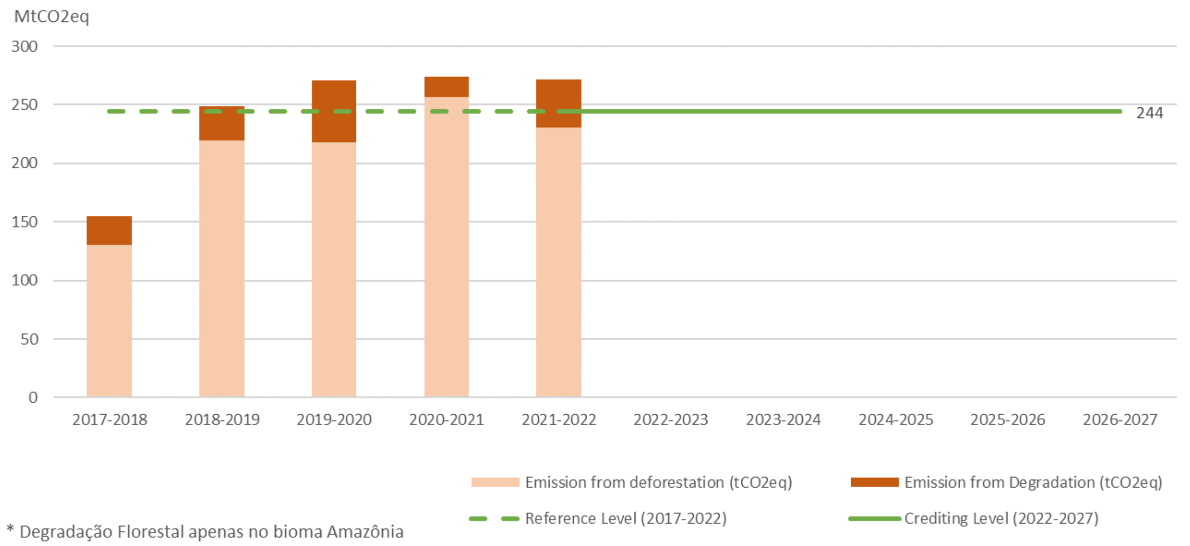
The experiences of Peru, Guatemala, and DRC demonstrated the importance of national involvement and communication between projects and national authorities in avoiding double-counting under national obligations. It is critical to have an integrated and cross-cutting approach to develop a REDD+ strategy with input from relevant stakeholders to guarantee the successful implementation of REDD+ nesting aligned with UNFCCC rules under the Paris Agreement.

An appropriate MRV framework, such as those from Guatemala and Australia, ensures the integrity of abatement and alignment with UNFCCC requirements and could reduce costs once the states and projects can use the national database.

4.3.3.2. ART/TREES crediting level and credit deductions in Pará

The United Nations Development Program (UNDP) helped the Amazon states to advance their compliance with ART/TREES requirements to negotiate REDD+ credits under the LEAF Coalition. Part of this support was to calculate the REDD+ crediting level using the same database and methodology of Brazil's FREL from 2017 to 2021 (UNFCCC, 2023). UNDP has also integrated the latest data on deforestation and forest degradation from PRODES and DETER for 2022 and has estimated uncertainties considering the Monte Carlo approach, requested by ART/TREES. The crediting level is related to the average deforestation and forest degradation emissions for the defined reference period (5 years). The Pará crediting level for the reference period of 2018 to 2022 was 244 MtCO_2eq (Figure 4.3 2), and degradation from the Cerrado biome has not been considered, as it represents around 1% of the state and emissions related to this source would be less than 10%, so it does not have to be accounted accordingly to ART/TREES requirements. The emissions uncertainty for Pará was estimated at around 20%, including deforestation and forest degradation.

One fact to highlight is that FREL considers deforestation related only to primary forests, based on the PRODES database. Nonetheless, it would be essential to ponder additionally secondary vegetation deforestation once it could represent GHG emissions.



Period	Emissions			Degradation assessment
	Emission from Degradation (tCO2eq)	Emission from deforestation (tCO2eq)	Emission from D&D (tCO2eq)	Degradation/ deforestation (%)
2017-2018	24 107 542	130 489 045	154 596 586	18,5%
2018-2019	29 127 612	219 554 286	248 681 898	13,3%
2019-2020	53 346 924	217 618 193	270 965 118	24,5%
2020-2021	17 150 248	256 848 603	273 998 851	6,7%
2021-2022	41 122 285	230 719 504	271 841 789	17,8%
Crediting Level		**211 045 926**	**244 016 848**	**16,2%**

Source: UNDP, 2024.

Figure 4.3 2. Crediting level for Pará (2018 to 2022) considering Brazil's FREL methodology.

As determined by ART/TREES, Pará would also have to discount a buffer related to reversals, which has 25% as a standard factor, allowing some discounts if the state has already developed measures to mitigate these reversals. Considering that Pará has i. the State Policy on Climate Change in Pará (PEMC/PA) (Governo do Estado do Pará, 2020a), which creates GHG mitigation goals and measurements to achieve them; ii. the 'Amazon Now State Plan' (PEAA) (Governo do Estado do Pará, 2020b), which could be interpreted as a REDD+ Implementation Plan once it involves actions related to combating deforestation and land regularization; and iii. climate governance instituted - the State System Management Committee on Climate Change (COGES-Clima), the Pará Forum on Climate Change and Adaptation (FPMAC)[46], and their technical chambers, there could be a discount of 5%.

In addition, we could consider PEAA, the State Bioeconomy Plan for Pará (Planbio) (Governo do Estado do Pará, 2022), and the Native Vegetation Recovery

[46] More information available on: https://www.semas.pa.gov.br/colegiado/fpmc/; accessed in March 2024.

Plan of the State of Pará (PRVN-PA)[47] as reversal mitigation actions and additional discount of 5% could be achieved. Pará has an interannual variability of deforestation higher than 15% (INPE, 2024), so no discounts regarding this mitigation factor would be applied. Thus, Pará must apply a buffer of 15% of its credits to mitigate reversals.

There would also be a 20% deduction for leakage once Pará has approximately 18% of the National Forest. In summary, Pará would have a deduction of 55% on its credits (Table 4.3.2).

Table 4.3.2. Deductions on Pará credits considering ART/TREES.

Deduction factor	Discount on generated credits
Buffer (Reversals)	15%
Leakage	20%
Uncertainties	20%
Total	**55%**

Source: own production.

Considering the crediting level from 2018 to 2022, the credit period for Pará would be from 2023 to 2027. Deforestation in Pará in 2023 was around 3,300 km^2, according to PRODES (INPE, 2024). Considering the average for Brazilian Amazon carbon stock around 130 tC ha-1 (MCTI, 2020), there would be an emission of about 157 $MtCO_2e$ in 2023, which becomes 182 $MtCO_2e$ when we include 16% of degradation emissions. Thus, in 2023, Pará would be reducing 62 $MtCO_2e$ (the difference between the crediting level – 244 $MtCO_2e$ - and the GHG emissions in 2023 -182 $MtCO_2e$), and the credits for this year would be 27.9 $MtCO_2e$, considering the deductions required by ART/TREES.

4.3.3.3. Accounting Impacts of Private REDD+ Projects in Pará

4.3.3.3.1. Private Project Inventory

UNDP search on the certifiers' platforms to detect REDD+ projects in Pará identified eleven projects registered in Pará: nine under the Verified Carbon Standard (VCS) from the VERRA certifier and two under the Cercarbono Standard (Table SM3. 1). As presented, credits issued by REDD+ private projects must be deduced from the credit period accordingly to ART/TREES standards. These REDD+ projects

[47] Native Vegetation Recovery Plan of the State of Pará. Available on:https://semas.pa.gov.br/prvn/. Accessed on 23 April 2024.

emitted about 40 $MtCO_2e$ in credits between 2012 and 2023 (Table SM3. 2), and it would be necessary to monitor the progress of issuing these credits until 2027.

4.3.3.3.2. Impacts on Emissions Accounting

In 2023, the existing REDD+ projects registered on the certifier's platforms in Pará emitted 9.9 $MtCO_2e$ in carbon credits. These projects had established their baselines according to the parameters of the standard, meaning the activity data (deforestation rates) and emission factors (vegetation carbon stocks) do not necessarily align with the Jurisdictional baseline, including the National FREL and, as explained before, in some cases, an overestimation was detected. Therefore, from the credit predicted for Pará in 2023 (27.9 $MtCO_2e$), it would remain 18 $MtCO_2e$, reflecting a decrease of 35% on the original estimated carbon credits. Since LEAF Coalition is paying a minimum of 10 US$ per tCO_2, Pará could receive 180 million dollars in 2023 for its TREES carbon credits.

4.3.3.4. Assessment of the Bill on the Regulation of the Carbon Market in Brazil

4.3.3.4.1. Analysis of the Bill

In 2023, there were several doubts about REDD+ credits, especially those issued by the VERRA certification company (Rajão and Marcolino, 2016; West, 2023). In a The Guardian report[48], based on studies carried out by the University of Cambridge, VERRA's procedures for approving REDD+ projects were questioned regarding its additionality and a lack of transparency on the part of the companies proposing projects and the certification body. This context brought a challenge to the last version of the Bill that is under discussion to regulate the Brazilian Greenhouse Gas Emissions Trading System (SBCE) to incorporate provisions on REDD+ initiatives, which was entirely omitted in the initial text and demanded by sectors of society, such as the third sector and the Federal Public Ministry, mainly because of infractions regarding safeguards.

[48] The Guardians Analysis on REDD+ projects. Available on: https://www.theguardian.com/environment/2023/jan/18/revealed-forest-carbon-offsets-biggest-provider-worthless-verra-aoe. Accessed on: 21 Jan. 2023.

The latest version of Bill No. 184/2024, which regulates SBCE, is now under revision by the Lower House (Senado Federal, 2024). In Article 2, the Bill includes definitions regarding jurisdictional programs with no market approach and market approach. Under the “Jurisdictional REDD+ programs with carbon market approach”, to avoid double counting, any advance sale or promise of sale relating to jurisdictional carbon credits for emission reduction or GHG removal relating to a future period is prohibited. So, in the case of Pará and other states, only voluntary carbon credits could be negotiated.

The law also considers under the REDD+ concept the inclusion of ‘avoided’ emissions, reflecting a difference regarding the UNFCCC concept. The SBCE Committee should accredit methodologies for REDD+ programs and projects, and CONAREDD+ would maintain a national registry of jurisdictional carbon credit programs. CONAREDD+ would receive information from carbon credit project generators about certified REDD+ projects underway in the country. Also, CONAREDD+ would be informed of potential carbon credit project generators wishing to have their property excluded from the jurisdictional program and the country's total mitigation results (Senado Federal, 2024).

The Bill reinforces the Union's ownership of carbon credits generated on vacant land, federal conservation units, and other federal properties; the States' ownership of carbon credits generated in state conservation units and other state properties; and municipalities´ ownership regarding municipal conservation units and other municipal properties. It determines the ownership of Indigenous communities over carbon credits generated on their lands, extractivists communities on carbon credits generated in Extractive Reserves, and Quilombola communities on carbon credits generated on the remaining lands of Quilombo communities. The international transfer of mitigation results would be conditioned on the previous authorization of the national designated authority (Senado Federal, 2024).

4.3.3.4.2. Implications for Integration

We understand that having methodologies accredited by the SBCE Committee could facilitate the alignment between REDD+ private projects and Jurisdictional programs, as they could establish baselines for MRV - as experienced by DRC. Colombia, Guatemala, Peru, and Australia -, and safeguards parameters. It would be indispensable to mention what sources and sinks would be included. Reforestation activities are typically easier to quantify because the results are calculated based on actual regrowth; nonetheless, if Brazil in the future accounts for removals from forest regrowth in its FREL, credits generated from local afforestation, reforestation, and revegetation (ARR) projects would need to be discounted from the national accountability.

Once the government receives information regarding the REDD+ projects and jurisdictional program results, excluding the emitted carbon credits from the total mitigation results will avoid double counting and move forward to a more complete MRV of NDC goals, as experienced by other countries we presented here. The Bill does not mention the National Emissions Registry System (SIRENE) (Brasil, 2017), the official NDC goals measurement tool, and it would be needed to understand the relation and integration of different MRV systems and their relationship with NDC goals.

4.3.3.5. CONAREDD+ Current Work and Project Registration Support

4.3.3.5.1. Contributions from CONAREDD+

CONAREDD+ has only been involved with payment for REDD+ results. Indeed, Resolution No. 3 of CONAREDD+, established by BRASIL (2019), recognizes the voluntary forest carbon market and reinforces that it does not imply, on the part of the federal government, the validation of projects, their methodologies, the volume of emissions transacted or any other points of voluntary projects (CONAREDD+, 2020).

In this context, Resolution no. 6 of CONAREDD+ (Brasil, 2015) defined the distribution of payment capture limits by results of REDD+ in the Amazon biome, with 40% directed to the federal government and 60% distributed by the Amazon-eligible states (CONAREDD+, 2017a). The states of Tocantins, Amazonas (Resolution no. 5; CONAREDD+ 2021), Pará, Amapá (Resolution no. 10; CONAREDD+, 2022a), Acre, and Mato Grosso (CONAREDD+, 2017b) are eligible for CONAREDD+ payments in the Amazon and the Federal District is eligible for CONAREDD+ payments in Cerrado (CONAREDD+, 2022b). The distribution is based on each state's performance in reducing deforestation and forest degradation and their contribution to the national REDD+ strategy.

Under its new Decree (Brasil, 2023), CONAREDD+ has also been developing a national registry for REDD+ projects and programs. This registry aims to ensure transparency and avoid double counting of emissions reductions. The registry will include information on the location, size, and type of REDD+ activities, the methodologies used, and the volume of emissions reductions achieved. This information will be made publicly available to enhance transparency and accountability.

4.3.3.5.2. Support for Project Registration

Even though the decree brings CONAREDD's responsibilities regarding the Voluntary Carbon Market (VCM) (Brasil, 2023), a law with more legal power would reinforce CONAREDD+´s role, which could be established within the SBCE Bill. CONAREDD+ needs to take the lead in registering and monitoring the REDD+ projects and programs so that Brazil can advance to a more comprehensive understanding of VCM initiatives. However, it is crucial to establish the state's capacity to meet these challenges, which would be technical (mainly regarding the crediting level methodology and additionality estimation), economic (as it could impact the carbon credits already estimated by project developers, some of which have already been sold), and political (as the government would need to engage with stakeholders with different interests and advocacy power). In this sense, we believe a national tax system, as promoted in Australia, could help CONAREDD+ better manage VCM issues.

The FREL is not using the database generated in the National GHG Inventories since the deforestation activity data are not annual. The Land Use, Land-Use Change, and Forestry (LULUCF) GHG estimates considered land-use maps for 1994, 2002, 2005 – only for the Amazon biome-, 2010, and 2016 and have annualized emissions from deforestation based on the PRODES database, leading to a lack of accuracy in annual estimates to be used as the basis for REDD+ payments. Moreover, the LULUCF National GHG Inventory does not consider relevant sources of emissions related to forest degradation, such as fire. Once these improvements in the estimates of emissions and removals from the LULUCF sector in the National

GHG Inventories are made, the activity data and emission and removal factors could serve FREL, facilitating the integration between these initiatives. Thus, it would also facilitate the integration between SIRENE and SBCE, which would also be necessary to guarantee the completeness of monitoring NDC goals.

The current SBCE Bill allows private REDD+ projects to be part of the National REDD+ Strategy (ENREDD+). To avoid overestimating additionality and carbon credit generation from local REDD+ projects, CONAREDD+ should establish a regulation to guarantee that subnational and local initiatives are aligned with FREL. This regulation would give more credibility to VCM in Brazil, including local initiatives that opt to participate in the Jurisdictional Program, with a decentralized approach for deforestation and forest degradation credits.

4.3.4. Conclusions

Improvements in the estimates of emissions and removals from the LULUCF sector in the National GHG Inventories, particularly regarding the intervals of activity data and the inclusion of emissions associated with forest degradation, could provide the necessary subsidies for the Brazilian FREL and facilitate the integration between these initiatives.

The successful implementation of REDD+ nesting aligned with UNFCCC rules under the Paris Agreement presents several challenges:

1. **Conceptual**: Private projects often consider 'avoided' deforestation and degradation emissions instead of 'reducing' deforestation and forest degradation emissions;
2. **Scientific/Methodological**: Different baselines are used by private projects and JREDD+;
3. **Economic**: Potential impacts on carbon credit projections under private projects;
4. **Political-Legal**: The need to engage and integrate inputs from relevant stakeholders to define the degree of centralization (or decentralization), the role of non-state actors and determine climate and carbon finance.

From our research around Pará REDD+ private projects and nesting experiences of other countries, it is evident that Brazil still needs to advance in ensuring transparency and registration of forest carbon projects. These projects must be aligned with the National FREL methodology to avoid discrepancies in baselines between state and national accountabilities. If the government aims to access project-scale voluntary markets and results-based finance, it is necessary to promote alignment in accounting at both the project and national (or subnational) levels. Establishing a national baseline that private initiatives could apply and understanding how to integrate SIRENE and SBCE will be essential. A national baseline would also reduce costs for sub-national and project scales.

Bill 184/2024 has made progress in establishing rules regarding REDD+ programs and projects, but it remains unclear how methodological approaches at the project level will be adjusted to the jurisdictional baselines. We believe the details on methodology could be included in regulatory decrees following the law's approval, considering that this negotiation has been prolonged.

Bill No 184/2024 could serve as an instrument to grant CONAREDD+ the legal power to register and ensure alignment between subnational initiatives and private projects. However, enhancing the state's capacity to meet these challenges will be indispensable.

Acknowledgments: we thank the United Nations Development Program (UNDP), particularly Bojan Philip Auhagen, Simone Souza Santos, and Letícia Guimarães for providing the data that made this research possible.

BIBLIOGRAPHIC REFERENCES

ART. The REDD+ Environmental Excellence Standard (TREES). **Architecture for REDD+ Transactions**, 2021a. Available on: https://www.artredd.org/wp-content/uploads/2021/12/TREES-2.0-August-2021-Clean.pdf. Accessed on: 21 Mar 2024.

_____. TREES Safeguards Cross Reference Table. **Architecture for REDD+ Transactions**, 2021b. Available on: https://www.artredd.org/wp-content/uploads/2021/12/TREES-Safeguards-Cross-Reference-Table.xlsx. Accessed on: 21 Mar 2024.

_____. TREES Concept Note Template. **Architecture for REDD+ Transactions**, 2021c. Available on: https://www.artredd.org/wp-content/uploads/2021/12/TREES-Concept-Final-August-2021.docx. Accessed on: 21 Mar 2024.

____. TREES Registration Document Template v2.0. **Architecture for REDD+ Transactions**, 2021d. Available on: https://www.artredd.org/wp-content/uploads/2021/12/TREES-Registration-Document-Template-FINAL-Aug-2021.docx. Accessed on: 21 Mar 2024.

AUSTRALIAN GOVERNMENT. FullCAM: Using Command Line and Plot Digest. **Australian Government**, 2021. Available on: https://www.dcceew.gov.au/sites/default/files/documents/fullcam-using-command-line-and-plot-digest.pdf. Accessed on: 21 Apr 2024.

BRASIL. Decreto nº 9.172, de 17 de outubro de 2017. Institui o Sistema de Registro Nacional de Emissões - Sirene, dispõe sobre os instrumentos da Política Nacional sobre Mudança do Clima a que se refere o inciso XIII do caput do art. 6º da Lei nº 12.187, de 29 de dezembro de 2009, e altera o Decreto nº 7.390, de 9 de dezembro de 2010, que regulamenta a referida Política. **Diário Oficial da União,** Brasília, 18 de outubro de 2017.

BRASIL. Decreto Nº 10.144, de 28 de novembro de 2019 (Revogado pelo Decreto nº 11.548, de 2023). Institui a Comissão Nacional para Redução das Emissões de Gases de Efeito Estufa Provenientes do Desmatamento e da Degradação Florestal, Conservação dos Estoques de Carbono Florestal, Manejo Sustentável de Florestas e Aumento de Estoques de Carbono Florestal - REDD+, 2019. **Diário Oficial da União**, Brasília, 2019.

BRASIL. Decreto Nº 11.548, de 5 de junho de 2023. Institui a Comissão Nacional para Redução das Emissões de Gases de Efeito Estufa Provenientes do Desmatamento e da Degradação Florestal, Conservação dos Estoques de Carbono Florestal, Manejo Sustentável de Florestas e Aumento de Estoques de Carbono Florestal - REDD+, 2023. **Diário Oficial da União**, Brasília, 2023.

CONAREDD+. Resolução nº 6, de 6 de julho de 2017. Define a distribuição dos limites de captação de pagamentos por resultados de redução de emissões provenientes do desmatamento no bioma Amazônia. **Ministério do Meio Ambiente**, 2017a. Available on: http://redd.mma.gov.br/images/central-de-midia/pdf/Documentos/conaredd-resolucao-no6-20170621-final.pdf. Accessed on: 21 Mar 2022.

CONAREDD+. Resolução nº 10, de 07 de dezembro de 2017. Aprova a elegibilidade de entidade federal e entidades estaduais para acesso e captação de pagamentos por resultados de redução de emissões provenientes do desmatamento no bioma Amazônia. **Ministério do Meio Ambiente**, 2017b. Available on: http://redd.mma.gov.br/images/conaredd/SEI_MMA---0160940---Resoluo-10.pdf. Accessed on: 21 Mar 2022.

CONAREDD+. Resolução nº 03, de 22 de junho de 2020. Reconhece o mercado voluntário de carbono florestal. **Ministério do Meio Ambiente**, 2020. Available on: http://redd.mma.gov.br/images/publicacoes/Resolucoes/Resolu%C3%A7%C3%A3o%20n%C2%BA%203%20de%2022%20de%20Julho%20de%202020%20-%20Mercado%20Voluntario%20de%20Carbono%20Florestal.pdf. Accessed on: 21 Mar 2022.

CONAREDD+. Resolução nº 5, de 29 de outubro de 2021. Aprova a elegibilidade de entidades estaduais para acesso e captação de pagamentos por resultados de redução de emissões provenientes do desmatamento no bioma Amazônia. **Ministério do Meio Ambiente**, 2021. Available on: http://redd.mma.gov.br/images/publicacoes/Resolucoes/SEI_MMA---0851468---Resoluo5.pdf. Accessed on: 21 Mar 2022.

CONAREDD+. Resolução no 10, de 29 de agosto de 2022. Aprova a elegibilidade de entidades estaduais para acesso e captação de pagamentos por resultados de redução de emissões provenientes do desmatamento no bioma Amazônia. **Ministério do Meio Ambiente**, 2022a. Available on: http://redd.mma.gov.br/images/conaredd/conaredd-res10-elegibilidade-amazonia.pdf. Accessed on: 21 Mar 2022.

CONAREDD+, Resolução no 12, de 19 de dezembro de 2022. Aprova a elegibilidade de entidade estadual para acesso e captação de pagamentos por resultados de redução de emissões provenientes do desmatamento no bioma Cerrado. **Ministério do Meio Ambiente**, 2022b. Available on: http://redd.mma.gov.br/images/conaredd/SEI_MMA---1465892---Resolucao-CONAREDD-No-12.pdf. Accessed on: 21 Mar 2022.

DEMOCRATIC REPUBLIC OF CONGO. REDD+ Investment Plan (2015-2020). **Democratic Republic of Congo**, 2015. Available on: https://redd.unfccc.int/uploads/3262_4_redd_investment_plan_eng.pdf. Accessed on: 14 Mar 2023.

EL CONGRESO DE COLOMBIA. Ley No. 1819 29 Dic 2016 por Medio de la cual se adopta una reforma tributaria estructural, se fortalecen los mecanismos para la lucha contra la evasión y la elusión fiscal, y se dictan otras disposiciones. **El Congreso de Colombia**, 2016. Available on: http://es.presidencia.gov.co/normativa/normativa/LEY%201819%20DEL%2029%20DE%20DICIEMBRE%20DE%202016.pdf. Accessed on: 12 Nov. 2023.

EL CONGRESO DE COLOMBIA. Ley No. 1931 27 Jul 2018 por la cual se establecen directrices para la gestión del cambio climático. **El Congreso de Colombia**, 2018. Available on http://es.presidencia.gov.co/normativa/normativa/LEY%201931%20DEL%2027%20DE%20JULIO%20DE%202018.pdf. Accessed on: 12 Nov. 2023.

GCF. FP134: Colombia REDD+ Results-based Payments for results period 2015-2016. **Green Climate Fund**, 2020. Available on: https://www.greenclimate.fund/sites/default/files/document/fp134-fao-colombia_0.pdf. Accessed on: 15 Nov. 2023.

GCF. Ecuador REDD-plus RBP for results period 2014. **Green Climate Fund**, 2022. Available on: https://www.greenclimate.fund/sites/default/files/document/fp110-annual-performance-report-cy2022-v.pdf. Accessed on: 18 Nov. 2023.

GOBIERNO DE LA REPUBLICA DE GUATEMALA. Approach and Principles of Nesting for REDD+ Initiatives (Projects and Programs) in Guatemala. Gobierno de La Republica de Guatemala, 2019. Available on:

https://www.forestcarbonpartnership.org/system/files/documents/English_Anex_XI_Enfoque_y_principios_de%20anidamiento_100219.pdf. Accessed on: 18 Dec. 2023.

GOVERNO DO ESTADO DO PARÁ. Secretaria de Estado de Meio Ambiente e Sustentabilidade. Institui a Política Estadual sobre Mudanças Climáticas do Pará (PEMC/PA), e dá outras providências. **Diário Oficial Estadual**, 2020a.

GOVERNO DO ESTADO DO PARÁ. Plano Estadual Amazônia Agora (PEAA). **Governo do estado do Pará**, Belém, Pará, 2020b. Available on: http://portal.iterpa.pa.gov.br/wp-content/uploads/2021/01/plano_estadual_amazonia_agora.pdf. Accessed on: 02 Nov. 2023.

GOVERNO DO ESTADO DO PARÁ. Plano Estadual de Bioeconomia do Pará – PlanBio. **Governo do estado do Pará**, 2022. Available on: https://www.semas.pa.gov.br/wp-content/uploads/2022/11/Plano-da-Bioeconomia-vers%C3%A3o-FINAL_01_nov.pdf. Accessed on: 01 Jan. 2024.

INPE. Monitoramento do Desmatamento da Floresta Amazônica Brasileira por Satélite. **PRODES**, 2024. Available on: http://terrabrasilis.dpi.inpe.br/app/dashboard/deforestation/biomes/legal_amazon/rates. Accessed on: 01 Apr. 2024.

RAJÃO, R.; MARCOLINO, C. Between Indians and “Cowboys”: The Role of ICT in the Management of Contradictory Self-images and the Production of Carbon Credits in the Brazilian Amazon. **Journal of Information Technology**, 31(4), 347-357, 2016.

SENADO FEDERAL. Projeto de Lei nº 184, de 2024 (nº 2148/2015, na Câmara dos Deputados). Institui o Sistema Brasileiro de Comércio de Emissões de Gases de Efeito Estufa (SBCE); e altera as Leis nºs 12.187, de 29 de dezembro de 2009, 12.651, de 25 de maio de 2012 (Código Florestal), 6.385, de 7 de dezembro de 1976, 11.033, de 21 de dezembro de 2004, e 6.015, de 31 de dezembro de 1973 (Lei de Registros Públicos). **Senado Federal**, 2024. Available on: https://legis.senado.leg.br/sdleg-getter/documento?dm=9543189&ts=1708443019184&disposition=inline. Accessed on: 01 Apr. 2024.

UNFCCC. Brazil’s National Forest Reference Emission Level for Results-based Payments for REDD+ under the United Nations Framework Convention on Climate Change. **United Nations Framework Convention on Climate Change**, 2023.

WEST, T.; WUNDER, S.; SILLS, E.; BÖRNER, J.; RIFAI, S. NEIDERMEIER, A.; PONZONI FREY, G.; KONTOLEON, A. Action needed to make carbon offsets from forest conservation work for climate change mitigation. **Science** 381. 873-877. 10.1126/science.ade3535, 2023.

WORLD BANK GROUP. Nesting of REDD+ Initiatives: Manual for Policymakers. **World Bank Group**, 2021. Available on: https://documents1.worldbank.org/curated/en/411571631769095604/pdf/Nesting-of-REDD-Initiatives-Manual-for-Policymakers.pdf. Accessed on: 01 Apr. 2023.

ZHOU, W.; GONG, P.; GAO, L. A Review of Carbon Forest Development in China. **Forests**, 8, 295, 2017.

5. DISCUSSÃO

5.1. Integração dos Resultados com os Conceitos de Política e Gestão

A análise dos modelos de desmatamento na Amazônia Brasileira revelou a necessidade do estabelecimento de um conjunto de ações do governo, ou seja, de políticas públicas robustas (Meirelles, 1995; Lynn, 1980) para alcançar as metas de redução de emissões de GEE. A implementação dessas políticas reflete a capacidade estatal (Gomide e Pires, 2024) dos diferentes níveis da Administração Pública de mobilizar recursos e esforços para solucionar problemas coletivos, conforme descrito por Procopiuck (2003).

Os resultados indicam que a etapa de formulação de uma política pública, parte inicial de seu ciclo (Frey, 2000; Howlett et al., 2013), deve ser coerente com as diferentes iniciativas do governo – considerando aqui especialmente as metas da NDC brasileira, que não foram desenhadas em conformidade com a metodologia utilizada no Inventário Nacional de Emissões de GEE, sendo este o instrumento de monitoramento dos compromissos assumidos pelo país na UNFCCC. Neste contexto, destacamos a importância de monitorar e avaliar continuamente as políticas e seus instrumentos de monitoramento para promover aperfeiçoamentos, conforme sugerido por Brasil (2014a) e IPEA (2018a), incluindo a atualização das metas da Política Nacional sobre Mudança do Clima (PNMC).

A análise dos desafios para a implementação do REDD+ no Brasil destaca a importância de uma governança integrada e de governabilidade, frente à necessidade de engajar e intermediar interesses de diferentes atores (Diniz, 2001; Procopiuck, 2013) para garantir a integridade das iniciativas de REDD+.

A proposta de um arranjo institucional para melhorar a mensuração das emissões e remoções de GEE do setor de LULUCF reflete a criação de procedimentos e a divisão de competências necessárias para uma melhor distribuição de poderes entre instituições do governo (Grindle, 2004; Propiuck, 2013). Essa institucionalização, assim como a criação de um sistema de registro integrado e regulamentado, como sugerido no Projeto de Lei 184/2024, pode melhorar a governança e a gestão dos recursos públicos, como apontado por Calmon e Costa (2013). Além disso, acarreta na necessidade de fortalecer a capacidade estatal para coordenar ações e mobilizar recursos (Santos, 1997; Gomide e Marenco, 2024) a fim de garantir a transparência e a sustentabilidade dos reportes brasileiros.

A implementação do REDD+ e a participação em coalizões globais, como a LEAF, são estratégias cruciais para fortalecer o compromisso do Brasil com a redução de emissões de GEE e a implementação de políticas climáticas (UNFCCC, 1992; 2015).

Neste contexto, destaca-se a necessidade de um sistema robusto de aninhamento entre iniciativas locais e jurisdicionais no país a fim de atender a padrões internacionais, como o ART/TREES, para garantir o acesso a financiamento climático e participação em futuras negociações no âmbito do Artigo 6.

5.2. Implicações Práticas e Teóricas

A avaliação dos resultados de diferentes modelos buscou ressalvar aos gestores públicos a importância do direcionamento de esforços para o conjunto de ações que visam reduzir o desmatamento na Amazônia brasileira e a importância do estabelecimento de metas coerentes com seus instrumentos de reporte. O não atingimento dos compromissos assumidos internacionalmente podem denegrir a imagem do país e colocar em risco sua efetiva contribuição para a mitigação da mudança do clima. Neste sentido, futuras revisões da NDC brasileira, assim como a atualização da PNMC, deveriam considerar o conjunto de dados utilizados pelo Inventário Nacional de Emissões de GEE.

A partir do desenho de arranjo institucional proposto, espera-se que a centralização da compilação dos inventários de emissões de GEE do setor de LULUCF seja revista, tendo em vista a oportunidade de otimizar recursos financeiros e humanos, facilitar a harmonização de reportes à UNFCCC – especialmente entre o FREL e o Inventário de Emissões de GEE - além de fortalecer a capacidade estatal de diferentes organizações, especialmente o INPE.

A compilação de lições aprendidas de outros países com relação ao aninhamento entre projetos locais e programas jurisdicionais de REDD+ buscou ressaltar a importância do país avançar em um sistema de registro destas diferentes iniciativas e da necessidade de empoderar e fornecer à CONAREDD+ os recursos necessários para assumir essa função. Esse avanço será fundamental não apenas para garantir uma mensuração íntegra da redução de emissões do país, mas também trará a governança necessária para garantir o respeito às salvaguardas socioambientais em diferentes escalas, trazendo mais credibilidade para o MVC brasileiro.

A pesquisa buscou trazer uma revisão dos principais conceitos de governança e gestão, um histórico da agenda de clima internacional e nacional, uma síntese das metodologias de diferentes estudos de modelagem de uso e cobertura da terra e do padrão ART/TREES e um repositório de dados relacionadas aos diferentes planos, programas e políticas relacionadas à mitigação de emissões de GEE do setor de LULUCF, que poderão facilitar o acesso à informação em pesquisas futuras.

CONSIDERAÇÕES FINAIS

Os resultados das projeções de desmatamento para a Amazônia brasileira dos diferentes modelos mostram que *a implementação do Código Florestal não garante a redução do desmatamento na Amazônia brasileira*. Um conjunto de ações será necessário para combater o desmatamento e a degradação florestal, incluindo a manutenção e a expansão de áreas protegidas, a regularização fundiária e a valorização de serviços ambientais. Vale ressaltar que iniciativas como o PLANAVEG e o Plano ABC serão primordiais para a redução das emissões do país e para garantir o alcance das metas da NDC.

A proposta de um arranjo institucional para a mensuração das emissões e remoções de GEE do setor de LULUCF mostra que *a utilização de dados oficiais, lastreados em ciência, garante transparência no relato brasileiro desse setor,* mas também sustentabilidade e completude na geração de dados e melhor governança e gestão pública.

Seria um retrocesso o país não avançar na institucionalização da compilação do Inventário Nacional de Emissões de GEE do setor de LULUCF, uma vez que, além de otimizar recursos humanos e financeiros e impulsionar o fortalecimento das capacidades estatais de suas organizações, o estabelecimento desse arranjo permitiria aumentar a acurácia das estimativas, contabilizar emissões por degradação por fogo, contabilizar remoções por regeneração e restauração no longo prazo, incluir remoções por vegetação protegida em territórios Quilombolas e propriedades privadas e usar bases de dados oficiais do PRODES, do TerraClass, do DETER e do Inventário Florestal Nacional. Além disso, o Inventário Nacional de Emissões de GEE estaria adequado para servir de base para a elaboração do FREL nacional, garantindo harmonização entre as iniciativas e maior confiança nos reportes brasileiros à UNFCCC.

O FREL nacional, por sua vez, poderia servir como linha de base para os projetos locais de REDD+, que vem sofrendo cada vez mais retalhação por suas superestimativas de créditos de carbono e desrespeito às salvaguardas socioambientais, colocando em risco o MVC no Brasil. Essa integração facilitaria o aninhamento entre iniciativas de REDD+ de diferentes escalas, permitindo ao Brasil não só atender a padrões internacionais de certificação de créditos de carbono, como o ART/TREES, e acessar fundos como o da Coalizão LEAF, mas também estar apto a participar de futuras transações no âmbito do Artigo 6 do Acordo de Paris.

Neste contexto, diante do potencial do país em contribuir com a mitigação da mudança do clima e de acessar financiamento climático pela promoção da conservação ambiental, é imprescindível avançar na regulamentação do mercado brasileiro de carbono, estabelecendo um sistema de registro integrado. Esse será um desafio não apenas técnico-científico, mas também econômico e político.

Assim, traçar estratégias para agir, mensurar e captar financiamento e manter 'círculo virtuoso' do REDD+ é imprescindível para o Brasil diminuir suas emissões de GEE, garantir integridade na contabilidade das suas metas da NDC e estar apto a captar financiamento climático, contribuindo para a mitigação da mudança do clima e promovendo o desenvolvimento sustentável.

REFERÊNCIAS BIBLIOGRÁFICAS

AGUIAR, A. P.; VIEIRA, I. C.; ASSIS, T. O.; DALLA-NORA, E. L.; TOLEDO, P. M.; SANTOS-JUNIOR, R. A.; BATISTELLA, M.; COELHO, A. S.; SAVAGET, E. K.; ARAGÃO, L. E.; NOBRE, C. A.; OMETTO, J. P. Land use change emission scenarios: anticipating a forest transition process in the Brazilian amazon. **Global Change Biology**. May;22 (5):1821-40, 2016.

AGUILERA, R. V.; JACKSON, G. Comparative and international corporate governance. **The Academy of Management Annals**, [s. l.], v. 4, n.1, p. 485-556, 2010.

ARAÚJO, V. C. A conceituação de governabilidade e governança, da sua relação entre si e com o conjunto da reforma do Estado e do seu aparelho. Brasília: **Escola Nacional de Administração Pública**, 2002.

ART. The REDD+ Environmental Excellence Standard (TREES). **Architecture for REDD+ Transactions**, 2021a. Disponível em: https://www.artredd.org/wp-content/uploads/2021/12/TREES-2.0-August-2021-Clean.pdf. Acesso em: 21 Mar 2024.

_____. TREES Safeguards Cross Reference Table. **Architecture for REDD+ Transactions**, 2021b. Disponível em: https://www.artredd.org/wp-content/uploads/2021/12/TREES-Safeguards-Cross-Reference-Table.xlsx. Acesso em: 21 Mar 2024.

_____. TREES Concept Note Template. **Architecture for REDD+ Transactions**, 2021c. Disponível em: https://www.artredd.org/wp-content/uploads/2021/12/TREES-Concept-Final-August-2021.docx. Acesso em: 21 Mar 2024.

____. TREES Registration Document Template v2.0. **Architecture for REDD+ Transactions**, 2021d. Disponível em: https://www.artredd.org/wp-content/uploads/2021/12/TREES-Registration-Document-Template-FINAL-Aug-2021.docx. Acesso em: 21 Mar 2024.

BAIERO, D. S. Governança, gestão de políticas públicas e arranjo institucional do setor florestal brasileiro. **Tese (doutorado) - Universidade Federal de Viçosa, Departamento de Engenharia Florestal**, 2022.

BRASIL. Decreto nº 2.652, de 1º de julho de 1998. Promulga a Convenção-Quadro das Nações Unidas sobre Mudança do Clima, assinada em Nova York, em 9 de maio de 1992. **Diário Oficial da União**, 1998.

BRASIL. Ministério da Ciência e Tecnologia. Secretaria de Políticas e Programas de Pesquisa e Desenvolvimento. Coordenação-Geral de Mudanças Globais de Clima. Comunicação Nacional Inicial do Brasil à Convenção-Quadro das Nações Unidas sobre Mudança do Clima. Brasília: **Ministério da Ciência e Tecnologia**, 2004.

BRASIL. Decreto nº 5.445, de 12 de Maio de 2005. Promulga o Protocolo de Quioto à Convenção-Quadro das Nações Unidas sobre Mudança do Clima, aberto a assinaturas na cidade de Quioto, Japão, em 11 de dezembro de 1997, por ocasião da Terceira Conferência das Partes da Convenção-Quadro das Nações Unidas sobre Mudança do Clima. **Diário Oficial da União**, 2005.

BRASIL. Lei nº 12.187, de 29 de dezembro de 2009. Institui a Política Nacional sobre Mudança do Clima - PNMC e dá outras providências. **Diário Oficial da União**: seção 1, Brasília, DF, p 109, 29 dez. 2009.

BRASIL. Ministério da Ciência e Tecnologia. Secretaria de Políticas e Programas de Pesquisa e Desenvolvimento. Segunda Comunicação Nacional do Brasil à Convenção-Quadro das Nações Unidas sobre Mudança do Clima. Brasília: **Ministério da Ciência e Tecnologia**, 2010.

BRASIL. Tribunal de Contas da União. Referencial para avaliação de governança em políticas públicas / Tribunal de Contas da União. – Brasília: **Tribunal de Contas da União**, 2014a. 91 p.

BRASIL. Primeiro Relatório de Atualização Bienal do Brasil. Ministério da Ciência, Tecnologia e Inovação. Secretaria de Pesquisa e Desenvolvimento de Políticas e Programas. **Coordenação Geral de Mudanças Globais de Clima**, 2014b.

BRASIL. **Terceira Comunicação Nacional do Brasil à Convenção-Quadro das Nações Unidas sobre Mudança do Clima** – Volume III/ Ministério da Ciência, Tecnologia e Inovação. Secretaria de Políticas e Programas de Pesquisa e Desenvolvimento. **Coordenação-Geral de Mudanças Globais de Clima**, 2016.

BRASIL. Decreto nº 9.073, de 5 de junho de 2017. Promulga o Acordo de Paris sob a Convenção-Quadro das Nações Unidas sobre Mudança do Clima, celebrado em Paris, em 12 De dezembro de 2015, e firmado em Nova Iorque, em 22 De Abril De 2016. **Diário Oficial da União**: seção 1, Brasília, DF, p. 3, 06 de junho de 2017a.

BRASIL. Segundo Relatório de Atualização Bienal do Brasil à Convenção-Quadro das Nações Unidas sobre Mudanças do Clima. **Ministério das Relações Exteriores e Ministério da Ciência, Tecnologia, Inovações e Comunicações**, 2017b.

BRASIL. Decreto nº 9.578, de 22 de novembro de 2018. Consolida atos normativos editados pelo Poder Executivo federal que dispõem sobre o Fundo Nacional sobre Mudança do Clima, de que trata a Lei nº 12.114, de 9 de dezembro de 2009, e a Política Nacional sobre Mudança do Clima, de que trata a Lei nº 12.187, de 29 de dezembro de 2009. **Diário Oficial da União**: seção 1, Brasília, DF, n. 225, p. 47, 23 nov. 2018.

BRASIL. Terceiro Relatório de Atualização Bienal do Brasil à Convenção-Quadro das Nações Unidas sobre Mudança do Clima. **Ministério das Relações Exteriores e Ministério da Ciência, Tecnologia, Inovações e Comunicações**, 2019.

BRASIL. Quarta Comunicação Nacional do Brasil à Convenção-Quadro das Nações Unidas sobre Mudança do Clima. Ministério da Ciência, Tecnologia e Inovação. Secretaria de Pesquisa e Formação Científica. **Coordenação-Geral de Mudança do Clima e Sustentabilidade**, 2020a.

BRASIL. Quarto Relatório de Atualização Bienal do Brasil à Convenção-Quadro das Nações Unidas sobre Mudança do Clima. **Ministério das Relações Exteriores e Ministério da Ciência, Tecnologia e Inovações**, 2020b.

BRASIL. Decreto nº 11.548, de 5 de junho de 2023. Institui a Comissão Nacional para Redução das Emissões de Gases de Efeito Estufa Provenientes do Desmatamento e da Degradação Florestal, Conservação dos Estoques de Carbono Florestal, Manejo Sustentável de Florestas e Aumento de Estoques de Carbono Florestal - REDD+, 2023. **Diário Oficial da União**, Brasília, 2023.

BRASIL. Decreto nº 12.040, de 5 de Junho de 2024. Altera o Decreto nº 11.550, de 5 de junho de 2023, que dispõe sobre o Comitê Interministerial sobre Mudança do Clima. **Diário Oficial da União**, Brasília, 2024.

BERLE, A.; MEANS, G. The modern corporation and private propriety. London; New York: **Macmillan**, 1932.

CALMON, P.; COSTA, A. T. M. Redes e Governança das Políticas Públicas. **Centro de Estudos Avançados de Governo e de Administração Pública (CEAG/UnB)**, 2013.

DINIZ, E. Globalização, reforma do estado e teoria democrática contemporânea. São Paulo: **São Paulo em Perspectiva**,15(4), 2001.

DYE, T. D. Understanding Public Policy.**Pearson**, 1984.

DONOFRIO, S.; PROCTON, A. ECOSYSTEM MARKETPLACE INSIGHTS REPORT Paying for Quality State of the Voluntary Carbon Markets 2023**. Ecosystem Marketplace**, 2023.

EUCLYDES, F. M.; MACEDO, A. S.; MACEDO, S. V.; VALADARES, J. L. Capacidades estatais e mineração: uma análise da agência nacional de regulação. **Revista de Administração Pública**, Rio de Janeiro 56(1): 163-175, jan. - fev. 2022.

EVANS, P. O Estado como problema e solução. **Nova Lua**, São Paulo, n. 28-29, p. 1-29, abr.1993.

FIORE, F. A.; BARDINI, V. S. S. ; CABRAL, P. C. P. Arranjos institucionais para a implantação de programa municipal de pagamento por serviços ambientais hídricos: estudo de caso de São José dos Campos (SP). **Engenharia Sanitária Ambiental**, v.25 n.2, 303-313, mar/abr 2020.

FREITAS, V. A.; SILVA, F. E. R. Administração pública e governança: uma discussão teórica. **Revista Controle**, Fortaleza, v. 20, n.1, p. 354-379, jan./jun. 2022.

FREY, K. Políticas públicas: um debate conceitual e reflexões referentes à prática da análise de políticas públicas no Brasil. **Planejamento e Políticas Públicas**, Brasília, n. 21, p. 211-259, jun, 2000.

GOLDSTEIN, A.; GONZALEZ, G. Turning over a New Leaf: State of the Forest Carbon Markets 2014. **Forest Trends**, 2014. Disponível em: https://www.forest-trends.org/wp-content/uploads/imported/sofcm-all-edits-112114-pdf.pdf. Acesso em: 12 Dez. 2023.

GOMIDE, A. ; MARENCO, A. Capacidades estatais: avanços e tendências / organizado por Alexandre Gomide e André Marenco. – Brasília, **Cadernos ENAP**, 133, 2024. 99 p.

GOMIDE, A.; PIRES, R. Capacidades estatais em ação:a abordagem dos arranjos de implementação de políticas públicas. In: ENAP. Capacidades estatais: avanços e tendências / organizado por Alexandre Gomide e André Marenco. **Cadernos ENAP**, 133, 99 p., Brasília, 2024.

GRANZIERA, B.; HAMRICK, K.; VERDIECK, J. Article 6 Explainer: Questions and answers about the COP27 Decisions on carbon markets and what they mean for NDCs, nature, and the voluntary carbon markets. **The Nature Conservancy**, 2023. Disponível em: https://www.nature.org/content/dam/tnc/nature/en/documents/TNC_Article_6_Explainer_260523.pdf. Acesso em: 04 Set. 2023.

GRASSI, G., SCHWINGSHACKL, C., GASSER, T., HOUGHTON, R. A., SITCH, S., CANADELL, J. G., ET AL. (2023). Harmonising the land-use flux estimates of global models and national inventories for 2000–2020. **Earth System Science Data** 15, 1093–1114, 2023.

GRINDLE, M. Good Enough Governance: Poverty Reduction and Reform in Developing Countries. **Governance: An International Journal of Policy, administration, and Institutions** 17(4): 525-548, 2004.

GRINDLE, M. Good Enough Governance Revisited. **Development Policy Review** 25(5): 553-574, 2007.

HAMRICK, K; WEBB, C.; ELLIS, R. Nesting REDD+ Pathways to Bridge Project and Jurisdictional Programs. **The Nature Consercancy**, 2021. Disponível em: https://www.nature.org/content/dam/tnc/nature/en/documents/REDDPlus_PathwaystoBridgeProjectandJurisdictionalPrograms.pdf. Acesso em: 04 Set. 2023.

HOWLETT, M; RAMESH, M; PERL, A. Políticas Públicas: seus ciclos e subsistemas, uma abordagem integral. Rio de Janeiro: **Elsevier**, 2013. 305 p.

IPCC – Intergovernmental Panel on Climate Change. Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Vol. 4. Agriculture, Forestry and Other Land Use. Ch. 4. Forestland. EGGLESTON, H. S.; BUENDIA, L.; MIWA, K.; NGARA, T.; TANABE, K. (eds.). Japan: **IGES**, 2006.

IPCC. Intergovernmental Panel on Climate Change. In: STOCKER, T. F.; QIN, D.; PLATTNER, G.-K.; TIGNOR, M.; ALLEN, S.K.; BOSCHUNG, J.; NAUELS, A.; XIA, Y.; BEX, V.; MIDGLEY, P. M. (eds.). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge; United Kingdom; New York: **Cambridge University Press**, 1535 p., 2013.

IPEA. Avaliação de políticas públicas : guia prático de análise ex ante, volume 1. / Casa Civil da Presidência da República, **Instituto de Pesquisa Econômica Aplicada** v. 1 (192 p.) il., gráfs., mapa color, 2018a.

IPEA. Legado do MDL: impactos e lições aprendidas a partir da implementação do Mecanismo de Desenvolvimento Limpo no Brasil / organizadores: Flavia Witkowski Frangetto, Ana Paula Beber Veiga, Gustavo Luedemann. – Brasília: **Instituto de Pesquisa Econômica Aplicada**, 2018b.

LIMA, A. B. Adaptação à Mudança do Clima, Coalizões e Aprendizado político: uma análise da construção de capacidade adaptativa no Brasil entre 2005 e 2016. **Dissertação de Mestrado. Centro de Desenvolvimento Sustentável**. Brasília, 2017.112 p.: il.

LYNN, L. E. Designing Public Policy: A Casebook on the Role of Policy Analysis. Santa Monica, California**. Goodyear**, 1980.

LOTTA, G. S.; VAZ, J. C. Arranjos institucionais de políticas públicas: aprendizados a partir de casos de arranjos institucionais complexos no Brasil. **Revista do Serviço Público** 66 (2) 171-194 abr/jun 2015.

LOWI, T. American business, public policy, case studies, and political theory. **World Politics**, v. 16, n. 4, p. 677-715, 1964.

MARTINS, H. Uma teoria da fragmentação de políticas públicas: desenvolvimento e aplicação na análise de três casos de políticas de gestão pública. **Tese apresentada à Escola Brasileira de Administração Pública e de Empresas**. Rio de Janeiro, 2003.

MCGLYNN, E.; LI, S.; BERGER, M. F.; AMEND, M.; HARPER, K. L. Addressing uncertainty and bias in land use, land use change, and forestry greenhouse gas inventories. **Climatic Change** 170, 5, 2022.

MENDES, T. A. Desenvolvimento sustentável, política e gestão da mudança global do clima: sinergias e contradições brasileiras. 672 f., il. **Tese (Doutorado em Desenvolvimento Sustentável) -** Universidade de Brasília, Brasília, 2014.

MEIRELLES, H. L. Direito administrativo brasileiro. 20ª Ed. São Paulo: **Malheiros,** 1995.

MCTI. Relatório De Referência: Setor Uso da Terra, Mudança do Uso da Terra e Florestas. 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. Brasília: **Ministério da Ciência, Tecnologia, Inovações e Comunicações**, 2020.

MIGUEZ, J. D. G.; ANDRADE, T. C. M. A. A continuidade do MDL ante o acordo de Paris e sua articulação com o MDS. In: FRANGETTO, F. W.; VEIGA, A. P. B.; LUEDEMANN, G. Legado do MDL: impactos e lições aprendidas a partir da implementação do Mecanismo de Desenvolvimento Limpo no Brasil. Brasília: **Instituto de Pesquisa Econômica Aplicada**, 2018.

MMA. Estratégia Nacional para REDD+ - ENREDD+. **Ministério do Meio Ambiente**, 2016. Disponível em: http://redd.mma.gov.br/images/publicacoes/enredd_documento_web.pdf. Acesso em: 18 Jan. 2023.

MMA. Info Hub Brasil. Resultados e pagamentos de REDD+. **Ministério do Meio Ambiente**, 2024. Disponível em: https://infohubbrasil.mma.gov.br/pt/resultados-e-pagamentos. Acesso em: 18 Jan. 2023.

MOREIRA, H. M.; GIOMETTI, A. B. dos R. Protocolo de Quioto e as possibilidades de inserção do Brasil no Mecanismo de Desenvolvimento Limpo por meio de projetos em energia limpa. **Contexto Internacional**, 30(1), 9–47, 2008.

OLIVEIRA, M. S. Capacidade estatal e implementação de política de desenvolvimento regional sustentável na Amazônia. **Novos Cadernos NAEA**, v. 18 n. 2, p. 271-291, set-dez. 2015.

OLIVEIRA, Y. P. L. O. Desafios do Mercado de Carbono após o Acordo de Paris: Uma revisão. **Meio Ambiente** (Brasil), v.4, n.1. 002-020, 2022.

OXFAM. Climate Finance Shadow Report 2023 Summary: Assessing The Delivery of the $100 billion Commitment. **OXFAM**, 2023. Disponível em: https://fly.jiuhuashan.beauty/https/oxfamilibrary.openrepository.com/bitstream/handle/10546/621500/bp-climate-finance-shadow-report-050623-summ-en.pdf?sequence=2&isAllowed=y. Acesso em: 23 Jun. 2024.

PAINTER, M.; PIERRE, J. Unpacking Policy Capacity: issues and themes. In: PAINTER, Martin; PIERRE, Jon. Challenges to State Policy Capacity. New York: **Palgrave Macmillan**, p. 1-18, 2005.

PINTO, E.; MOUTINHO, P.; RODRIGUES, L.; OYO FRANÇA, F.; MOREIRA, P. F. DIETZSCH, L. Cartilha: Perguntas e Respostas Sobre Aquecimento Global. 5a edição revisada. **Instituto de Pesquisa Ambiental da Amazônia**. Belém, 2010.

PROCOPIUCK, M. Políticas Públicas e fundamentos da administração pública: análise e avaliação, governança e rede de políticas públicas, administração judiciária. São Paulo: **Atlas**, 2013.

REPÚBLICA FEDERATIVA DO BRASIL. Pretendida Contribuição Nacionalmente Determinada. **República Federativa Do Brasil**, 2015. Disponível em: https://antigo.mma.gov.br/images/arquivo/80108/BRASIL%20iNDC%20portugues%20FINAL.pdf. Acesso em: 18 Mar. 2021.

ROBERTS, J. T.; WEIKMANS, R.; ROBINSON, S. A.; CIPLET, D.; KHAN, M.; FALZON, D. Rebooting a failed promise of climate finance. **Nature Climate Change**.

11, 180–182, 2021.

ROCHEDO, P. R. R.; SOARES-FILHO, B.; SCHAEFFER, R.; VIOLA, E.; SZKLO, A.; LUCENA, A. F. P.; KOBERLE, A.; DAVIS, J. L.; RAJÃO, R.; RATHMANN, R. The threat of political bargaining to climate mitigation in Brazil. **Nature Climate Change** 8, 695–698, 2018.

SANTILLI, M.; MOUTINHO, P.; SCHWARTZMAN, S.; NEPSTAD, D.; CURRAN, L.; NOBRE, C. Tropical deforestation, and the Kyoto Protocol: an editorial essay. **Instituto de Pesquisa Ambiental da Amazônia,** 2000.

SANTOS, M. H. C. Governabilidade, Governança e Democracia: Criação de Capacidade Governativa e Relações Executivo-Legislativo no Brasil Pós-Constituinte. Rio de Janeiro: **Dados**, v. 40, nº 3, 1997.

SECCHI, L. Políticas públicas: conceitos, esquemas de análise, casos práticos. São Paulo: **Cengage Learning**, 2010.

SILVA BEZERRA, F. G.; VON RANDOW, C.; ASSIS, T. O.; BEZERRA, K. R. A.; TEJADA, G.; CASTRO, A. A; GOMES, D. M. P.; AVANCINI, R.; AGUIAR, A. P. New land-use change scenarios for Brazil: Refining global SSPs with a regional spatially-explicit allocation model. **PLoS ONE** 17 (4): e0256052, 2022.

SOARES-FILHO, B. S.; NEPSTAD, D. C.; CURRAN, L. M.; CERQUEIRA, G. C.; GARCIA, R. A.; RAMOS, C. A.; VOLL, E.; MCDONALD, A.; LEFEBVRE, P.; SCHLESINGER, P. Modelling conservation in the Amazon basin. **Nature** 23; 440 (7083):520-3, 2006.

SOUZA, F. A. Z. Gestão de unidades de conservação da natureza no estado de São Paulo: a influência do arranjo institucional nas ações governamentais. **Tese (doutorado) – Universidade Estadual de Campinas, Instituto de Filosofia e Ciências Humanas.** Campinas, 2020.

SOTERRONI, A. C.; IMPÉRIO, M.; SCARABELLO, M. C.; SEDDON, N.; OBERSTEINER, M.; ROCHEDO, P. R. R.; SCHAEFFER, R.; ANDRADE, P. R.; RAMOS, F. M.; AZEVEDO, T. R.; OMETTO, J. P. H. B.; HAVLÍK, P.; ALENCAR, A. A. C. Nature-basedsolutions are critical for putting Brazil on track towards net-zero emissions by 2050. **Global Change Biology**, *29*, 7085–7101, 2023.

STANLEY, M. P. HAMILTON, K. DEVELOPING DIMENSION: State of the Voluntary Carbon Markets 2012. **Ecosystem Marketplace & Bloomberg New Energy Finance**, 2012. Disponível em: https://www.forest-trends.org/wp-content/uploads/imported/svcm_2012_final-draft_6-13-12_rev5-pdf.pdf. Acesso em: 21 Dez. 2021.

THE WORLD BANK. Sub-Saharan Africa: From Crisis to Sustainable Growth. **The International Bank for Reconstruction and Development**, 1989.

_____. Governance and Development. **The International Bank for Reconstruction and Development**, 1992.

UNITED NATIONS. United Nations Framework Convention on Climate Change. **United Nations**, 1992. Disponível em: https://unfccc.int/resource/docs/convkp/conveng.pdf. Acesso em: 21 Mar. 2021.

UNFCCC. Kyoto Protocol to the United Nations Framework Convention on Climate Change. **United Nations Framework Convention on Climate Change**, 1997. Disponível em: https://unfccc.int/sites/default/files/resource/docs/cop3/l07a01.pdf. Acesso em: 02 Abr. 2022.

UNFCCC. Report of the Conference of the Parties on its thirteenth session, held in Bali from 3 to 15 December 2007. **United Nations Framework Convention on Climate Change**, 2008. Disponível em https://unfccc.int/decisions?f%5B0%5D=session%3A3400. Acesso em 03 Abr. 2021.

UNFCCC. Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009. **United Nations Framework Convention on Climate Change**, 2010. Disponível em: https://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf#page=4. Acesso em 21 Mar. 2021.

UNFCCC. Report of the Conference of the Parties on its sixteenth session, held in Cancun from 29 November to 10 December 2010. **United Nations Framework Convention on Climate Change**, 2011. Disponível em: https://unfccc.int/decisions?f%5B0%5D=session%3A3454. Acesso em 21 Mar. 2021.

UNFCCC. Doha amendment to the Kyoto Protocol. **United Nations Framework Convention on Climate Change**, 2012. Disponível em: https://unfccc.int/files/kyoto_protocol/application/pdf/kp_doha_amendment_english.pdf. Acesso em 21 Mar. 2021.

UNFCCC. Report of the Conference of the Parties on its nineteenth session, held in Warsaw from 11 to 23 November 2013. **United Nations Framework Convention on Climate Change**, 2014. Disponível em: https://unfccc.int/resource/docs/2013/cop19/eng/10a01.pdf#page=34. Acesso em 14 Abr. 2021.

UNFCCC. Paris Agreement. **United Nations Framework Convention on Climate Change**, 2015. Disponível em: https://unfccc.int/sites/default/files/english_paris_agreement.pdf. Acesso em: 10 Set. 2021.

UNFCCC. Report of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on the third part of its first session, held in Katowice from 2 to 15 December 2018. **United Nations Framework Convention on Climate Change**, 2019. Disponível em: https://unfccc.int/sites/default/files/resource/CMA2018_03a02E.pdf. Acesso em: 22 fev 2023.

UNFCCC. Federative Republic of Brazil. Paris Agreement. Nationally Determined Contribution (NDC). **United Nations Framework Convention on**

Climate Change, 2022. Disponível em: https://unfccc.int/sites/default/files/NDC/2022-06/Updated%20-%20First%20NDC%20-%20%20FINAL%20-%20PDF.pdf. Acesso em: 10 Set. 2022.

UNFCCC. Federative Republic of Brazil Nationally Determined Contribution (NDC) to the Paris Agreement under the UNFCCC. **United Nations Framework Convention on Climate Change,** 2023a. Disponível em: https://unfccc.int/sites/default/files/NDC/2023-11/Brazil%20First%20NDC%202023%20adjustment.pdf. Acesso em 18 Fev. 2024.

UNFCCC. Brazil’s National Forest Reference Emission Level for Results-based Payments for REDD+ under the United Nations Framework Convention on Climate Change. **United Nations Framework Convention on Climate Change**, 2023b.

VCS. Verified Carbon Standard. VMD0055. Estimation of Emission Reductions from avoiding unplanned deforestation. **Verified Carbon Standard**, 2024. Disponível em: https://verra.org/wp-content/uploads/2024/02/VMD0055-Estimation-of-Emission-Reductions-from-Avoiding-Unplanned-Deforestation-v1.0-2024.02.20-update.pdf. Acesso em: 22 jan 2024.

VELOSO, L. V. S. Evolução dos inventários nacionais de gases de efeito estufa para o setor de uso da terra, mudança de uso da terra e florestas. **Dissertação (mestrado) – Universidade Federal de Minas Gerais**, Departamento de Cartografia, 2019.

VERBURG, P. H. Simulating Feedbacks in Land Use and Land Cover Change Models. **Landscape Ecology**, 21, 1171–1183, 2016.

VIOLA, E. A dinâmica das potências climáticas e o acordo de Copenhague. **Boletim da Sociedade Brasileira de Economia Ecológica**, Edição Especial (23-24), 16-22, 2010. Disponível em: <http://ecoeco.org.br/wp-content/uploads/2018/08/boletim_Ecoeco_23_24.pdf>. Acesso em: 26 Mai. 2021.

VON LÜPKE, H.; LEOPOLD, L.; TOSUN, J. Institutional coordination arrangements as elements of policy design spaces: insights from climate policy. **Policy Science** 56, 49–68, 2023.

WORLD BANK GROUP. The International Bank for Reconstruction and Development. Worldwide Governance Indicators (WGI). **World Bank**, 2013. Disponível em: <http://info.worldbank.org/governance/wgi/index.aspx#faq>. Acessoem: 01 Out. 2022.

WORLD BANK GROUP. Nesting of REDD+ Initiatives: Manual for Policymakers. **World Bank**, 2021. Disponível em: https://documents1.worldbank.org/curated/en/411571631769095604/pdf/Nesting-of-REDD-Initiatives-Manual-for-Policymakers.pdf. Acesso em: 15 Mai. 2023.

WU, X.; RAMESH, M.; HOWLETT, M. Policy Capacity: a conceptual framework for understanding policy competencies and capabilities. **Policy and Society**, v. 34, p. 165-171, 2015.

ANEXOS

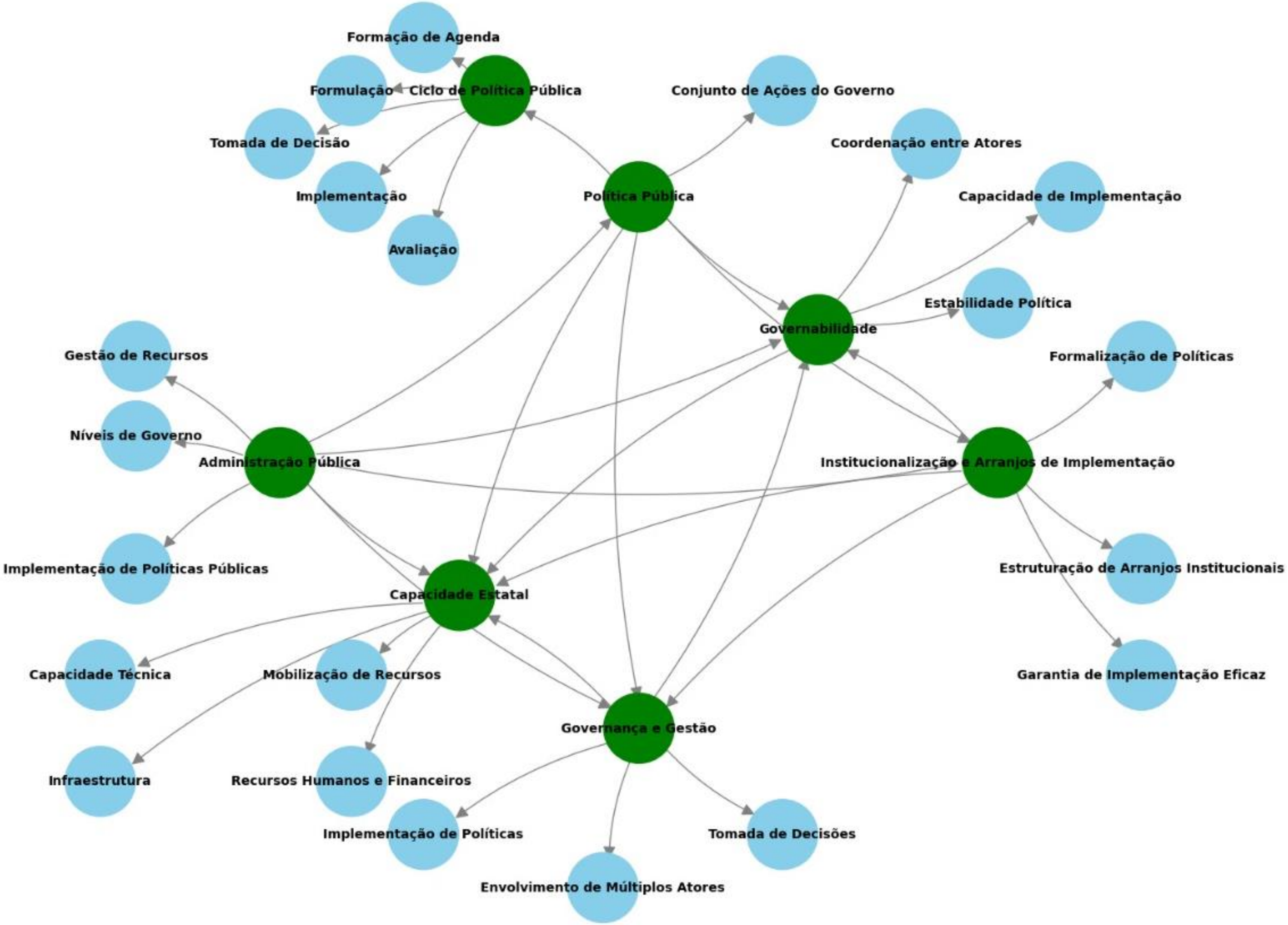


Figura A. 1. Diagrama Causal de Política e Gestão.

SUPPLEMENTARY MATERIAL

SM1- 1. Soares-Filho *et al*. (2006)

The authors used the software Dinamica [49] to conduct the analysis, considering infrastructure maps (highways, local roads, railways, gas pipelines, river channels, and ports), administrative units (states, countries, and macro-regions), protected areas (federal and state conservation units and indigenous lands), and biophysical aspects (vegetation, soil, and topography) to locate the presumable areas to be deforested and hence reproduce the patterns of deforestation progression.

The pessimistic scenario ("Business as usual" - BAU) in this study considered historical deforestation trends across the Amazon basin and added to this term an acceleration factor arising from the paving of a set of roads. In all scenarios, road paving followed the predefined calendar. The optimistic governance scenario also considered historical deforestation trends across the basin. However, in this case, the deforestation projection took on an inverted U-shaped curve, reflecting the gradual increase in governance across the Amazon.

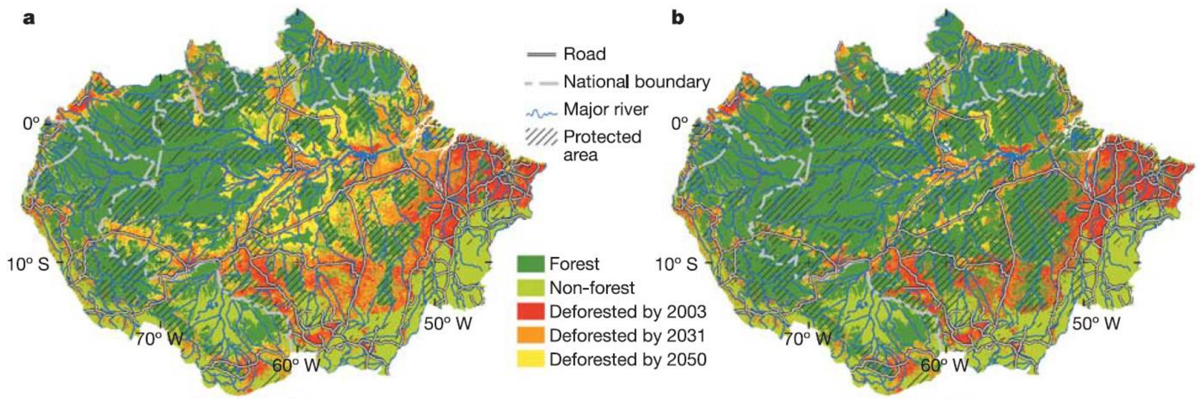


Figure SM1. 1. Forest cover for BAU (a) and governance (b) scenario by Soares-Filho *et al*. (2006).

[49]More information about DINAMICA Ego: https://csr.ufmg.br/dinamica/

Table SM1. 1. Summary of Soares-Filho et al. (2006) modeling process.

Reference	Calibration and parameterization data	Drivers (Influencing variables) and assumptions	Predicted variables	Modeling framework	Scenarios	Uncertainties estimation	Projected years
Soares-Filho *et al*. (2006)	- Legal Amazon deforestation rate from 1997 to 2002 (INPE, 2004)	- **Infrastructure** (highways, local roads, railways, gas pipelines, river channels and ports); - **Administrative units** (states, countries, and macro-regions); - **Protected areas** (federal and state and Indigenous lands); - **Biophysical aspects** (vegetation, soil, and topography).	- **Deforestation** for the 47 sub-regions of the basin; - **Roads to be paved** (default calendar); - Extensions of **forest remnants**; - **Current and planned protected areas** in each of the sub-regions	**SimAmazonia** (**Dinamica EGO**)	1) **Business as usual (BAU):** 85% of the original forest cover in private properties (above the limits established by the Forest Code); protected areas can lose up to 40% of their original forest cover due to lack of environmental inspection 2) **Historical scenario**, including only the recent trend of acceleration of logging 3) **BAU with new Arpa**, but **without overt environmental inspection**, which can allow up to 40% deforestation in these areas 4) **BAU without new Arpa**, but **with ostensible environmental** inspection of current protected areas 5) **BAU with new Arpa** and **ostensible environmental inspection** in order to ensure the full preservation of these areas 6) **Governance scenario without new Arpa** 7) **Governance scenario without new asphalting** 8) **Optimist Governance scenario**: deforestation does not exceed 50% of the original forest cover in private properties and extension of protected areas (considering Arpa Program*)	Not quantified	2003 to 2050

ARPA: Amazon Protected Areas Program

SM1- 2. Aguiar *et al*. (2016)

The authors used LuccME[50] to project annual deforestation, where cells with a positive change potential received a percentage of the annual change that had to be allocated to the whole area proportionally to their potential. For this study, they created an alternative method that considered temporal changes in the spatial drivers and the distance to previously opened areas. Also, they have changed the allocation mechanism to control the change in each cell per year so that law enforcement could be represented in different scenarios.

INPE-EM[51] was used to generate secondary vegetation dynamics. INPE-EM is "a deforestation-driven carbon emission modeling framework based on the book-keeping model." The model considers the different carbon pools (aboveground biomass, belowground biomass, and dead organic matter - wood and litter) and represents three processes: Clear-cut deforestation, Secondary Vegetation, and Old Growth Forest Degradation. The Clear-Cut Deforestation component estimates emissions of 1st order (100% of the carbon is released when the land cover changes) and 2nd order (temporal process of carbon emission, combining instantaneous emissions by fire and gradual biological decomposition). The Secondary Vegetation component parameters considered the percentage of the deforested area in each cell that would be abandoned after some years of agricultural use and the number of years it would take for that growing vegetation to be removed again. In the old-growth forest Degradation Component, the forest carbon stock changes due to each cell's forest degradation process (logging and fire). The scenarios combined qualitative and quantitative factors into 25 x 25 km^2 regular cells (Table SM1. 2).

The 'Sustainability' scenario (Scenario A), which represents the ideal one, presented similar deforestation distribution as the 'Middle of the road'' scenario (Scenario B), while the 'Fragmentation' scenario (Scenario C), which represents the pessimistic one, showed a concentration of the deforestation around previously opened areas and new frontiers around some planned roads (Figure SM1. 2a), what is also reflected in Figure SM1. 2 (c). Nonetheless, forest regrowth is much higher in Scenario A compared to Scenarios B and C (Figure SM1. 2b).

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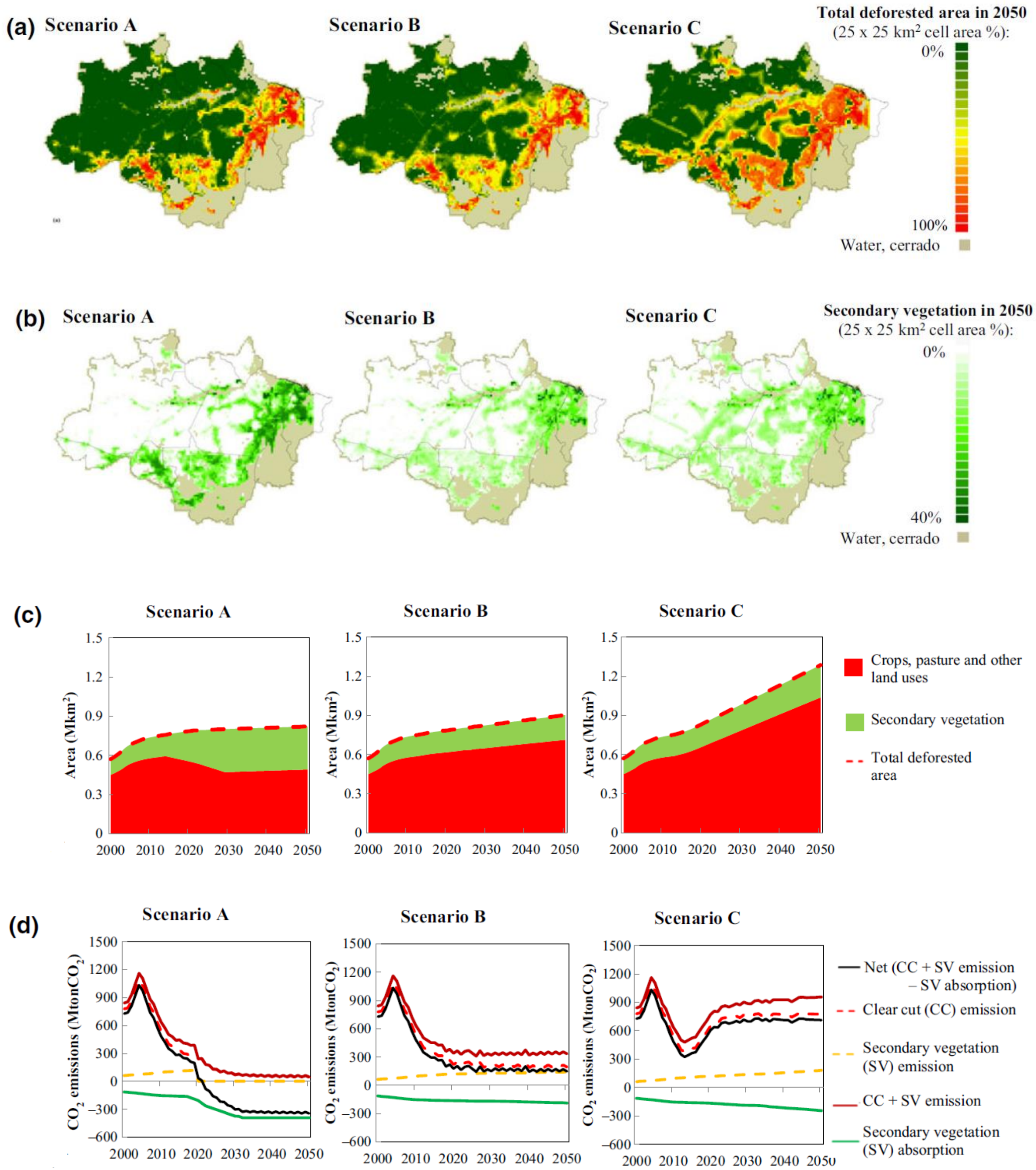
[50] LuccME is a framework to develop spatially explicit land-use and cover change models. More information on: http://luccme.ccst.inpe.br/

[51] More information about INPE-EM available on: http://inpe-em.ccst.inpe.br/



Source: Aguiar *et al.*, 2016

Figure SM1. 2. LuccME/INPE-EM scenario results – (a) Spatial distribution of the deforested areas in 2050; (b) spatial distribution of the secondary vegetation areas in 2050; (c) evolution of total deforested area and secondary vegetation area from 2000–2050; (d) evolution of CO2 emissions from 2000–2050 under ‘Sustainability’ scenario (Scenario A), ‘Middle of the road’’ scenario (Scenario B), and 'Fragmentation' scenario (Scenario C).

Table SM1. 2. Summary of Aguiar *et al*. (2016) modeling process.

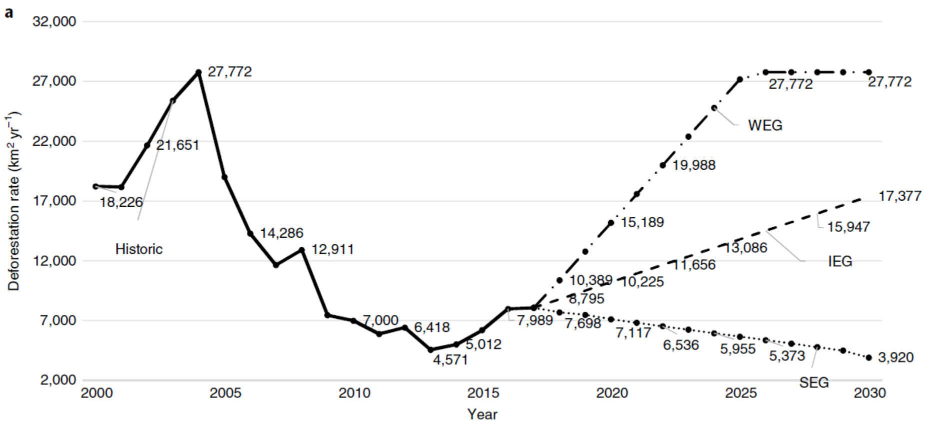
Reference	Calibration and parameterization data	Drivers (Influencing variables) and assumptions	Predicted variables	Modeling framework	Scenarios	Uncertainties estimation	Projected years
Aguiar *et al.* (2016)	<u>Land-Use Change</u>: - Observed increase in deforestation from 2004 to 2010 (INPE, 2015) for deforestation calibration; - TerraClass 2008 (INPE, 2015) for the initial percentage of the secondary vegetation (2002–2013) concerning the deforested area in each cell (21%); - DEGRAD from 2007 to 2013 (INPE, 2015) for Old Growth Forest Degradation. <u>GHG emissions</u>: - Above-ground live biomass from Nogueira *et al*. (2008) with the inclusion of other pools (roots 25.8%, dead wood 8.8%, litter 4,9%)	<u>Drives</u>: - Accessibility (distance to roads and connection to national markets); - Agrarian projects for agricultural use; - Soils with high fertility; - Protected areas. <u>Story and Simulation (SAS) approach that considers</u>: (a) **Forest Code enforcement** (b) **Future clear-cut deforestation and old-growth forest degradation** (c) **Secondary vegetation dynamics** (d) Road **network and Protected areas** <u>For GHG emissions</u>: - 40% of carbon loss after degradation process and 50 years to regenerate total biomass; - Assumption of the same average rate of degradation observed from 2007 to 2013 (14 700 km^2 yr -1) since 1980; - CO_2 removals from secondary vegetation are based on passive regeneration; - 50% of above-ground biomass is instantaneously released by fire and the remaining gradually during the following years by biological decomposition and cyclic fires.	25x25 km^2 cells with: - Clear-cut deforestation; - Secondary vegetation dynamics; - Old Growth Forest Degradation; - GHG emissions.	**TerraME / LuccME** to land-use maps and **INPE-EM** to secondary vegetation dynamics and GHG emissions	(1) **'Sustainability' scenario (Scenario A) -** ideal/desired: a) Forest Code restoration; b) Deforestation in 2020 is 3,900 km^2 (voluntary emission reduction national target), decreases to 1,000 km^2 by 2025 and to zero by 2050; c) Secondary vegetation increases by 35% in every cell of the deforested area from 2015 to 2030. Existing secondary vegetation not disturbed after 2020; d) On-going paving concluded in 2017 (BR-163, BR-319, and BR-230); no other roads built after 2017, and maintenance of 2010 protected areas. 2) **''Middle of the road'' scenario (Scenario B):** a) Compensation mechanisms to forest code, such as quotas; b) Deforestation is 3,900 km^2 from 2020 to 2050; degradation maintains 14,700 km^2 y-1; c) Secondary vegetation follows the current dynamic, but old secondary forests are preserved; d) All paving and planned roads built distributed in 2017, 2025, 2030, and 2042 with measures to avoid uncontrolled occupation and protected areas of 2010 less protected in more densely occupied areas. 3) **'Fragmentation' scenario (Scenario C) -** pessimistic/undesired: a) Forest Code not respected and deforestation control measures discontinued; b) Deforestation rates rise from 2014 to 2020 and continue uncontrolled until 2050, and degradation rates maintain 14,700 km^2 yr-1; c) Secondary vegetation follows the current dynamic (less secondary vegetation in more densely occupied areas, ~5 years half-life), including old secondary forests; d) All paving and planned roads built distributed in 2017, 2025, 2030, and 2042 and decrease in extension and protection of protected areas - gradually returning to the 2002 extension (2018 = 2006; 2020 = 2004; 2022 = 2002)	Not quantified	2014 to 2050

SM1- 3. Rochedo*et al*. (2018)

The authors outlined three environmental governance scenarios: i) the Weak Environment Governance (WEG) scenario, which considers the neglect of deforestation control and the encouragement of predatory agricultural practices; ii) the Intermediate Environment Governance (IEG) scenario, which maintains deforestation control policies while supporting predatory practices, and iii) the Strong Environment Governance (SEG) scenario, which represents environmental solid governance, expanding preservation policies.

The study used the spatially explicit land-use model OTIMIZAGRO [52] to simulate land use, land-use change, forestry, deforestation, regrowth, and associated carbon emissions under different scenarios of agricultural land demand and environmental policies.

To simulate the evolution of the Brazilian energy, industrial, land-use, and waste sectors, as well as their GHG emissions through 2050, the authors used the Integrated Assessment Model (IAM) called BLUES (Brazilian Land Use and Energy System)[53], built on the Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE)[54]. The IAM pondered the demand for food and energy services (lighting, heating/cooling requirements, mechanical energy, and mobility, among others), considering the industrial, transportation, and building sectors (Table SM1. 3).



Source: Rochedo*et al*. (2018)

Figure SM1. 3. Deforestation for the Amazon biomes in different environment governance scenarios: Weak Environment Governance (WEG), Intermediate Environment Governance (IEG), and Strong Environment Governance (SEG).

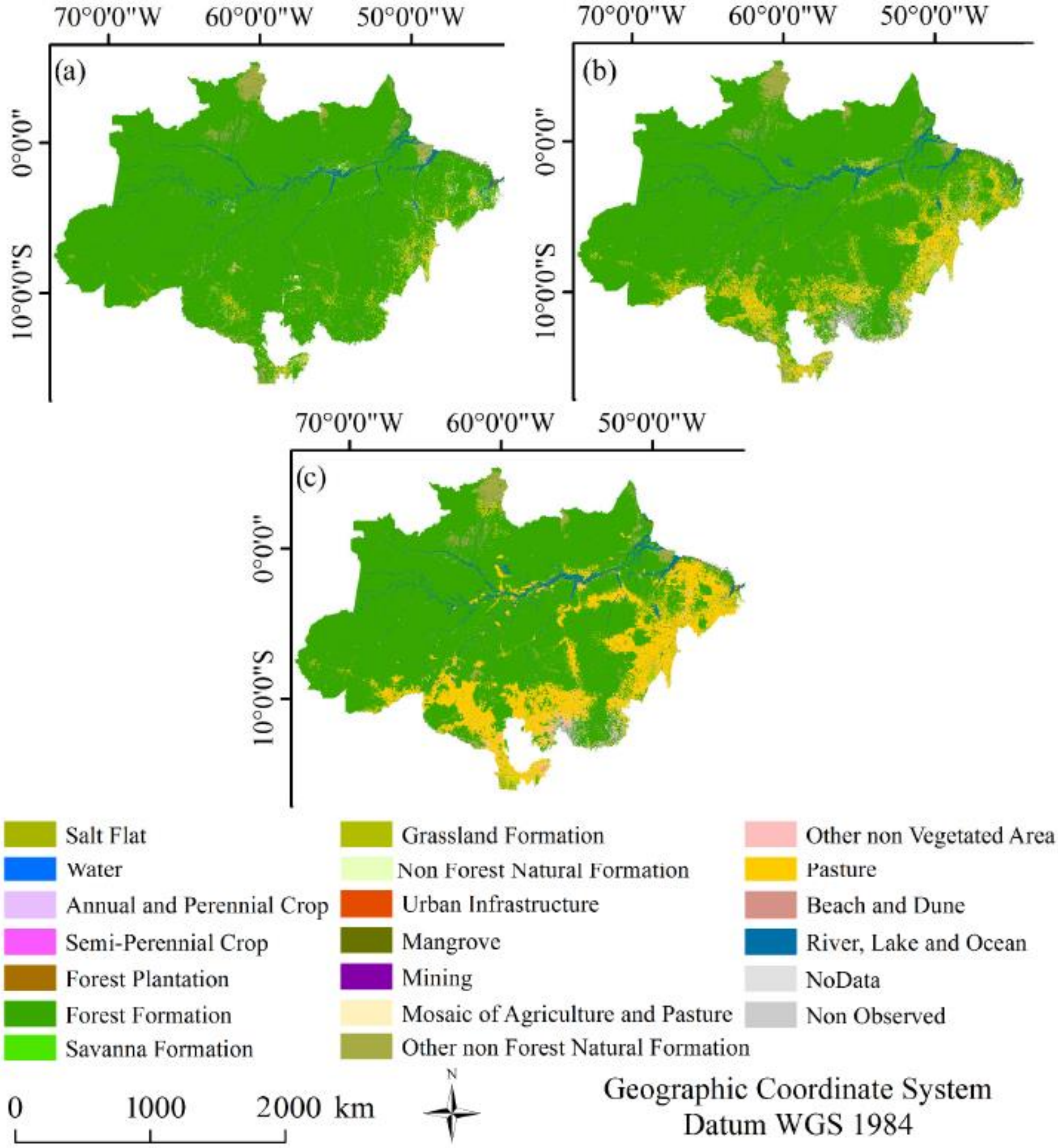
[52] More information about OTIMIZAGRO on: https://csr.ufmg.br/otimizagro/
[53] More information about BLUES on: https://www.iamconsortium.org/resources/model-resources/brazilian-land-use-and-energy-system-blues/
[54] More information about MESSAGE on: https://www.energyplan.eu/othertools/global/message/

Table SM1. 3. Summary of Rochedo *et al*. (2018) modeling process.

Reference	Calibration and parameterization data	Drivers (Influencing variables) and assumptions	Modeled variables	Modeling framework	Scenarios	Uncertainties estimation	Projected years
Rochedo *et al*. (2018)	Land-use change: - Amazon biome; - Micro-regions from IBGE; - Brazilian municipalities; - A raster grid with 25 ha spatial resolution (500x500m); - Initial land-use map of 2012 composed by: 1) PRODES increase in deforestation maps (INPE); 2) TerraClass land-use maps (INPE); 3) Urban areas from IBGE census (IBGE); 4) Large mechanized croplands (INPE); 5) Maps of crop aptitude and profitability; - Deforestation rates from 2010 to 2016 from PRODES. For GHG emissions: - Third National Communication biomass map, which includes all carbon pools (AGB, BGB, DW, and litter); - Pasture carbon stock = 7.57 tC/ha; - Crop carbon stock = 5.00 tC/ha; - Carbon removals by regeneration = 44% of the original biomass.	For land-use changes: - Politics to land-use governance; - Distance to roads; - Previously deforested areas; - Demands for crops. For LUUCF GHG emissions: - Net emissions consider gross emissions from deforestation and removals from native vegetation regeneration; - SEG scenario includes removals from restoration of native vegetation; - No removals considered to protected areas nor forest plantation. For optimization of Brazil´s energy system: - Demand for food and energy services (lighting, heating/cooling requirements, mechanical energy, and mobility, among others), considering the industrial sector, the transportation sector, and the building sector; - OTIMIZAGRO provided results from land use from 2010-2030.	A raster grid with 25ha spatial resolution: - Projected annual deforestation from 2017 to 2030; Land-use change scenarios (forestry, deforestation, regrowth)4; - GHG emissions. - Level of effort and investment costs required from other economic sectors to compensate for higher emissions from deforestation	**OTIMIZAGRO** (explicit land-use model) / **Dinamica EGO**and **BLUES** (Brazilian Land Use and Energy System) IAM model	1) **Weak environmental governance (WEG):** abandonment of current deforestation control policies and strong political support for predatory agricultural practices - based on deforestation rates observed between 2002 and 2008, limited to the 2004 peak of 27,772 km2. 2) **Intermediate environmental governance (IEG) or BAU**: legal support for land-grabbing practices, creation of fewer protected areas, and the downsizing of key protected areas together with lax enforcement of the Forest Code - based on deforestation rates observed between 2012 and 2016, limited to 2004 peak of 27,772 km^2. 3) **Strong environmental governance (SEG)**: expansion of current deforestation command-and-control policies and full political support for the environmental agenda in the country, including full implementation of the Forest Code alongside economic incentives for forest conservation - projects rates to reach 3,920 km2 by 2030, in compliance with PNMC, only in constrained areas of Forest Code.	Not quantified for land-use and GHG emission scenarios	2017 to 2030

SM1- 4. Barbosa de Sousa *et al*. (2023)

The authors used land use and land cover data for 1985 and 2014 from the MapBiomas Project[55] – Collection 3.0 of Brazil's Annual Serie of Land Cover and Land Use Maps to model land-use changes in the Amazon biome until 2044 (Table SM1. 5).



Source: Barbosa de Sousa *et al.*(2023).

Figure SM1. 4. Land use and land cover for Amazon biome in 1985 (a), 2014 (b), and simulation for 2044 (c).

[55] Mapbiomas produces maps with 30 m of spatial resolution, through the pixel-by-pixel classification of Landsat satellite images. The classification process is carried out using machine learning algorithms on the Google Earth Engine platform. More information on: https://brasil.mapbiomas.org/

Table SM1. 4. Quantification of land use and land cover classes for 1985, 2017, and 2044.

	1985		2014		2017		2044	
Classes	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Forest Formation	3,844,800.75	91.20	3,452,129.25	81.89	3,482,721.50	82.61	3,115,892.25	73.91
Savanna Formation	4708.50	0.11	4804.50	0.11	3060.25	0.07	4804.50	0.11
Mangrove	7234.25	0.17	7510.25	0.18	6827.50	0.16	7510.25	0.18
Planted Forest	25.00	0.00	305.25	0.01	438.00	0.01	305.25	0.01
Non-Forest Natural Formation	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grassland Formation	3340.75	0.08	5573.75	0.13	3574.25	0.08	5573.75	0.13
Salt Flat	139.25	0.00	283.00	0.01	401.75	0.01	283.00	0.01
Other Non-Forest Natural Formation	117,054.50	2.78	110,970.75	2.63	114,915.75	2.73	110,970.75	2.63
Pasture	71,046.50	1.69	437,670.00	10.38	375,159.50	8.90	773,907,00	18.36
Annual and Perennial Culture	793.25	0.02	41,232.50	0.98	44,500.50	1.06	41,232.50	0.98
Semi-Perennial Culture	0.00	0.00	709.00	0.02	608.75	0.01	709.00	0.02
Mosaic of Agriculture and Pasture	58,849.75	1.40	33,311.75	0.79	69,413.25	1.65	33,311.75	0.79
Urban infrastructure	1939.75	0.05	2798.50	0.07	2781.25	0.07	2798.50	0.07
Mining	13.25	0.00	119.00	0.00	146.75	0.00	119.00	0.00
Beach and Dune	31.00	0.00	53.50	0.00	43.00	0.00	53.50	0.00
Other Non-Vegetated Area	6299.25	0.15	3079.25	0.07	3316.50	0.08	3079.25	0.07
Water bodies	6.00	0.00	0.00	0.00	8.25	0,00	0.00	0.00
River, Lake, and Ocean	99,112.25	2.35	114,814.50	2.72	107,465.25	2.55	114,814.50	2.72
Not observed	53.75	0.00	160.75	0.00	57.75	0.00	160.75	0.00
No Data	195.00	0.00	117.75	0.00	203.50	0.00	117.75	0.00
Total	4,215,643.25	100	4,215,643.25	100	4,215,643.25	100	4,215,643.25	100

Source: Barbosa de Sousa *et al.*(2023)

Table SM1. 5. Summary of Barbosa de Sousa *et al*. (2022) modeling process.

Reference	Calibration and parameterization data	Drivers (Influencing variables) and assumptions	Modeled variables	Modeling framework	Scenarios	Uncertainties estimation	Projected years
Barbosa de Sousa *et al.* (2023)	- Amazon biome; - 1985 and 2014 land use and land cover data from the MapBiomas Project (30m spatial resolution).	- Altitude and Slope: Digital Elevation Model (DEM) from the Shuttle Radar Topography Mission (SRTM); - Annual Average Precipitation: Rainfall images - Modern-Era Retrospective analysis for Research and Applications project, Version 2 (MERRA-2), made available through the National Aeronautics and Space Administration (NASA); - Distance from Highways; - Distance from Watercourses (ANA); - Distance from Urban Infrastructure; - Distance from pasture; - Distance of Annual and Perennial Culture; - Distance from Semi-Perennial Culture; - Distance from Agriculture and Pasture Mosaic; - Distance from Mining; - Distance from Federal Protected Areas (ICMBIO); - Distance from Change Areas.	Raster with 30m resolution land use and cover maps for 2017 and 2044	**Land Change Modeler change analysis module** (LCM) coupled with **TerrSet version 18.0 software**	**BAU**: observed conditions of change in land use and land cover between 1985 and 2014 would remain unchanged	The validation of the land cover simulation was performed by comparing the mapped and simulated land cover maps for the year 2017 using the Validate function from Terrset - methodology proposed by Pontius Junior, Huffaker, and Denman [45], which considers that value equal to or greater than 0.80 is considered strong. It is reasonable to make future projections plausible. The result obtained in this evaluation was 93.76%.	2017 and 2044

SM1- 5. Soterroni et al. (2023)

The authors applied a regional IAM approach to investigate if existing and expected national policies would allow Brazil to meet its net-zero GHG emissions goal by 2050. The authors used the regional version of the GLObalBIOsphere Management model (GLOBIOM)[56] to project LULUCF and Agricultural emissions. The BLUES model (explained in the analysis of Study 3) was applied to project emissions from the energy, industrial processes, and waste sectors. Both are regional versions of global models, allowing a good representation of Brazil's specificities through better input data, resolution, calibration, and validation.

GLOBIOM-Brazil is an economic bottom-up partial equilibrium land-use model that simulates the competition for land focusing on major global land-based sectors, i.e., agriculture, forestry, and bioenergy sectors subjected to resources, technology, and policy constraints. Deforestation is not forced into the model exogenously; it is estimated by the model based on market signals in conjunction with land suitability, biophysical evidence, production and land conversion costs, and scenario restrictions. Therefore, production is endogenously adjusted to support food, feed, fibers, and bioenergy demands for 30 regions and countries that intersect beyond international trade. The model uses a geographical grid of 0.5° × 0.5° in Brazil (approximately 50 km x 50 km at the Equator) (Soterroni *et al*., 2023).

The authors ran GLOBIOM-Brazil with 5-year time steps for the Agriculture and LULUCF sectors and BLUES for the Energy, Waste, and Industrial Processes sectors. The BLUES Agricultural sector was used to quantify the additional areas needed for biofuel production to bridge the gap to net-zero emissions by mid-century (Table SM1. 6).

[56] More information on: www.globiom.org.

Table SM1. 6. Summary of Soterroni*et al*. (2023) modeling process.

Reference	Calibration and parameterization data	Drivers (Influencing variables) and assumptions	Modeled variables	Modeling framework	Scenarios	Uncertainties estimation	Projected years
Sotterroni, A. *et al*. (2023)	-Land Use map of 2000 from Collection 4.1 of the Brazilian Annual Land Use and Land Cover Mapping Project (MapBiomas); - Statistics on crop area from the official yearly crop surveys (PAM/IBGE); - Protected areas from MMA.	Land-Use changes: - Gross domestic product (GDP), population growth, and dietary trends derived from the Shared Socioeconomic Pathways (SSPs); - Exogenous biofuels demand - 2010 World Energy Outlook projections (International Energy Agency, 2010); - Demand for sugarcane ethanol - Energy Research Enterprise (EPE) projections of the Ministry of Mines and Energy (MME) (EPE, 2017); - Restoration implementation costs and opportunity costs based on GLOBIOM-Brazil outputs and prices of commodities; - Agricultural opportunity costs - major commodity prices (soybeans, maize, sugarcane, and beef). GHG emissions from LUC: - CO_2 emissions or removals resulting from the difference in the carbon content (above- and below-ground biomass) between the original and the new classes - does not consider dead wood, litter, and soil organic carbon; - Native vegetation [cut: Forest] restoration considers the PLANAVEG schedule and growth curves. For example,	2025, 2030, 2035, 2040, 2045 and 2050 land-use rasters with 50x50 km2 cells with information on: - Native vegetation (unmanaged); - Planted forest (afforestation) - Pinus and Eucalyptus; - Managed forest; - Pasture (livestock ranching); - Cropland1; - Non-productive land (Mosaic of natural vegetation and areas previously converted from agriculture but not currently under production); - Other agricultural land (coffee, cocoa, and orange); - Wetland; - Not related lands (Bare areas, water	**GLOBIOM -Brazil** is responsible for the emissions of the LULUCF and agricultural sectors, with BLUES projects for energy, industrial processes, and waste sectors.	1) Baseline (BASE): Weak environmental governance with imperfect illegal deforestation control. Deforestation continues up to 2050, with Amazon deforestation rates above 1Mha, on average, between 2020 and 2030. No native vegetation restoration. Agricultural practices follow current trends, including ABC+ Plan goals. The energy sector considers agreed and installed infrastructure2 and international policies3; SSP2 (28% growth in population and a 174% growth in GDP for Brazil between 2000 and 2030); 2) Forest Code (FC): Zero illegal deforestation. Native vegetation restoration (~13 Mha) takes place in illegally deforested areas, excluding environmental debts in small farms (amnesty); the energy sector considers agreed and installed infrastructure2 and international policies3; 3) Forest Code Plus (FC+): Zero illegal and legal deforestation. Native vegetation restoration (~35 Mha) takes place in areas illegally deforested and in small farms that have been granted amnesty (no CRA) - follows the PLANAVEG schedule (geometric progression) from	Deforestation: the BASE scenario projects an average annual deforestation rate of 1.08 Mha in the Amazon biome between 2020 and 2030, which is close to the latest estimates from PRODES (1.01 Mha in 2019, 1.08 Mha in 2020, 1.3 Mha in 2021, and 1.16 Mha in 2022); for the period 2001-2015, the difference in accumulated deforestation between GLOBIOM-Brazil and PRODES estimates for the Amazon and Cerrado biomes is smaller than 7%	2021 to 2050

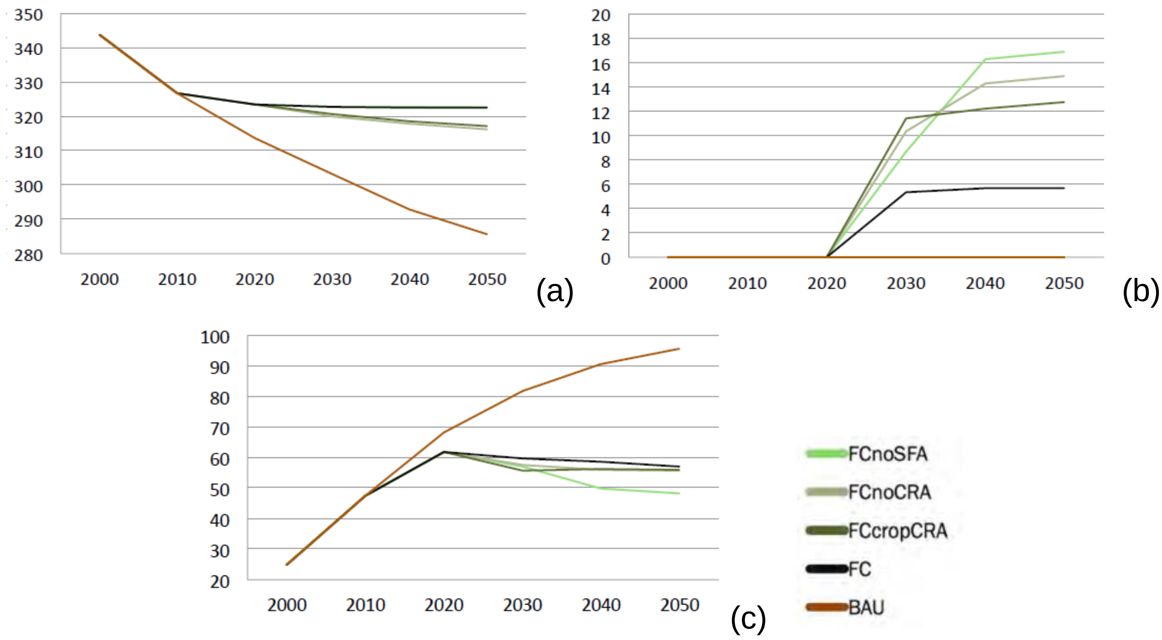
Reference	Calibration and parameterization data	Drivers (Influencing variables) and assumptions	Modeled variables	Modeling framework	Scenarios	Uncertainties estimation	Projected years
		forest in the Amazonia and Cerrado biomes takes 25 years to recover 70% of the original biomass; - A fixed carbon removal by native forests per year, from 2015 to 2050, following Brazil's 4th NC average estimates for 2010–2016 (i.e., 522 $MtCO_2$ per year); - Considers emissions reduction from the recovery of degraded pastures by 1 tC/ha/year; - Carbon stock information comes from different biomass maps, but it is mainly based on the 3rd National GHG Inventory BLUES: - Energy demands exogenously calculated from the SSP2 pathway, using elements such as future GDP and population growth; - International policies; - Energy costs - exploitation of energy resources, construction of power utilities, electricity transmission and distribution, installation of refinery facilities, fuels and biofuel production, and transport of energy carriers.	bodies, snow, and ice); - Restoration; - Land-Use Change GHG Emissions.		2020 to 2035; energy sector considers agreed and installed infrastructure2 and international policies3; 4) Baseline Net Zero (BASENZ): Increase in efficiency, biofuels use, and deployment of negative emissions technology from the energy sector4; 5) Forest Code Net Zero (FCNZ): Zero illegal deforestation, native vegetation restoration (~35 Mha), increase in efficiency, biofuels use, and deployment of negative emissions technology from the energy sector4; 6) Forest Code Plus Net Zero (FC+NZ): Zero illegal and legal deforestation. Native vegetation restoration (~35 Mha) occurs in areas illegally deforested and in small farms that have been granted amnesty (no CRA), increase in efficiency, biofuel use, and deployment of negative emissions technology from the energy sector4.	GHG emissions: Between 2011 and 2015, in the BASE scenario, Brazil's accumulated gross LULUCF emissions were approximately 9% greater than the gross emissions from SEEG. For 2015, the gross emissions from the LULUCF sector projected by the BASE scenario were 8% greater than the gross LULUCF emissions from the 4th NC and 15% greater than SEEG estimates.	

1 18 GLOBIOM crops: barley, dry beans, cassava, chickpeas, corn, cotton, groundnut, millet, potatoes, rapeseed, rice, sorghum, soya, sugarcane, sunflower, sweet potatoes, wheat, and oil palm; 2 Considers (i) the completion of the Angra 3 nuclear plant between 2025 and 2030; (ii) continuity of operation of the Jorge Lacerda coal-fired thermal power plant until 2040; (iii) the expansion of natural-gas-fired power plants; and (iv) the implementation of mandatory blending of biodiesel to all diesel fuel sold in the country at 20% (volumetric basis, B20) from 2028 onwards; 3 International policies in place, such as the decarbonization goals of the International Maritime Organization (IMO) and the International Air Transport Association (IATA), with emission reduction targets of 50% in 2050, relative to 2008 and 2005 emissions, respectively; 4 It can use all technological options, including CCS and BECCS.

SM1- 6. Câmara *et al*. (2015)

Câmara *et al*. (2015) conducted the REDD+ Policy Assessment Centre project (**REDD-PAC**)[57], financed by Germany´s International Climate Initiative. The REDD-PAC project aimed to support Brazil in developing its REDD+ policies and plans for emission reductions in the LULUCF sector.

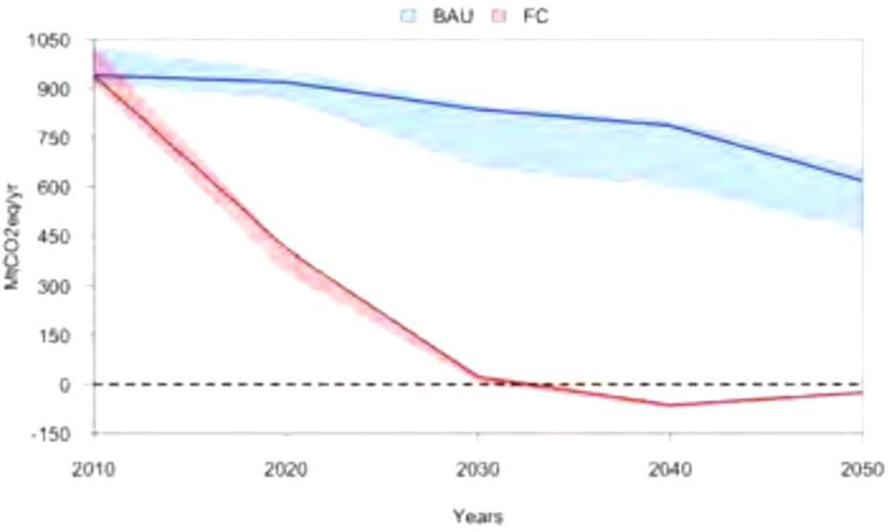
The REDD-PAC project team adopted the global economic GLObalBIOsphere Management model (GLOBIOM). The authors ran a "Business as Usual" (BAU) scenario for the Amazon biome from 2001 to 2010 based on a land use and cover map for the year 2000. The BAU scenario reflects an ineffective control of deforestation, so it allows illegal deforestation and does not include the rules of the Forest Code (FC). Based on this BAU projection from 2001 to 2010, they ran four different scenarios from 2010 to 2050. The initiative also estimated GHG emissions from the agricultural sector and the impacts of land use change on biodiversity (Table SM1. 7).



Source: Câmara *et al*., 2015.

Figure SM1. 5. (a) Projected total mature forest, (b) Projected forest regrowth, and (c) Evolution of pasture for different scenarios in the Amazon biome in Mha.

[57]More information on: www.redd-pac.org.



Source: Câmara *et al*., 2015.

Figure SM1. 6. Net CO2 emissions from land-use change and forestry in MtCO2e/yr for Brazil and Amazonia for BAU and FC scenarios. The solid line represents the median value, and the shadow represents the range defined by the minimum and maximum values.

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Table SM1. 7. Summary of REDD PAC - Câmara *et al*. (2015) modeling process.

Reference	Parameterization data	Influencing variables and premises	Modeled variables	Spatial simulator (Model)	Scenarios	Uncertainties estimation	Projected years
REDD PAC (2015)	For Land-Use modeling: - A land cover map for the **Legal Amazon in 2000** was produced considering the classes: 'natural and managed forest', 'wetlands', 'not relevant', 'cropland', 'planted forest', 'pasture', 'other agricultural land' and 'natural land', based on a MODIS land cover map of 2000 and Protected areas of 2013 - Conservation Units (MMA), Indigenous areas (FUNAI) and forest concessions by from the Brazilian National Forest Service; - The IBGE 2006 Agricultural Census; - The IBGE Municipal Crop Production Survey (PAM) from 2000 to	For Land-Use modeling: - **Internal transport costs**: federal roads and transportation costs within them, considering the proportions of internal consumption and export per product and each agriculture, livestock, and forestry product; - **Land transition matrix**; - **Gross domestic product (GDP), Population Growth, Food and Biofuels Demand**: "Food demand is driven by growth of population and GDP per capita, and wood demand by GDP per capita growth"; - **Land productivity and production costs;** **- International trade:** tariffs and transportation costs differentiated among products and trading partners divided into 30 regions; - **No productive uses in protected areas;** **- Forest Code (2012) rules:** Legal Reserve (80% in the Legal Amazon); Environment reserve quotas (CRA) and Small farms amnesty (Farms with areas deforested exceeding the legal reserve limit after 2008 will have to recover its legal reserve or obtain environmental reserve	50x50 km^2 cells: - Deforestation; - Cropland and pasture distribution; - Livestock distribution; - Total forest (mature and managed forest and forest regrowth); - Forest regrowth; - Mature forest conservation; - Planted forest; - Natural lands dynamic; - Land-Use Change and Forestry GHG Emissions.***	**GLOBIOM** (adapted to Brazil)	1) **Business as Usual (BAU)**: environmental situation as it was in 2000, without effective control of deforestation; allows illegal deforestation, does not include the rules of the Forest Code and forest regrowth; 2) **Forest Code (FC)**: BAU as the baseline for the period 2000-2010; from 2011 to 2050: no illegal deforestation, legal reserve recovery, CRA, small farms amnesty; 3)	For Land-Use projections results: - PRODES/INPE data set was used to validate the GLOBIOM estimates for deforestation in the Amazon biome from 2001 to 2010. The accumulated deforestation in 2010 was 16.5 Mha for PRODES/INPE and 16.9Mha for GLOBIOM-Brazil. - When comparing the distribution of livestock from GLOBIOM-Brazil and IBGE/PPM in the Amazon biome, the difference is lower than 5% in 2010. When comparing the total crop area, the model underestimates it in the Amazon biome. For deforestation, GHG emissions projections result from 2001-2010,	2000 to 2050

Reference	Parameterization data	Influencing variables and premises	Modeled variables	Spatial simulator (Model)	Scenarios	Uncertainties estimation	Projected years
	2010; - The IBGE Municipal Livestock Production Survey (PPM) from 2000 to 2010. For GHG emissions: - Short-rotation plantations: Kindermann *et al*. (2008); - Grasslands and other natural vegetation: Ruesch and Gibbs (2008); - Pan-tropical maps of above-ground live woody vegetation: Baccini *et al*. (2012) and Saatchi *et al*. (2011).	quotas to compensate for the missing reserve) - Areas of Permanent Preservation (APPs) were not considered; - **Public lands assumption**: in all of the states, except for Amazonas, all land that is not protected is, or will be, under private ownership - only 20% of the public lands in the state of Amazonas will become private farms; - **Forest regrowth assumption**: regrowing forests in Amazônia are assumed to recover 70% of their original biomass in 25 years and the remaining 30% over the next 50 years. For GHG emissions estimates: - Agricultural use is assumed to have no carbon stock; - Litter, dead wood, and soil organic carbon are not accounted for.			**FCcropCRA**: Forest Code restricted to the use of quotas only by crop farmers (landowners with high opportunity costs); 4) **FCnoSFA**: Forest Code without small farms amnesty; 5)**FCnoCRA**: Forest Code without CRA.	comparison with: - Brazil's Forest Reference Emission Level (FREL) - 2001-2010: 3%; - Aguiar *et al.* (2012) - 2000-2009: 3%. For LUCF GHG emissions projections result from 2001-2010, comparison with: - Greenhouse Gas Emission Estimation System (SEEG, 2014) - 2001-2010: 2%.	

SM1- 7. MCTI (2017)

The project **“Options for Mitigating Greenhouse Gas Emissions in Key Sectors in Brazil”** was financed by the Global Environment Facility (GEF) and implemented by the Ministry of Science, Technology, and Innovation (MCTI) in partnership with the United Nations Environment Program (UNEP) (MCTI, 2017). The initiative aimed to help the Brazilian government strengthen its technical capacity to support the implementation of actions to mitigate GHG emissions in key sectors of the economy. One key sector is the Agriculture, Forestry and Other Land Use (AFOLU), which we explored in this research, except for the Agriculture estimates, because it was not the focus here. The study also evaluated the costs and revenues of the sector's mitigation options, such as Implementation, Monitoring, and Assessment of the Rural Environmental Registry by Property, inspection actions, payment for environmental services, restoration of native vegetation, adoption of no-till farming (SPD), forests planted, and integration systems (ILP and ILPF), that we also have not explored in this research.

The study used the spatially explicit land-use model OTIMIZAGRO to simulate land-use conversions, deforestation trajectories, and forest regeneration under different scenarios. These scenarios include, among other premises, the goals of restoration of native vegetation of the Forest Code and PLANAVEG, reducing deforestation of the PNMC, and low-carbon strategies of the ABC Plan. The modeling of the AFOLU sector was integrated with the other sectors considered, such as industry, energy, transport, and waste. This interaction is necessary since the productive sectors depend on the availability of land to meet the associated demands.

The authors elaborated on a reference scenario (REF) that considers the premises described before and an alternative low-carbon scenario (BC) that reflects the expansion of low-carbon activities concerning the REF and implementing new practices that permeate the public policy instruments.

Table SM1. 8. Summary of MCTI (2017) modeling process.

Reference	Parameterization data	Influencing variables and premises	Modeled variables	Spatial simulator (Model)	Scenarios	Uncertainties estimation	Projected years
MCTI (2017)	Land-use change: - Brazilian Micro-regions, States, and municipalities from IBGE; - A raster grid with 25 ha spatial resolution (500x500m); - Initial land-use map of 2012 composed by: 1) PRODES deforestation map (INPE, 2016); 2) TerraClass land-use maps (INPE, 2014); 3) Urban areas from IBGE census (IBGE, 2012); 4) Large mechanized croplands (CANASAT; INPE); 5) Maps of profitability, transport logistics, agricultural suitability, and climate favorability5; 6) Water bodies areas; 7) Protected areas and Indigenous Lands; 8) Planted areas (IBGE, 2012); 9) Planted forest (ABRAF, 2012); 10) Brazilian Federation of No-Till Farming and Irrigation (FEBRAPDP) to divide no-till farming; - Deforestation from the TNC from 2002 to 2010; - The IBGE Municipal Crop Production Survey (PAM) from 1973 to 2013; - Production projection of the main	For land-use changes: - Goals of restoration of native vegetation of the Forest Code and the National Plan for the Recovery of Native Vegetation – PLANAVEG (MMA, 2014); - Goals of reducing deforestation of the National Plan for Climate Change – PNMC (BRASIL, 2008); - Goals for low-carbon strategies of the ABC Plan (MAPA, 2012b); - Demand for biofuels, ethanol and biodiesel;	A raster grid with 0.25 km^2 spatial resolution: - Land-use change maps; - Total area by type of land use; - Deforested area; - CO2 emissions (deforestation, removals from regrowth, and planted forests and soil).	**OTIMIZAGRO** (explicit land-use model) / **DinamicaEGO**	**1) Reference scenario (REF)**: - The Political Instruments and premises described before, considering: - 80% of cultivated areas with no-till farming or ILP/ILPF (Annual increase of 400 thousand ha by 2020 and maintenance of the proportion of adoption about the agricultural area from 2020 to 2050); - Expanded goal for PLANAVEG - 16,5 million ha reforested until 2050; **2) Low carbon scenario (BC)**: - Increase of 10% of sugarcane	Not quantified	2012 to 2050

Reference	Parameterization data	Influencing variables and premises	Modeled variables	Spatial simulator (Model)	Scenarios	Uncertainties estimation	Projected years
	segments that consume fresh wood from forestry plantations of Pinus and Eucalyptus (IBÁ, 2014) - cellulose, reconstituted wood panels, sawn wood, firewood for industrial and residential use, and charcoal - associated with specific parameters (such as Gravimetric yield, native or planted wood, and Productivity). For GHG emissions: - Third National Communication biomass map, which includes all carbon pools (AGB, BGB, DW, and litter); - Pasture carbon stock = 7.57 tC/ha; Crop carbon stock = 5.00 tC/ha; Pinus forest = 87.03 tC/ha; Eucalyptus forest = 49.83 tC/ha; Perennial agriculture = 2.6 tC/ha ano; 21 tC/ha; Regeneration in agricultural areas = 4.73 tC/ha ano; Regeneration in pasture areas = 2.85 tC/ha ano; Grassland regeneration = 0.52 tC/ ha ano; Forest regeneration = 4.96 tC/ha ano; Soil carbon map; Carbon change factors the same from the TNC; Carbon removals by regeneration = 44% of original biomass.	- Demand for coal and biomass by the industrial and residential sectors. For LUUCF GHG emissions: - 55% of pasture is degraded; - contain pasture, and in ILP, 30% of the area will have the adoption of pasture with a second or even third harvest; - No removals considered for conserved forests in UC and TI.			production; - 90% of cultivated areas with no till-farming or ILP/ILPF (Annual increase of 400 thousand ha by 2020 and 200 thousand ha from 2020 to 2050); - More degraded pastures recovered; - Expansion of commercial forest plantations exclusively on low-productivity pasture areas unsuitable for large-scale mechanized agriculture		

SM1- 8. Silva Bezerra *et al*. (2022)

The scenarios created by the authors were aligned with the global Shared Socioeconomic Pathways (SSPs) and Representative Concentration Pathway (RCPs) framework developed by the global change research community to support the IPCC (Popp *et al*., 2017 *apud* Silva Bezerra *et al*., 2019).

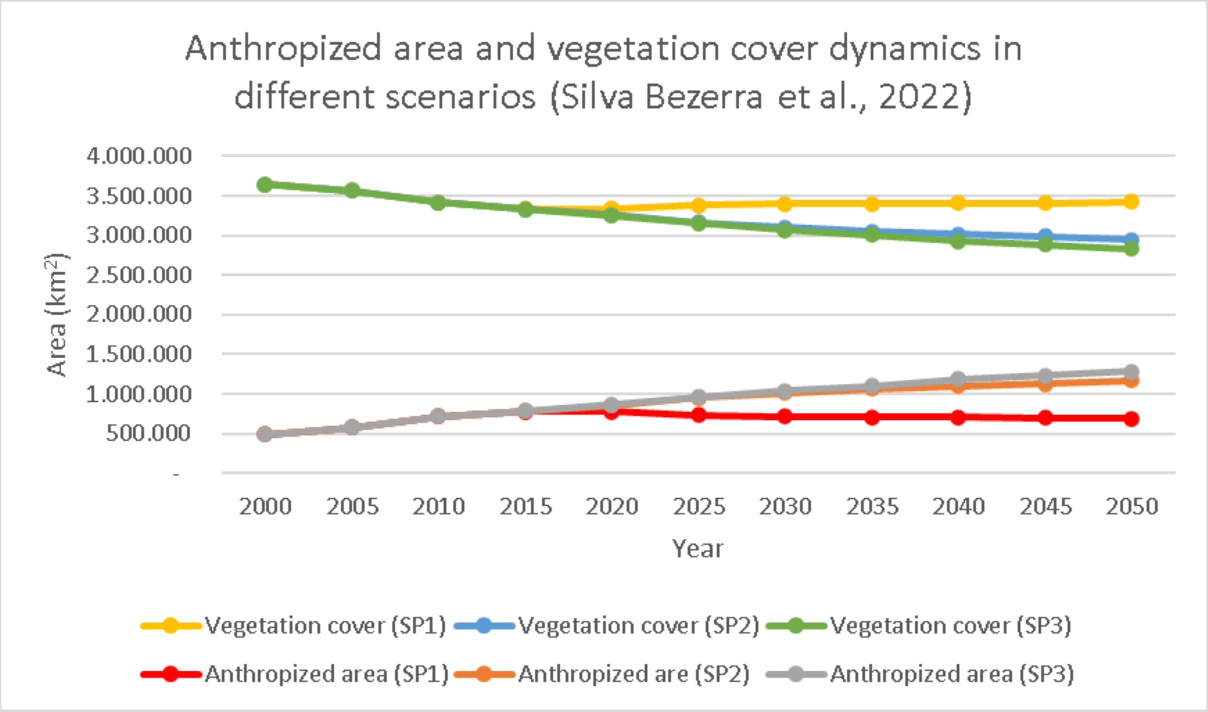
SSPs consider five different development paths for social trends to represent distinct degrees of mitigation and adaptation challenges (Table SM1. 9). The mitigation assumptions from SSP are linked to the four RCPs that represent the atmosphere's expected radiative forcing at the end of 2100 (in Wm^{-2}). The RCPs pathways are RCP1.9 (1.9 W m^{-2}), RCP2.6 (3 Wm^{-2}), RCP4.5 (4.5 Wm^{-2}), RCP6.0 (6.0 Wm^{-2}), RCP7.0 (7.0 Wm^{-2}) and RCP8.5 (8.5 Wm^{-2}). The RCP 2.6, for example, assumes a 3 Wm^{-2} peak before 2100 and a decline to 2.6 Wm^{-2} by 2100 (Silva Bezerra *et al*., 2022).

Table SM1. 9. Synthesis of core premises differentiating the SSPs concerning land use.

	SSP 1	SSP 2	SSP 3	SSP 4	SSP 5
Land-use change regulation	Strong regulation to avoid environmental tradeoffs	Medium regulation; slow decline in the rate of deforestation	Limited regulation; continued deforestation	Highly regulated in medium-income (MICs) and high-income (HICs) countries; lack of regulation in low-income countries (LICs) lead to high deforestation rates	Medium regulation, slow decline in the rate of deforestation
Land productivity growth	High improvements in agricultural productivity; Rapid diffusion of best practices	Medium pace of technological change	Low technology development	High productivity for large-scale industrial farming, low for small-scale farming	Highly managed, resource-intensive; rapid increase in productivity
Environmental Impact of Food Consumption	Low Growth in Food Consumption, Low-Meat Diets	Material-Intensive Consumption, Medium Meat Consumption	Resource-Intensive Consumption	Elites: High-consumption Lifestyles; Rest: Low Consumption	Material-Intensive Consumption
International Trade	Moderate	Moderate	Strongly constrained	Moderate	High, with regional specialization in production
Globalization	Connected markets, regional production	Semi-open globalized economy	De-globalizing, regional security	Globally connected elites	Strongly globalized
Land-based mitigation policies	No delay in international cooperation for climate change mitigation Full participation of the land-use sector	Delayed international cooperation for climate change mitigation Partial participation of the land-use sector	Heavily delayed international cooperation for climate change mitigation. Limited participation of the land-use sector	No delay in international cooperation for climate change mitigation Partial participation of the land-use sector	Delayed international cooperation for climate change mitigation Full participation in the land-use sector

Source: Popp*et al*. (2017) in Silva Bezerra *et al*., 2022.

The group used the LuccME modeling framework for the regional scenarios. Silva Bezerra *et al*. (2022) used the Integrated Model to Assess the Global Environment (IMAGE) for the global scenarios. To integrate the scales, they reclassified vegetation classes, defined the quantity of change of LuccME based on the IMAGE results for the selected combinations of SSPs and RCPs, and generated water deficit using the integrated surface process model (INLAND). The selected combinations of SSPs and RCPs were SSP1 RCP 1.9 (Sustainable development scenario), SSP2 RCP 4.5 (Middle of the road scenario), and SSP3 RCP 7.0 (Strong inequality scenario). These scenarios ranged from low to high social development and high to low environmental development (Table SM1. 9).



Source: adapted from Silva Bezerra *et al*., 2022.

Figure SM1. 7. Anthropized area and vegetation cover dynamics in different scenarios, where SP1 represents a Sustainable development scenario, SP2 represents a middle-of-the-road scenario, and SP3 refers to a strong inequality scenario.

Table SM1. 10. Summary of Silva Bezerra *et al*. (2022) modeling process.

Reference	Calibration and parameterization data	Drivers (Influencing variables) and assumptions	Modeled variables	Modeling framework	Scenarios	Uncertainties estimation	Projected years
Silva Bezerra *et al.* (2022)	Land-use and Cover Data for 2000, 2010, and 2012 from IBGE (2016) - consistent with TerraClass and Mapbiomas - to calibration	- Influence of neighboring areas (**potential and allocation**): 10 km × 10 km cells taking as base years 2000 and 2010, and considering: Agronomic aspects: - Slope (Percentage of cell area covered by slope more than 3 to 8%; 8 to 13%, 13 to 20%, 20 to 45%)6; - Agricultural Suitability (Percentage of cell area covered by low and medium-low agricultural suitability)4; - MCWDA (Maximum cumulative water deficit)2. Agrarian structure - Agricultural Establishments (Percentage of areas of agricultural establishments with 100 ha; less than 10 ha; 10 to less than 100 ha; more than 100 ha)5. Economic aspects - Paved and Unpaved Roads (Euclidean distance to the federal and state road)1; - National Markets (Connectivity index via the road network to São Paulo or Recife)3;	Maps of the spatial distribution of land use and coverage for Brazil from 2015 to 2050, in 10 x 10 km cells, with percentage of forest vegetation, grassland vegetation, managed pasture, agriculture, mosaic of occupation, and forestry	Regional Scenarios: TerraME / LuccMEBR modeling framework Global Scenarios: Integrated Model to Assess the Global Environment (IMAGE) and integrated surface process model (INLAND)	1) Sustainable development scenario (SSP1 RCP 1.9): FC enforced and even surpassed; Maintenance of the 2016 protected areas fully protected; no major federal or state roads were built after 2020; Existing settlements are maintained, and non-conventional ones (sustainable) are well protected. Inequality is reduced, and consumption is oriented toward low material growth, less resource and energy use, and healthier and less wasteful diets. 2) Middle of the road scenario (SSP2 RCP 4.5): FC measures are satisfied by compensation mechanisms (CRA) instead of local restoration; Maintenance of the 2016 protected areas fully protected but with less protection and more densely occupied areas; Ongoing paving concluded in 2025 (BR-163, BR-319, and BR-230). All paving and planned roads (Federal and State) will be built and distributed by 2025, 2030, and 2040, respectively, accompanied by measures to avoid uncontrolled occupation. Existing settlements are	The IBGE map of 2014 was used to validate the simulation. The results of the simulations were validated by the multiresolution adjustment validation metric, adapted from Costanza [33] and Pontius Jr [34]. The performance of the LuccMEBR model was 84.44% when comparing the patterns of both maps, which is considered satisfactory	2015 to 2050

Reference	Calibration and parameterization data	Drivers (Influencing variables) and assumptions	Modeled variables	Modeling framework	Scenarios	Uncertainties estimation	Projected years
		- Ports (Connectivity index via the road network to ports)3; - Railway (Euclidean distance to the railway)1; - Urban Centers (Euclidean distance to the urban centers with more than 10 thousand inhabitants, more than 100 thousand inhabitants)1; - Land demand7; - Rivers (Euclidean distance to the rivers)1. Restrictive aspects - Agricultural Settlements (Percentage of agricultural settlements without sustainable use settlements)5; - Protected Areas1; - Forest Code rules regarding the amount of legal reserve required according to the regions of the Brazilian territory were also considered.			maintained, but the non-conventional ones (sustainable) are less protected; there is a slight decrease in the use of resources and energy; population growth remains moderate. 3) Strong inequality scenario (SSP3 RCP 7.0): Forest Code is not respected, and deforestation control measures are discontinued; Decrease in the extension and level of protection of Protected Areas by 2030 and maintenance of Regularized and Approved Indigenous Land; Ongoing paving concluded in 2025 (BR-163, BR-319, and BR-230). All paving and planned roads (Federal and State) will be built and distributed by 2025, 2030, and 2040, respectively. Rural settlements are canceled, and their areas become private property. Economic development is slow; consumption is material-intensive, and the Population tends to increase.		

1- DNIT; 2 - INLAND; 3 - LUCCMEBR; 4 - MMA; 5 - IBGE; 6 - EMBRAPA; 7 - IMAGE

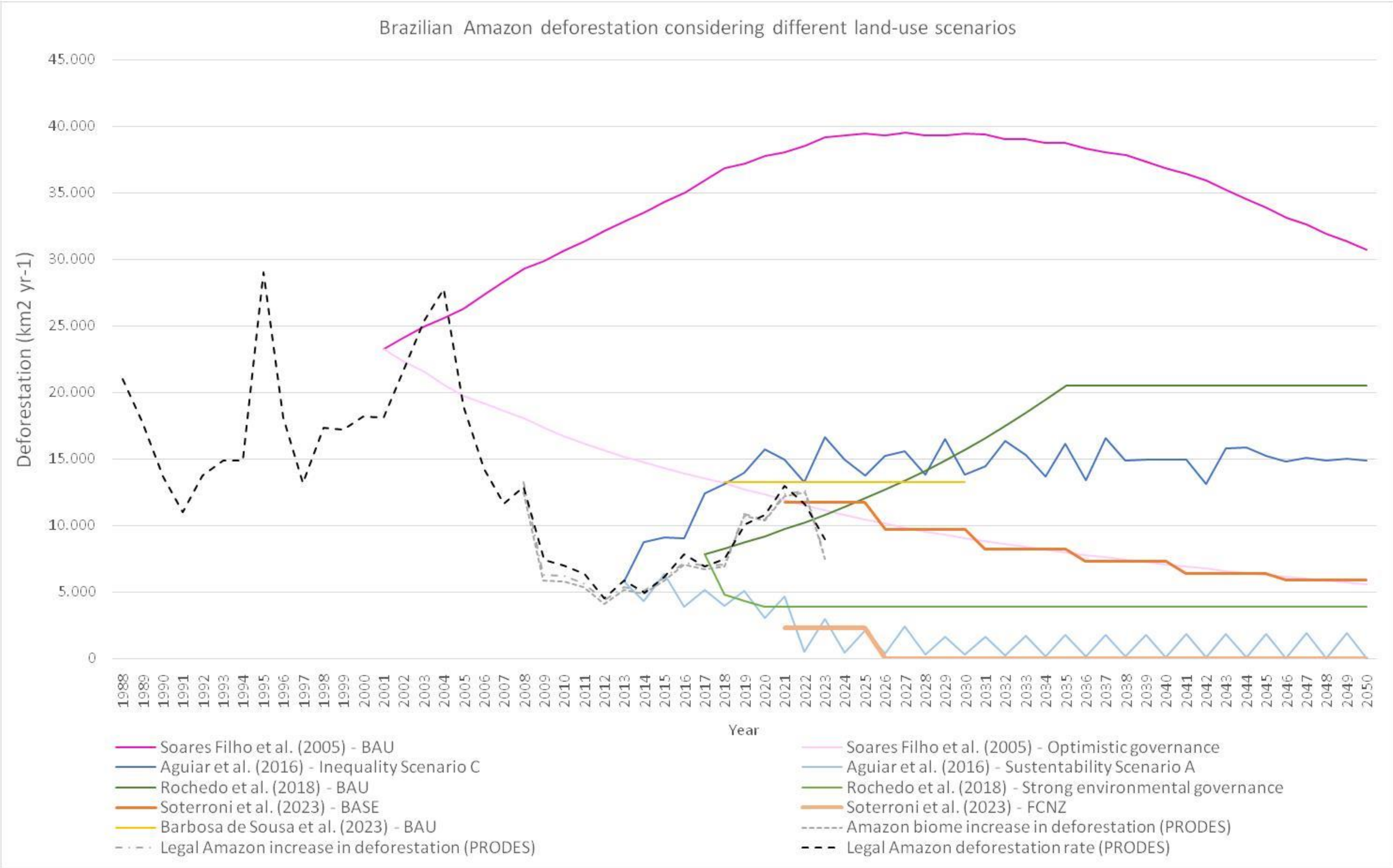


Figure SM1. 8. Amazon deforestation projections under different scenarios.

Table SM1. 11. Summary of deforestation projections in the different scenarios and PRODES.

Year	Deforestation (km2)											
	Soares Filho *et al*. (2006) - BAU	Soares Filho *et al*. (2006) – Optimistic governance	Aguiar *et al*. (2016) - Inequality Scenario C	Aguiar *et al*. (2016) – Sustentability Scenario A	Rochedo *et al*. (2018) - BAU	Rochedo *et al*. (2018) - Strong environmental governance	Barbosa de Sousa *et al*. (2023) - BAU	Soterroni *et al*. (2023) - BASE	Soterroni *et al*. (2023) - FCNZ	Legal Amazon increase in deforestation (PRODES)	Amazon biome increase in deforestation (PRODES)	Legal Amazon deforestation rate (PRODES)
1988												21.050,00
1989												17.770,00
1990												13.730,00
1991												11.030,00
1992												13.786,00
1993												14.896,00
1994												14.896,00
1995												29.059,00
1996												18.161,00
1997												13.227,00
1998												17.383,00
1999												17.259,00
2000												18.226,00
2001	23.267	23.267										18.165,00
2002	24.083	22.363										21.650,00
2003	24.965	21.552										25.396,00
2004	25.631	20.624										27.772,00
2005	26.303	19.764										19.014,00
2006	27.346	19.194										14.286,00
2007	28.360	18.656										11.651,00
2008	29.343	18.102								13.300,62	12.447,71	12.911,00
2009	29.932	17.357								6.307,32	5.902,21	7.464,00
2010	30.684	16.752								6.290,42	5.845,87	7.000,00
2011	31.396	16.187								5.691,70	5.401,89	6.418,00
2012	32.140	15.654								4.428,66	4.128,68	4.571,00
2013	32.870	15.207	5.843,00	5.843,00						5.395,59	5.152,82	5.891,00
2014	33.596	14.757	8.764,62	4.344,90						5.109,13	4.872,34	5.012,00
2015	34.322	14.320	9.130,88	6.376,15						6.117,73	5.911,51	6.207,00
2016	35.063	13.924	9.051,79	3.942,10						7.268,07	7.079,17	7.893,00
2017	36.002	13.592	12.462,45	5.195,48	7.893,00	7.893,00				6.999,85	6.757,69	6.947,00
2018	36.890	13.249	13.191,55	3.988,48	8.323,40	4.835,83	13.308,70			7.096,50	6.958,58	7.536,00
2019	37.265	12.762	14.013,54	5.109,83	8.777,26	4.352,43	13.308,70			10.895,38	10.703,25	10.129,00
2020	37.813	12.364	5.731,82	3.064,14	9.255,87	3.917,36	13.308,70			10.499,39	10.355,59	10.851,00

Year	Deforestation (km2)											
	Soares Filho *et al.* (2006) - BAU	Soares Filho *et al.* (2006) – Optimistic governance	Aguiar *et al.* (2016) - Inequality Scenario C	Aguiar *et al.* (2016) – Sustentability Scenario A	Rochedo *et al.* (2018) - BAU	Rochedo *et al.* (2018) - Strong environmental governance	Barbosa de Sousa *et al.* (2023) - BAU	Soterroni *et al.* (2023) - BASE	Soterroni *et al.* (2023) - FCNZ	Legal Amazon increase in deforestation (PRODES)	Amazon biome increase in deforestation (PRODES)	Legal Amazon deforestation rate (PRODES)
2021	38.125	11.943	4.983,22	4.660,09	9.760,58	3.917,36	13.308,70	11.775	2.355,08	12.416,00	12.192,66	13.038,00
2022	38.594	11.561	3.330,31	536,58	10.292,82	3.917,36	13.308,70	11.775	2.355,08	12.695,47	12.481,13	11.594,00
2023	39.236	11.221	16.674,52	3.012,85	10.854,07	3.917,36	13.308,70	11.775	2.355,08	7.665,86	7.505,25	9.001,00
2024	39.377	10.857	14.960,81	457,94	11.445,93	3.917,36	13.308,70	11.775	2.355,08			
2025	39.512	10.518	13.809,84	2.179,30	12.070,06	3.917,36	13.308,70	11.775	2.355,08			
2026	39.381	10.179	15.260,14	383,07	12.728,23	3.917,36	13.308,70	9.724	0,14			
2027	39.579	9.889	15.614,31	2.429,28	13.422,28	3.917,36	13.308,70	9.724	0,14			
2028	39.358	9.601	13.832,52	346,32	14.154,18	3.917,36	13.308,70	9.724	0,14			
2029	39.402	9.334	16.501,04	1.654,82	14.925,99	3.917,36	13.308,70	9.724	0,14			
2030	39.474	9.095	13.841,38	309,00	15.739,89	3.917,36	13.308,70	9.724	0,14			
2031	39.451	8.859	14.469,84	1.691,07	16.598,16	3.917,36	13.308,70	8.262	0,07			
2032	39.092	8.635	16.417,12	263,85	17.503,24	3.917,36	13.308,70	8.262	0,07			
2033	39.052	8.420	15.343,46	1.736,68	18.457,67	3.917,36	13.308,70	8.262	0,07			
2034	38.804	8.218	13.750,39	220,76	19.464,14	3.917,36	13.308,70	8.262	0,07			
2035	38.779	8.027	16.159,34	1.777,48	20.525,50	3.917,36	13.308,70	8.262	0,07			
2036	38.397	7.831	13.412,89	190,14	20.525,50	3.917,36	13.308,70	7.319	0,04			
2037	38.121	7.650	16.580,98	1.810,32	20.525,50	3.917,36	13.308,70	7.319	0,04			
2038	37.886	7.481	14.917,77	166,84	20.525,50	3.917,36	13.308,70	7.319	0,04			
2039	37.388	7.303	15.019,34	1.832,78	20.525,50	3.917,36	13.308,70	7.319	0,04			
2040	36.871	7.131	15.003,56	134,63	20.525,50	3.917,36	13.308,70	7.319	0,04			
2041	36.477	6.971	14.970,18	1.866,02	20.525,50	3.917,36	13.308,70	6.383	0,01			
2042	35.959	6.811	13.187,16	111,50	20.525,50	3.917,36	13.308,70	6.383	0,01			
2043	35.236	6.658	15.823,61	1.888,35	20.525,50	3.917,36	13.308,70	6.383	0,01			
2044	34.592	6.502	15.892,08	93,15	20.525,50	3.917,36	13.308,70	6.383	0,01			
2045	33.954	6.356	15.281,86	1.907,07	20.525,50	3.917,36		6.383	0,01			
2046	33.167	6.208	14.878,71	78,56	20.525,50	3.917,36		5.893	0,00			
2047	32.627	6.067	15.120,95	1.921,36	20.525,50	3.917,36		5.893	0,00			
2048	31.918	5.921	14.908,18	59,48	20.525,50	3.917,36		5.893	0,00			
2049	31.368	5.783	15.086,91	1.941,27	20.525,50	3.917,36		5.893	0,00			
2050	30.780	5.643	14.890,06	50,34	20.525,50	3.917,36		5.893	0,00			

Link to supplementary material: https://drive.google.com/drive/folders/1f-VRDjdE_pC5j50i3cQdHq9FuhXecn52?usp=drive_link

Setor		1990		2005		2025		2030	
Energia [1]		194	14%	332	16%	598	44%	688	57%
Agropecuária		356	25%	484	23%	470	35%	489	40%
Florestas e Uso da Terra [2]	Emissão	826	58%	1.398	66%	392	29%	143	12%
	Remoção			211	10%	274	20%	274	23%
	Líquido			1.187	56%	118	9%	-131	-11%
Processos Industriais [3]		48	3%	77	4%	98	7%	99	8%
Tratamento de Resíduos [4]		12	1%	54	3%	61	5%	63	5%
Total		**1.436**		**2.133**		**1.346**		**1.208**	
Redução em relação à 2005						**37%**		**43%**	

Fonte: elaboração própria a partir de MCT (2010) e MMA (2015).

Source: Fundamentals for preparing the Intended Nationally Determined Contribution (iNDC) of Brazil in the context of the Paris Agreement under the UNFCCC. Available on: https://antigo.mma.gov.br/images/arquivos/clima/convencao/indc/Bases_elaboracao_iNDC.pdf. Accessed on: 25 May 2024.

Figure SM1. 9. Emissions by Sector (in millions of tCO_2e – GWP - 100)

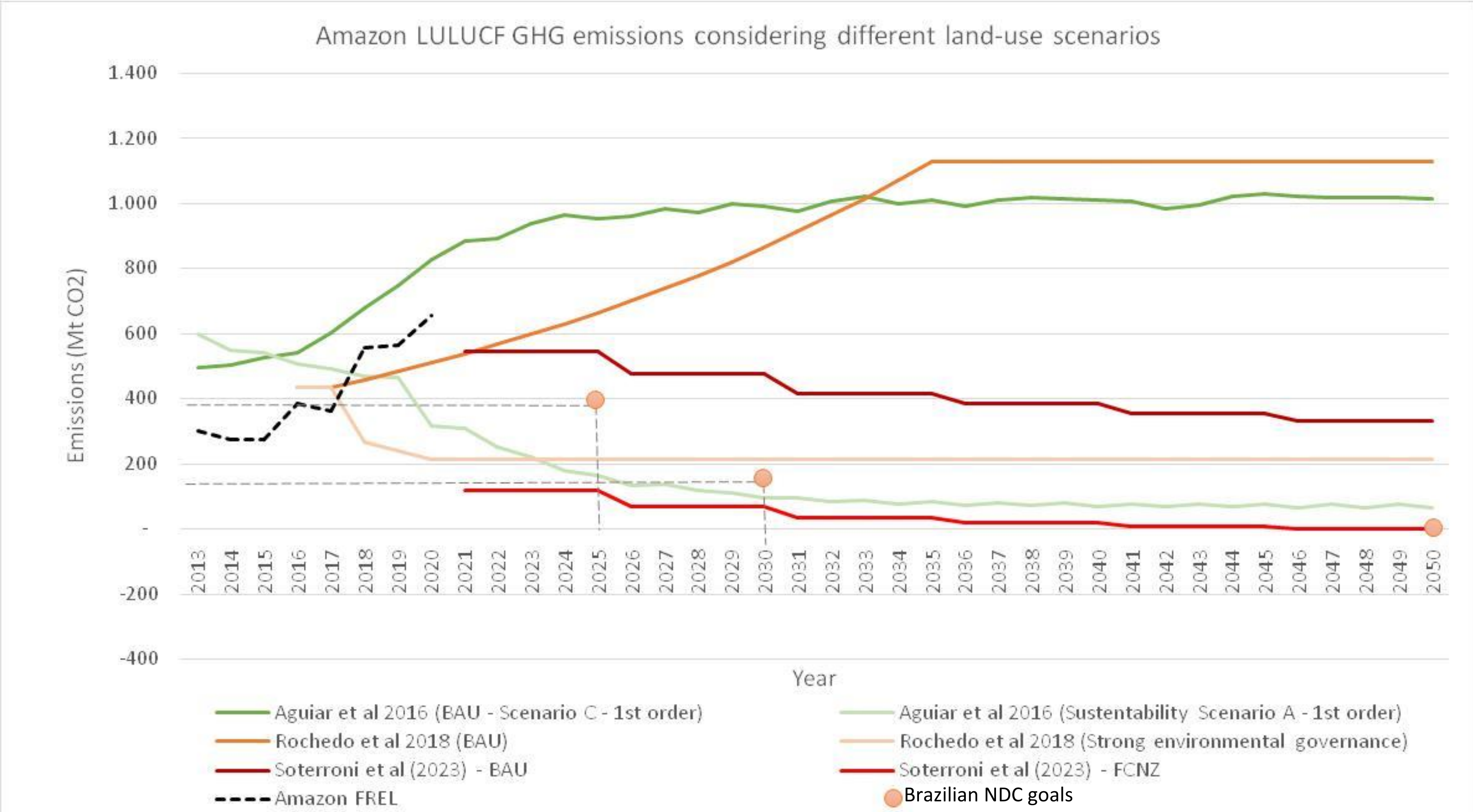


Figure SM1. 10. Brazilian Amazon LULUCF GHG emissions considering different land-use scenarios.

Table SM1. 12. Summary of GHG emissions projections in the different scenarios

GHG emissions (MtCO2e)						
Aguiar *et al.* (2016) - BAU - Scenario C - 1st order	**Aguiar *et al.*, (2016) - Sustentability Scenario A - 1st order**	**Rochedo *et al*. (2018) - BAU**	**Rochedo *et al*. (2018) - Strong environmental governance**	**Soterroni *et al.* (2023) - BAU**	**Soterroni *et al.* (2023) - FCNZ**	**Amazon FREL**
						908,96458
						1334,4583
						1375,2241
						1380,1422
						1163,8791
						576,13673
						609,10148
						669,21506
						373,06646
						362,50709
						285,50779
						236,68415
443	443,00					301,84785
453	392,00					273,5916
479	382,00					273,5916
494	348,00	434,12	434,12			386,23377
557	330,00	434,12	434,12			360,73603
633	293,00	457,79	265,97			557,82242
701	275,00	482,75	239,38			565,49622
782	112,00	509,07	215,45			657,2879
838	76,00	536,83	215,45	545,89	119,57	
844	- 13,00	566,10	215,45	545,89	119,57	
890	- 55,00	596,97	215,45	545,89	119,57	
916	- 110,00	629,53	215,45	545,89	119,57	
903	- 142,00	663,85	215,45	545,89	119,57	
911	- 184,00	700,05	215,45	477,61	69,77	
933	- 196,00	738,23	215,45	477,61	69,77	
922	- 229,00	778,48	215,45	477,61	69,77	
946	- 249,00	820,93	215,45	477,61	69,77	
938	- 280,00	865,69	215,45	477,61	69,77	
932	- 281,00	912,90	215,45	414,44	34,94	
960	- 308,00	962,68	215,45	414,44	34,94	
972	- 303,00	1.015,17	215,45	414,44	34,94	
948	- 314,00	1.070,53	215,45	414,44	34,94	
958	- 307,00	1.128,90	215,45	414,44	34,94	
938	- 318,00	1.128,90	215,45	384,18	20,32	
956	- 310,00	1.128,90	215,45	384,18	20,32	
962	- 320,00	1.128,90	215,45	384,18	20,32	
956	- 312,00	1.128,90	215,45	384,18	20,32	
953	- 322,00	1.128,90	215,45	384,18	20,32	
950	- 313,00	1.128,90	215,45	353,19	6,60	
925	- 323,00	1.128,90	215,45	353,19	6,60	
937	- 314,00	1.128,90	215,45	353,19	6,60	
964	- 324,00	1.128,90	215,45	353,19	6,60	
970	- 314,00	1.128,90	215,45	353,19	6,60	
962	- 325,00	1.128,90	215,45	329,92	0,74	
958	- 315,00	1.128,90	215,45	329,92	0,74	
955	- 326,00	1.128,90	215,45	329,92	0,74	
955	- 315,00	1.128,90	215,45	329,92	0,74	
953	- 326,00	1.128,90	215,45	329,92	0,74	

SM2- 1. The National Policy for the Recovery of Native Vegetation (PROVEG)

The National Policy for the Recovery of Native Vegetation (PROVEG) aims to integrate, articulate, and promote actions, programs, and policies that induce the recovery of forests and endorse the environmental regularization of rural properties in at least 12 million hectares by 2030. Article 7 establishes the National Committee for Native Recovery (CONAVEG), which coordinates the implementation, monitoring, and evaluation of PROVEG (Brasil, 2017a).

The main instrument of its implementation is the National Plan for the Recovery of Native Vegetation (PLANAVEG), launched through Interministerial Ordinance no 230/2017 (Brasil, 2017b, 2017c).

PLANAVEG mentions a platform to plan and monitor the vegetation recovery process. It was supposed to generate or store spatial information as land cover and use maps, maps of areas with potential for recovery of native vegetation, degraded land with low agricultural potential, and degraded land suitable for agroforestry and forestry and field data. It also references possible partners such as INPE, MMA, MAPA, MCTI, Embrapa, state and municipal governments, the University of São Paulo (USP), and research institutions with experience in spatial modeling, remote sensing, and data processing, non-governmental organizations, and the private sector (Brasil, 2017d).

SM2- 2. The Forest Code

The Forest Code creates the Rural Environmental Registry (CAR) under the National Information on Environment (SINIMA) (Brasil, 2012a) The Forest Code establishes general norms on the protection of vegetation, such as Permanent Preservation Areas (APP)[58] and Legal Reserve areas (RL)[59]; forest exploitation; the supply of forest raw materials; control of the origin of forest products; and the control and prevention of forest fires and provides economic and financial instruments for achieving its objectives. It creates the Rural Environmental Registry (CAR) under the

[58] APP are forests and other forms of natural vegetation that are located among rivers, lakes, springs, and hilltops.
[59] RL is an area of rural property dedicated to protecting vegetation cover. If located within the Legal Amazon, the RL should represent 80% of a property in a forest area, 35% in the Cerrado area and 20% in grasslands. It should represent 20% of the property in other regions of the country.

National Information on Environment (SINIMA) [60] to integrate environmental information from rural properties and possessions, composing a database for control, monitoring, environmental and economic planning, and combating deforestation. The Environmental Regularization Programs (PRA) comprise the actions or initiatives developed by landowners and/or rural owners to adapt and promote the environmental regularization of their rural properties (Brasil, 2012a).

Registration in the CAR is mandatory for all rural properties in the country and represents the first step toward environmental regularization. CAR provides spatial variables related to the RL areas, the APP areas, and the Environmental Reserve Quota[61] (CRA).

The state environmental agencies are responsible for promoting the validation of CAR and PRA submissions. States that do not have their CAR system can use the Registration Module, available at the National Rural Environmental Registry System (SiCAR) through the Brazilian Forest Service, launched in 2012[62]. SiCAR provides satellite images with a special resolution of 5 meters to the technical performance of landowners' CAR. In the cases of states with their systems, updating all the information in the SiCAR once this is the official federal database is fundamental.

SM2- 3. The National System for Conservation Units (SNUC)

Created in 2000, the National System for Conservation Units (SNUC) provides the criteria and norms for developing, implementing, and managing conservation units, constituted by the set of federal, State, and municipal conservation units. Its objective includes maintaining the national territory's biological diversity and genetic resources, protecting endangered species, contributing to the preservation and restoration of the diversity of natural ecosystems, and promoting sustainable development, among others (Brasil, 2000).

National Environmental Council (CONAMA) is the advisory and deliberative body that monitors the implementation of the System, while MMA is the central body

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[60] SINIMA it is one of the instruments of the National Environmental Policy (Law nº 6.938/81). It is the conceptual platform based on the integration and sharing of information between the various existing systems or to be built within the scope of the National Environmental System (SISNAMA). SINIMA, therefore, is the instrument responsible for organizing, integrating, sharing and making available environmental information.

[61] CRA represents an area with native vegetation existing or in the process of recovery that exceeds the legal requirements in the same biome.

[62] More information about SiCAR on: https://www.car.gov.br/#/

that coordinates the System. The executing bodies are represented by the Chico Mendes Institute (ICMBio) and the Brazilian Institute for the Environment and Renewable Natural Resources (Ibama) - on a supplementary basis, the state and municipal bodies, with the function of implementing the SNUC, subsidizing the creation proposals and administering the federal, State and municipal conservation units, in the respective spheres of action (Brasil, 2000).

SNUC divides the conservation units into Integral Protection Units[63] and Sustainable Use Units[64] (Brasil, 2000).

SM2- 4. The National Policy for Territorial and Environmental Management of Indigenous Lands (PNGATI)

The National Policy for Territorial and Environmental Management of Indigenous Lands (PNGATI) is related to Article 84 of the Brazilian Constitution (Brasil, 1988) and Convention No. 169 of the International Labor Organization (OIT) (Brasil, 2019b). PNGATI aims to ensure and promote the protection, recovery, conservation, and sustainable use of natural resources in Indigenous territories and lands and to "ensure the integrity of Indigenous assets, improve quality of life, and guarantee that the current and future generations of Indigenous peoples are fully capable of physical and cultural reproduction, respecting their socio-cultural autonomy, in terms of the legislation in force" (Brasil, 2012b). Ethno-mapping[65] and ethno-zoning[66] are tools for PNGATI, and its governing bodies are the PNGATI Management Committee, the National Foundation of Indigenous Peoples (FUNAI) Regional Committees, and the National Indigenous Policy Commission (CNPI).

FUNAI is the official body that organizes the spatial information related to indigenous land[67]. It must approve the identification and delimitation of areas occupied by indigenous peoples and update this information monthly.

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[63] Integral Protection Units include Ecological Station; Biological Reserve; National Park; Wildlife Refuge; Natural Monument.

[64] Sustainable Use Units include Environmental Protection area; Area of Relevant Ecological Interest; National Forest; Extractive reserve; Fauna Reserve; Sustainable Development Reserve; Private Natural Heritage Reserve.

[65] Ethno-mapping: participatory mapping in areas of environmental, socio-cultural,and productive relevance for indigenous peoples, based on their knowledge.

[66] Ethno-zoning: participatory planning instrument aimed at categorizing areas of environmental, socio-cultural, and productive relevance for indigenous peoples, developed from ethno-mapping

[67] More information on: https://www.gov.br/funai/pt-br/atuacao/terras-indigenas/geoprocessamento-e-mapas

SM2- 5. Quilombola Territories

Quilombola territories are lands occupied by remnants of Quilombola communities that are used to guarantee their physical, social, economic, and cultural reproduction. Quilombola communities are the ethnic-racial groups, according to criteria of self-attribution, with their historical trajectory endowed with specific territorial relations, with the presumption of black ancestry related to the resistance to the historical oppression suffered (Brasil, 2003). Self-identification aligns with the international Human Rights norm, Convention 169 of OIT (Brasil, 2019d), which considers conscience a key criterion.

Ministry of Agrarian Development (MDA), through the National Institute of Colonization and Agrarian Reform (INCRA), is responsible for identifying, recognizing, delimiting, demarcating, and entitling the lands occupied by the remnants of Quilombola communities, without prejudice to the concurrent competence of the States, the District Federal and Municipalities. In addition to INCRA, the Secretariat of Union Assets (SPU) is also responsible for issuing titles or Contract of Concession of Real Rights of Use to Quilombola communities located in areas of its management. It is up to the States and Municipalities to issue the titles to the Quilombola communities on state and municipal domain lands, respectively (INCRA, 2017).

The states of Pará, Bahia, Maranhão, Mato Grosso do Sul, Piauí, Rio de Janeiro, São Paulo, Mato Grosso, Goiás, Espírito Santo, Sergipe, Rio Grande do Sul, and Santa Catarina have specific laws to regularize Quilombola territories (INCRA, 2017). Spatial information regarding Quilombola territories can be accessed on INCRA's land collection website, which can also be downloaded as a shapefile[68]. Nonetheless, it is worth mentioning that there are a lot of Quilombola territories that have not been securitized yet.

SM2- 6. The management of public forests for sustainable production

Under forest concession granted by the Union, State, Federal District, or Municipality, the public forest could be sustainably managed to obtain economic, social, and environmental benefits, respecting the sustaining mechanisms of the ecosystem under management and considering the use of multiple timber species,

[68] More information on: https://certificacao.incra.gov.br/csv_shp/export_shp.py

multiple non-timber products and by-products, as well as the use of other goods and services of a forestry nature (Brasil, 2006; MAPA, 2019).

These concessions should be recorded in the National Registry of Public Forests (CNFP), linked to the National System of Rural Registry (SNCR[69]), and integrated by the General Registry of Public Forests of the Union (CGFPU) and by the registries of Public Forests in the States, the Federal District, and the Municipalities.

SFB uses for monitoring federal forest concessions: production control, wood tracking, and remote sensing systems using satellite images and flyovers; detailed validation, in the field, of the implementation and conduction of all forest concession activities; assessment through experimental plots of the dynamics of forest development and possible impacts on biodiversity; and the evaluation of the external impacts of the forest concessions concerning the environmental, social and economic aspects of the areas of influence of the bidding areas.

The database has been available annually from 2008 to 2020, and it comprehends information from FUNAI (Indigenous Lands), ICMBio and MMA (Federal Conservation Units), and INCRA (settlement projects and non-allocated land collected). Public forests under the control of the Ministry of Defense and the Armed Forces are also being incorporated.

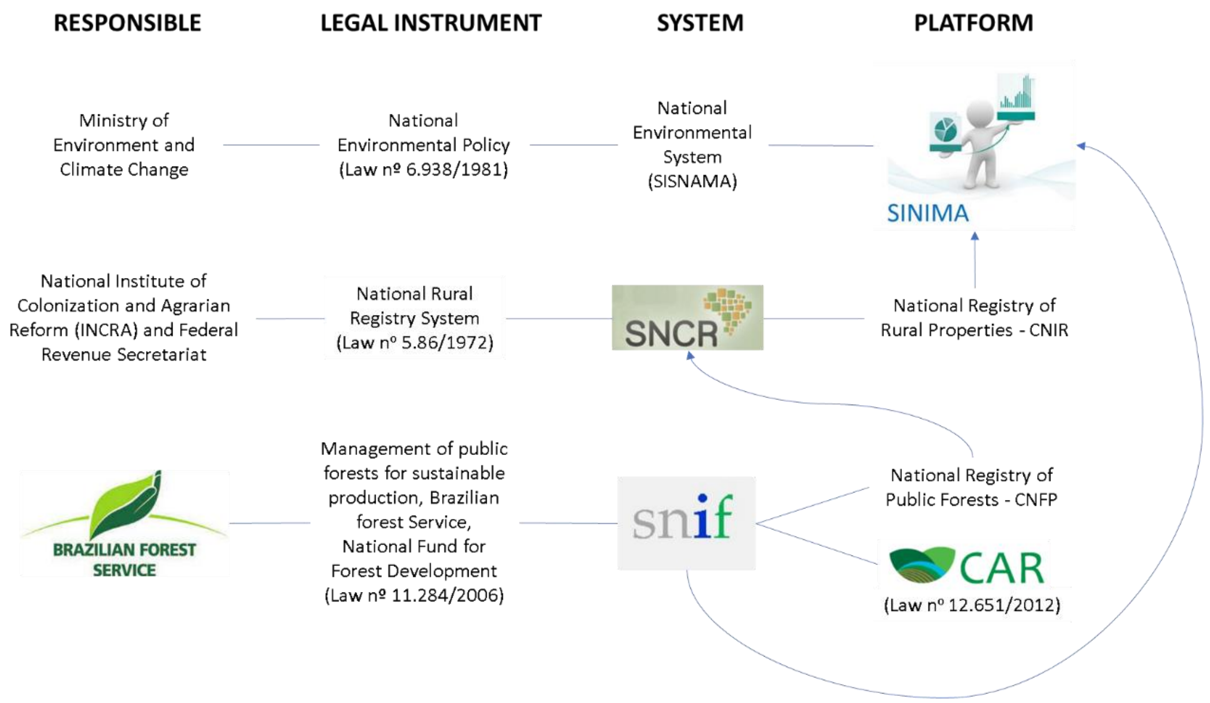
The registration of public forests follows three stages:

1) Identification: mapping of forests located in public areas;
2) Delimitation: registration of the forest perimeter next to the registration of the public property and
3) Demarcation: implantation of topographic landmarks and placement of informative plaques in the field.

The CNFP divides forests into three types:

a) Type A (FPA): forests with a specific destination and domain, such as nature conservation units, indigenous lands, public rural settlements, military areas, and other destination forms provided by law. They are intended for the protection and conservation of the environment and the use of traditional communities;
b) Type B (FPB): the forests located in areas collected by the Public Power but which have not yet been destined;
c) Type C (FPC): forests located in areas of an undefined domain, commonly called vacant lands.

[69] SNCR comprises the registration of rural properties; register of Owners and Holders of Rural Properties; Registration of Tenants and Rural Partners; Registry of Public Lands and the National Registry of Public Forests.



Source: own production.

Figure SM2. 1. Platforms related to the management of public forests for sustainable production.

According to the SFB website [70], in 2020, a total area of 1,050 million hectares of public forests was under federal forest concession. This area corresponds to 18 forest management units in six national forests in the Rondônia (RO) and Pará (PA) states. Three are in the Jamari National Forest (RO), four in the Saracá-Taquera National Forest (PA), two in the Jacundá National Forest (RO), two in the do Crepori (PA), four in the Altamira National Forest (PA) and three in the Caxiuanã National Forest (PA).

SM2- 7. ABC Plan

Among the six programs related to mitigation actions from 2010 to 2020, the ones that reflect on the LULUCF sector emissions and removal are the recovery of 15 million hectares of degraded pastures, the expansion of the integrated crop-livestock-forest system by 4 million hectares (ILPF) and Agroforestry systems (SAF); the expansion of the practice of no-till farming in 8 million hectares; and expansion of forest planting in 3 million hectares (Brasil, 2012c; MAPA, 2013). The indicators of

[70] More information on forest concessions: https://www.gov.br/agricultura/pt-br/assuntos/servico-florestal-brasileiro/concessao-florestal/concessoes-florestais-em-andamento-1

results proposed for each program (considering just those related to the LULUCF sector) were: i) recovered pasture area, ii) area implanted with ILPF and SAFs, iii) area managed under the no-tillage and iv) area implanted with forests (Brasil, 2012c) (Table SM2. 1).

Creating a Multi-institutional System for Climate Change and Agriculture was foreseen for systematic monitoring and periodic progress assessments toward commitments (Brasil, 2012c) (Table SM2. 2).

The ABC Plan presents the technological processes, the relative national commitments (increase in adoption or use), and the potential of mitigation for reducing GHG emissions (millions of Mg CO_2 eq) (Table SM2. 3).

Table SM2. 1. ABC Plan's technological process, commitments, removal factor, and mitigation potential.

Technological process	Commitment (millions of ha)	Removal factor (Mg de CO_2 eq.ha-1. year-1)	The potential of mitigation (millions of Mg CO_2 eq)
Recovery of degraded pastures	15	3.79[1]	83 to 104
CLFI (considering SAFs)	4	3.79[1]	18 to 22
No-tillage	8	1.83[1]	16 to 20
Forest plantation	3	Unaccounted for	-

Source: Adapted from ABC Plan (Brasil, 2012c). [1] No reference presented.

Table SM2. 2. Initial products and responsibilities under the ABC Plan.

Product	Responsible and partners
Mapping degraded pastures and/or areas with low productive potential	MAPA, the old Ministry of Agrarian Development (MDA), MMA, and the National Institute for Space Research (INPE)
Elaborate and implement the pasture zoning in the Legal Amazon	Embrapa, MMA, old MDA, and Strategic Affairs Secretariat (SAE)
Mapping areas with potential for ILPF implementation	MDA, MMA, INPE, and state governments
Mapping areas with the potential for implementing SAFs	MAPA, MMA, INPE, and state governments
Mapping strategic regions for the implementation of the no-tillage	MAPA, old MDA, MMA, INPE, and state governments
Mapping areas with the potential for planting forests	MAPA, old MDA, MMA, INPE, and state governments

Source: Adapted from tables on pages 84, 97, 109, and 129 from Brasil, 2012c.

Table SM2. 3. Technological process, the goals achieved between 2010 and 2018 compared to the commitment until 2020 (%), the factors applied, and the mitigation performed until 2018 compared to 2020 under the ABC Plan.

Technological process	Expansion of adoption in period (millions of ha)	Source of data	Commitment until 2020 (millions of ha) (% achieved concerning goal)	Default emission factor and National Literature Emission Factor (Reference) (Mg de CO_2 eq. ha-1. year-1)	Mitigation until 2018 / Predicted until 2020 (% achieved concerning goal) (millions of Mg CO_2 eq)
Recovery of degraded pastures	3,31	Areas financed by the ABC Program from the Brazilian Central Bank (BACEN, in the Portuguese acronym) from 2010 to 2018	15 (22%)	3,79 (BRASIL, 2012) [1]	12,54 to 18,23 / 83 to 104 (13 to 20%)
	10,44	Estimates the expansion of well-managed pasture areas, obtained through the animal stocking rate (> 5 animals/hectare) based on Municipal Agricultural Research (PAM, in the Portuguese acronym) data from the Brazilian Institute of Geography and Statistics (IBGE, in the Portuguese acronym), as proposed by Azevedo *et al*. (2018) from 2010 to 2017	15 (70%)	5,50 (Bustamante *et al*., 2006)	39,57 to 57,52 / 83 to 104 (42 to 62%)
ILPF (considering SAFs)	5,83	Sample survey, carried out by the ILPF Network Association and ABC Platform from 2010 to 2016	4 (146%)	3,79 (BRASIL, 2012) and 6,24 (Carvalho *et al*. 2010)	22,11 to 36,40 / 18 to 22 (111 to 182%)
No-tillage	12,72	2010 to2017 Agricultural Census	8 (159 %)	1,83 (Cerri *et al*., 2007)	23,28 / 16 to 20 (129 %)
Forest plantation	0,634	Carbon fixation in plant biomass of the expansion area financed directly by the ABC Program from 2013 to 2018	3 (21%)	3,89 (Bustamante *et al*., 2015)	25,37 / N.E.
		Fixation of carbon in the soil promoted by the areas financed directly by the ABC Program from 2013 to 2018		0,80 (Lima *et al*., 2006)	0,54 / N.E.
	0,130	Fixation of carbon in the soil promoted by the expansion of the planting of other forest essences (rubber tree, acacia, teak, paricá, araucaria, populus, and others) estimated by Brazilian Tree Industry (IBÁ, in the Brazilian acronym) from 2013 to 2018	3 (4%)	0,80 (Lima *et al*., 2006)	0,65 / N.E.

Source: adapted from tables 6, 7, 8, 10, 11, 12 and 14 from Embrapa, 2020. [1]Reference not identified. N.E. = not estimated.

SM2- 8. ABC +

"Sectorial Plan for Adaptation to Climate Change and Low Carbon Emissions in Agriculture, with a view to Sustainable Development (2020-2030) - ABC+", or in its short form "Plan for Adaptation and Low Carbon Emissions in Agriculture - ABC+," it is a national strategic agenda of the Brazilian government that gives continuity to the sectoral policy to face climate change in the agricultural sector (Brazil, 2022).

We focus on the ABC+ pillar to maintain and expand Sustainable Production Systems, Practices, Products and Processes (SPSABC). Agroforestry Systems (SAF), together with the Integrated Crop-Livestock-Forestry Systems (ILPF), are in ABC+ and are named "Integrated Systems" (IS). Practices for Recovery of Degraded Pastures (PRPD) now consider the recovery and renewal of pastures with some degree of degradation (Brazil, 2022). In addition to the goals of its first phase under the ABC plan between 2010 and 2020, the ABC+ plan includes the following goals until 2030 in the LULUCF sector: 30 million ha of recovered pasture; 12,5 million ha with no-tillage; 10 million ha with ILPF; 0,10 million of ha with SAFs and 4 million ha with reforestation (Table SM2. 4).

Table SM2. 4. ABC+ goals between 2020 and 2030.

Technology	**Technology**	**Goal (in million ha)**	**Mitigation goal (in million Gg CO_2 eq)**
Practices for Recovery of Degraded Pastures (PRPD)[1]	Practices for Recovery of Degraded Pastures (PRPD)[1]	30	113,70[2]
No-Tillage System (NTS)	No-Tillage System for Grain Production	12.50[3]	12,11[4]
Integrated Systems (IS)	Integrated Crop-Livestock-Forestry (ILPF)	10.0[5]	37.90[6]
Integrated Systems (IS)	Agroforestry Systems (SAF)	0.10	0.38[7]
Commercial Forestry	Commercial Forestry	4.00	510.00[8]

Source: Adapted from Table 2 in Brazil, 2022. [1]Considering recovery or reclaiming degraded pastures; [2]Considering a default emission/removal factor of 3,79 Mg CO2eq ha-1 ano-1 (IPCC, 2006); [3]Considering 4.5 million hectares in NTS and 8.0 million hectares in no-tillage; [4]Considering C sequestration rates of 1,75 Mg C ha-1 year -1 for NTS and 0,53 Mg C ha-1 year -1 for, no-tillage; [5]Considering 1 million hectares with tree species; [6]Considering emission/ removal factor of 33,79 Mg CO_2eq ha-1 year-1 (Carvalho *et al.,* 2010); [7]Considering default emission/ removal factor of 3,79 Mg CO_2 eq ha-1 year-1 (IPCC, 2006); [8]Considering default emission/removal factor for eucalyptus, pine and other commercial tree species (IPCC, 2006).

The methodology to monitor ABC+ results should be approved by the ABC Plan Integrated Information System (SINABC), which will interact with the Technical Committee to monitor the Plan ABC (CTABC). Embrapa should also stimulate the creation of a public-private collaborative network to monitor GHG mitigation actions and operationalize the ABC Platform (Brasil, 2021).

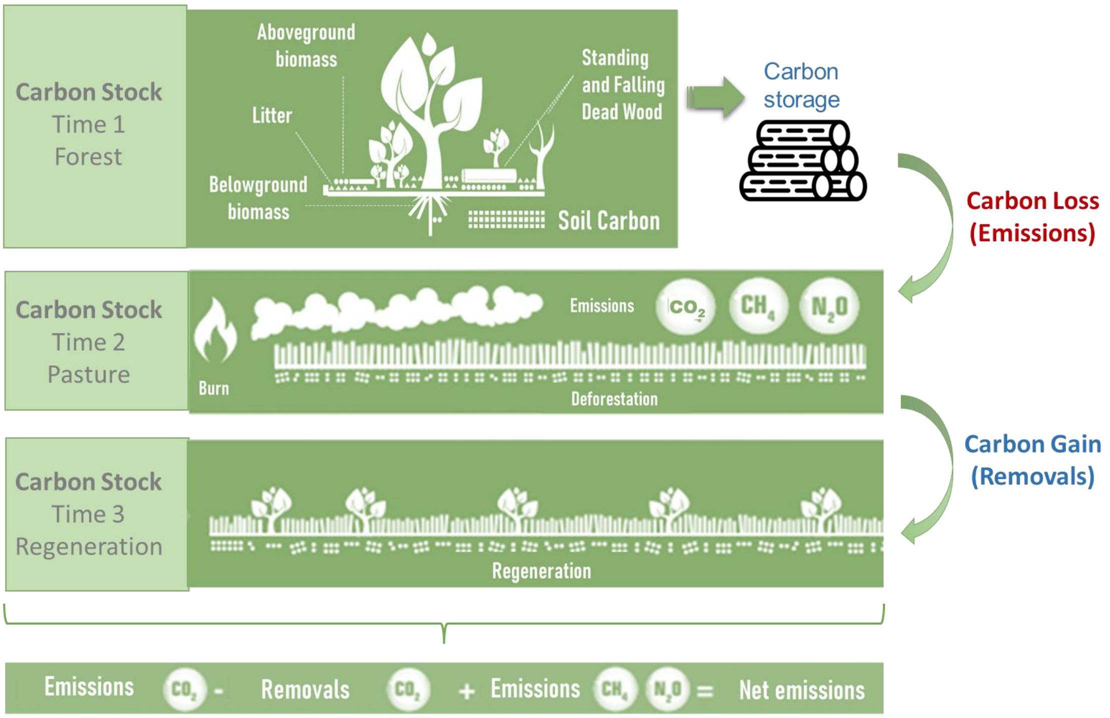
SM2- 9. LULUCF 4th National GHG Inventory

During the 4th National GHG Inventory, the LULUCF sector counted on a specialist in the MCTI team and with the Brazilian Climate Change Research Network (Rede Clima) technical-scientific coordination – in LULUCF case, the University of Brasília (UnB). During the inventory development, through the CIM, each ministry pointed out its focal points to follow up on elaboration.

MCTI hired a company (chosen by an open selection process) that had updated the activity data (i. e., land cover and use maps) for 2016 and estimated the emissions and removals associated with each land use conversion from 1990 to 2016. Emission and removal factors, as other necessary information for the estimates, were organized and provided by Rede Clima specialists with MCTI LULUCF specialist support. Embrapa Florestas[71] developed the Harvest Wood Products (HWP) estimates based on the IPCC 2006 atmospheric flow approach (IPCC, 2006; Brazil, 2021).

The 4th National GHG Inventory followed the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). Thus, for estimating the land use emissions and removals, the carbon stock difference between initial land cover/use and final land cover/user was estimated (Figure SM2. 2). For this, it is necessary to have information regarding carbon stock variations in different Brazilian types of vegetation and other land uses (such as pasture and agriculture), considering the different pools required by IPCC (above and below-ground living biomass and dead organic matter – standing and falling deadwood and litter).

[71] Embrapa Florestas. Available on: https://www.embrapa.br/florestas/apresentacao. Accessed on: 22 April 2022.



Source: adapted from SIRENE, 2023.

Figure SM2. 2. Example of estimation of GHG emissions and removals estimation by different land use conversions.

The land use and cover maps used for the 4th National GHG Inventory were for 1994, 2002, 2005 (only Amazon biome), and 2010 – from the previous inventories - and updated for 2016. The land-use classes considered were Managed Forest (within a protected area, i. e. Conservation Unit or Indigenous Land), Unmanaged Forest, Secondary Forest, Selective Logging (for the Amazon biome only), Reforestation, Managed Grassland (within a protected area), Unmanaged Grassland, Secondary Grassland, Pasture, Agriculture, Settlements, Wetlands, Artificial Reservoirs, Rock, Sand Dunes, Exposed Soil, Mining, and Unobserved Areas (clouds and/or shadows in satellite imagery). Complementary data on land use were used as crop type areas (annual or perennial) by state for each year mapped (for a breakdown of the Agriculture for the years prior to 2016); planted forest area by species and state (for a breakdown of the Reforestation); area by state and type of planting system (conventional or no-tillage) (for factors of organic carbon change in the soil); area per state of pasture conditions (natural, planted under good conditions, planted under poor conditions) (for factors of organic carbon change in the soil) (Brazil, 2021).

Considering Brazilian biodiversity and extension, the carbon stock maps were produced by biome to represent better the carbon stock variations in its territory vegetation, considering an adapted map of past natural vegetation. For the Brazilian Amazon, the 4th National GHG Inventory used data from one of the most relevant airborne laser data collected for the Brazilian Amazon, developed by a research group at INPE, referenced as Amazon Biomass Estimate (EBA) (Ometto *et al*., 2023). For the other biomes, a literature review of scientific papers was carried out to associate carbon values with different vegetation types.

Data on stock/removal from biomass in pastures, croplands, secondary vegetation, and protected natural vegetation were obtained from scientific literature; in some cases, IPCC default values were used (IPCC, 2006). Categories such as Settlements, Exposed Soil, Mining, Artificial Reservoirs, Sand Dunes, and Rock had their carbon stock associated with zero.

The soil carbon map followed the methodology proposed by Bernoux *et al*. (2002), with adaptations on the soil map of Brazil (Embrapa, 2003) at a scale of 1:5,000,000 and the vegetation map of Brazil (IBGE, 2004) on a scale of 1:5,000,000 for generating the soil-vegetation association map – more details in MCTI, 2020. Factors of organic carbon change in the soil were obtained from data from national field data for reforestation, croplands (no-till planting vs. conventional planting), and pastures (natural/planted under good conditions/planted under poor conditions/severely degraded pastures) (Brazil, 2021).

To annualize estimates, gross vegetation emissions were adjusted based on available deforestation rates by biome; removals by protected natural formations were annualized based on the date of creation of UCs or TIs, and the removals from other land use, and cover conversions were distributed equally for each year of the period, as well as the emissions and removals from the soil. Secondary vegetation growth removals were considered just in the first conversion (i. e., if a pasture in 2002 is identified as regeneration in 2010 and 2016, the removals are accounted for just in the first period, after the conversion, because of the lack of information between the two maps and the gap in information regarding forest regrowth). Estimates for non-CO_2 gases (CH_4, N_2O, CO, and NO_x) were based on the natural vegetation converted for an anthropogenic use, discounting the removal of some of the original biomass in the form of firewood for the manufacture of furniture or use as fuel (Brazil, 2021; MCTI, 2020).

According to the IPCC, a country must estimate anthropogenic emissions and removals only in “managed areas”, i.e., those with relevant ecological, economic, and/or social interests (IPCC, 2006). For the National GHG Inventory, beyond areas identified as pasture, agriculture, reforestation, and secondary vegetation, CO_2 removals were also accounted for protected natural vegetation within a Conservation Unit or Indigenous Land (Brazil, 2021; MCTI, 2020).

The National Communications and GHG Inventories, Sector Reference Reports, and emissions results are presented in the National Emissions Registration System (SIRENE)[72] (Brasil, 2017d).

SM2- 10. The Amazon and Other Biomes Monitoring Program (PAMZ+)

The Amazon and Other Biomes Monitoring Program (PAMZ+) was developed by the Earth Observation and Geoinformatics Division (DIOTG) at the Amazon Space Coordination (COEAM) at INPE. PAMZ+ comprises three operational systems (PRODES, DETER, and TerraClass) to monitor changes in land cover use through satellite images, as described below.

The Satellite Monitoring Program of the Brazilian Amazon Forest (PRODES)

Since 1988, PRODES has monitored the advance of deforestation by clear-cutting in the Legal Amazon[73]. The program was expanded, and the annual loss of primary vegetation in all Brazilian biomes (Amazônia, Cerrado, Mata Atlântica, Caatinga, Pampa, and Pantanal) was systematically monitored. PRODES uses Landsat-like images (NASA/USGS), which range in spatial resolution from 20-30 meters and have at least three available spectral bands (green, red, and infrared) within the electromagnetic spectrum. PRODES currently uses images from Landsat-8, SENTINEL-2 (European Union), and CBERS-4/4A (INPE/CRESDA, Brazil/China) (INPE, 2019).

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[72] SIRENE. Available on: http://sirene.mctic.gov.br/. Accessed on 12 March 2023.

[73] The Brazilian Legal Amazon was created as a political concept aimed at regional planning and development through law 1,806 of 01/06/1953, amended subsequently by law 5,173 of 10/27/1966 and by complementary law 31 of10/11/1977. It occupies an area that corresponds to 59% of the Brazilian territory and encompasses a total of eight states (Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima and Tocantins) and part of the State of Maranhão (west of the meridian44ºW), totaling 5.0 million km² (INPE, 2019).

Forestlands are classified according to the RADAMBRASIL project (1976) for the Amazon. To exclude areas that do not belong to this domain, at the beginning of PRODES, the INPE team mapped the “non-forest” area, which is not considered in the systematic mapping carried out in PRODES to this day. The non-forest area occupies about 961,000 km². INPE does not analyze the legality of the suppression and/or degradation; it only quantifies and spatializes these occurrences (INPE, 2019).

For the Legal Amazon, PRODES Amazônia only identifies polygons of deforestation by clear-cutting (removal of complete primary forest cover) whose area exceeds 6.25 ha. In an image to be analyzed, areas may not be observed due to cloud cover. These areas must be considered when calculating the estimated increment for each image. In cases of high cloud cover, images from multiple satellites (or dates) can compose a location (INPE, 2019).

It is assumed that most deforestation occurs during the dry season. Due to the large extension of the Legal Amazon, the dry season varies depending on the region. The date of the dry season for that location was established for each image based on climatological parameters. To provide an annualized rate of deforestation in an image, the deforestation increments are designed for a standard reference date. Considering the large number of images whose dry season is between June and September, August 1 (Julian Day 211) was the reference date for calculating annualized rates. The PRODES Amazônia year, or deforestation calendar year, refers to the period that runs from August 1st of one year to July 31st of the following year. For example, the rate published for PRODES 2019 estimates the deforestation between 08/01/2018 and 07/31/2019 (INPE, 2019).

An exclusion mask also includes areas with no natural occurrence of forests, called “non-forest” in PRODES Amazônia, and hydrographic areas mapped as deforestation (INPE, 2019).

For the other biomes, the minimum área considered is 1ha, and the methodology is similar to that applied for the PRODES Amazônia.

Near Real-Time Deforestation Detection System (DETER)

Near Real-Time Deforestation Detection System (DETER), launched in 2004, is a system to support the inspection and control of deforestation and degradation in the Legal Amazon. DETER identifies and maps deforested and/or degraded areas in tropical forest formations in the Amazon. DETER's coverage area is the Legal Amazon, like PRODES (INPE, 2019).

Since 2015, DETER has used images from the WFI sensor onboarding CBERS-4, CBERS-4A/INPE, and Amazônia-1/INPE satellites (56-64 meters of spatial resolution). Photointerpreters map deforestation and forest degradation using color composite satellite images in addition to soil and shadow fraction images generated through Linear Spectral Mixture Models (LSMM), which highlight, respectively, image features related to selective logging and burning scars. Forest cover pattern identification in images is based on five main elements: tonality, color, form, texture, and context.

DETER produces change alerts daily in forest cover for areas larger than 3 hectares. Alerts from DETER are divided into two groups: i) deforestation classified as deforestation with exposed soil, deforestation with vegetation, and mining, and ii) degradation alerts classified as degradation: selective geometric logging, selective logging, and forest fire scar.

Land Use and Occupation Mapping System Project (TerraClass)

The Terraclass project was launched in 2010 for the Legal Brazilian Amazon and since 2020 in the Cerrado biome. The TerraClass project is developed and executed by INPE's Amazon Regional Center (CRA) in partnership with the Brazilian Agricultural Research Corporation (Embrapa). It qualifies deforestation previously mapped and published by the PRODES[74]. Terraclass minimum mapping area is 4 ha, used to generate data every two years.

Through visual interpretation of color composites and application of remote sensing techniques (such as Linear Spectral Mixture Models, segmentation, cloud detection, and threshold slicing) to Landsat satellite images (30 m of spatial resolution), Terraclass classifies areas identified as deforestation in PRODES into primary forest, secondary forest, silviculture, cultivated pasture on shrubland, cultivated pasture on herbaceous land, perennial agricultural crop, semi-perennial agricultural crop, temporary agricultural crop, mining, urban areas, 'others', not observed area, current year deforestation, non-forest vegetation, and hydrography within the Brazilian Legal Amazon.

[74] More information on: http://www.inpe.br/cra/projetos_pesquisas/dados_terraclass.php

In the Cerrado biome, deforestation is qualified as secondary forest, silviculture, cultivated pasture, perennial agricultural crop, semi-perennial agricultural crop, one cycle temporary agricultural crop, over one cycle temporary agricultural crop, mining, urban areas, other edified areas, others, not observed, annual deforestation, and hydrography. All data are presented in the TerraBrasilis portal[75].

SM2- 11. National Forest Inventory (NFI)

The National Forest Inventory (NFI)[76] is one of the primary surveys carried out by the federal government to produce information on Brazilian forest resources. The National Forest Service (SFB) is responsible for this initiative. One of the differentials of the NFI is the collection of data directly in the forests – natural and planted – including the collection of botanical and soil samples, the measurement of the trees, and the carrying out of interviews with the residents of the vicinity.

With national coverage and a unique methodology for all biomes, data is collected at points distributed every 20 km across the country. Detailed and regular information is produced on the structure, composition, health, and vitality of forests, biomass, wood, and carbon stocks. The proposal is that the study be carried out periodically, with the measurements repeated in the same places. With this, monitoring changes in these aspects over time will also be possible.

The NFI sampling system consists of sampling points with a distribution according to a national grid established by the SFB. The sampling intensity of the inventory is defined by the distance between the points on the NFI National Grid of Sampling Points over a given territory, which determines the number of points to be visited, which may vary according to the application objectives of the NFI. NFI's sampling process for data collection considers environmental changes that may occur over time. For this, all sampling points will be revisited in a proposed cycle of five years.

The biophysical data to be collected in the conglomerates are directly related to forest resources, such as soil, necromass, litter, classes of land use, and vegetation, which will serve as a basis for obtaining more complex information about the main attributes of the forest in the different regions of the country.

[75] TerraBrasilis portal. Available on: https://terrabrasilis.dpi.inpe.br/. Accessed on 21 March 2023.
[76] More information on: https://www.gov.br/agricultura/pt-br/assuntos/servico-florestal-brasileiro/ifn-inventario-florestal-nacional

Table SM2. 5. Activity data and emission and removal factors to achieve a transparent and complete environmental MRV for LULUCF mitigation activities.

Policy / Program / Plan	Quantitative goals	Activity Data Needed	Official database	Emission / Removal factor	Source for Emission / Removal factor
PNMC / PPCDAm / PPCerrado	Reduction of 36,1% and 38,9% of project emissions for 2020 An 80% reduction in annual deforestation rates in the Legal Amazon, about the average verified between 1996 and 2005. Reduction of 40% of the annual deforestation rates in the Cerrado biome concerning the standard confirmed between the years 1999 and 2008	All the ones related here. Deforested areas in the Amazon and Cerrado	National GHG Inventory (SIRENE) PRODES	All the ones related here. Vegetation and other land-use carbon stocks	All the ones related here. Rede Clima Network Land-Use subnet; NIF; Scientific papers
Updated NDC	Reduction of GHG by 48.4% by 2025, 53.1% until 2030, related to 2005, and neutrality by 2050	All the ones related here	National GHG Inventory (SIRENE)	All the ones related here	All the ones related here
PNMC / PROVEG / PLANAVEG	Restoring and reforesting 12 million hectares of forests by 2030	Secondary vegetation areas	TerraClass	Removal from different types of secondary vegetation, considering age and land-use history	Scientific papers, NIF
PNMC / ABC Plan	Recovery of 15 million hectares of degraded pastures by 2020	Recovered pasture area	IBGE; AGROTAG[77]; Pasture Atlas (Lapig)[78]	Carbon soil map and factor of carbon loss; pasture AGB and BGB stocks considering	Embrapa Solos soil carbon map; Scientific papers, compilations carried

[77] The AgroTag System includes the application and the WebGIS online interface, and allows partner users to quickly access data collected in the field.The geospatial database enables access to spatial information to carry out integrated online consultations and analyses, with generation of maps and automatic reports. More information: https://www.agrotag.cnptia.embrapa.br/#!/

[78] The Pasture Atlas is a tool developed by the Image Processing and Geoprocessing Laboratory (Lapig/UFG), to make data related to Brazilian pastures accessible online and free of charge. More information: https://atlasdaspastagens.ufg.br

Policy / Program / Plan	Quantitative goals	Activity Data Needed	Official database	Emission / Removal factor	Source for Emission / Removal factor
				different stages of degradation	out by MAPA; Carbscan[79]
	Expansion of the crop-livestock-forest integration system (ILPF) and SAFs by 4 million hectares by 2020	Area implanted with ILPF and SAFs	AGROTAG; ILPF Network; SATVEG[80]	SAFs and ILPF AGB and BGB stocks and increment	ILPF Network
	Expansion of the practice of no-tillage system planting in 8 million hectares by 2020	Area managed under no-tillage system	IBGE; AGROTAG	Soil carbon emission and removal factors	Embrapa Solos
	Expansion of forest planting in 3 million hectares by 2020	Reforestation area, considering age and species	TerraClass	Factor of soil carbon gain/loss; reforestation AGB and BGB gain considering different species	Embrapa Florestas
ABC+	Recovery of 30 million hectares of degraded pastures between 2020 and 2030	Recovered pasture area	AGROTAG; Pasture Atlas (LAPIG)	Carbon soil map and factor of carbon loss; pasture AGB and BGB stocks considering different stages of degradation	Embrapa Solos soil carbon map; Scientific papers, compilations carried out by MAPA
	Expansion of the practice of grain no-tillage system planting in 12,5 million hectares between 2020 and 2030	Area of grain managed under no-tillage system	IBGE; AGROTAG; SATVEG	Gain and loss soil carbon factors	Embrapa Solos
	Expansion of the crop-livestock-forest integration system (ILPF) by 10 million hectares between 2020 and 2030	Area implanted with ILPF	AGROTAG; ILPF Network; SATVEG	ILPF AGB and BGB stocks and increment	Embrapa, ILPF Network
	Expansion of the SAFs by 0,1 million hectares between 2020 and 2030	Area implanted with SAFs	AGROTAG; SATVEG	SAFs AGB and BGB stocks and increment	Embrapa

[79] The Multi-sensor Collection and Analysis System for Carbon Estimation (CARBSCAN) was developed to organize, analyze and make available the information compiled and collected within the scope of monitoring Low Carbon Agriculture. More information: https://www.embrapa.br/meio-ambiente/plataforma-abc/carbscan

[80] SATVeg - Vegetation Temporal Analysis System - is a web tool developed by Embrapa Agricultura Digital, intended for accessing and viewing temporal profiles of NDVI and EVI vegetative indices from the MODIS sensor in any location in South America. Regularly updated, SATVeg provides the user with a Google Maps interface for locating areas of interest, tools for filtering time series, modules for loading vector files, among other features. More information: https://www.satveg.cnptia.embrapa.br/satveg/login.html

Policy / Program / Plan	Quantitative goals	Activity Data Needed	Official database	Emission / Removal factor	Source for Emission / Removal factor
	Expansion of forest planting in 4 million hectares between 2020 and 2030	Area implanted with forests.	TerraClass	Carbon removals per year for each species or vegetation type	Rede Clima Network Land-Use subnet; NIF; Embrapa Florestas
SNUC	Expand the scale of sustainable management systems for native forests through georeferencing and traceability systems applicable to the management of native forests to discourage illegal and unsustainable practices.	Municipalities, State and Federal Conservation Units, and Managed plans with the intensity of exploration allowed.	CNUC	Carbon removals per year for each vegetation type on the different biomes	Rede Clima Network Land-Use subnet; NIF
PNGATI	Expand the scale of sustainable management systems for native forests through georeferencing and traceability systems applicable to the management of native forests to discourage illegal and unsustainable practices.	TI land	FUNAI	Carbon removals per year for each vegetation type on the different biomes	Rede Clima Network Land-Use subnet; NIF
Quilombolas territories	Expand the scale of sustainable management systems for native forests through georeferencing and traceability systems applicable to the management of native forests to discourage illegal and unsustainable practices.	Quilombola land	INCRA	Carbon removals per year for each vegetation type on the different biomes	Rede Clima Network Land-Use subnet; NIF
Forest Code	Zero illegal deforestation by 2030 in the Brazilian Amazon, compensating for legal suppression of vegetation by 2030; Strengthen compliance with the Forest Code at the federal, state, and municipal levels.	APP, LR, CRA for all the territory	SiCAR	Carbon removals per year for each vegetation type on the different biomes	Rede Clima Network Land-Use subnet; NIF
Management of public forests for sustainable production	Expand the scale of sustainable management systems for native forests through georeferencing and traceability systems applicable to the management of native forests to discourage illegal and unsustainable practices	Forest Concessions: Managed plans with the intensity of exploration allowed	SNIF	Carbon removals per year for each vegetation type on the different biomes	Rede Clima Network Land-Use subnet; NIF

Source: own production

Table SM2. 6. Participants on LULUCF National GHG Inventories elaboration.

Coordination	Inventory WG Member	Participation scope
LULUCF Coordinator CGCL (MCTI)	IBGE	• Biomes, States, municipalities limits • Vegetation map • Well-managed pasture areas • Areas with no-tillage
	ICMBio	• Natural managed lands (UC)
	FUNAI	• Natural managed lands (TI)
	INCRA	• Natural managed lands (Quilombola territories)
	SFB	• Private areas (SiCAR) • National Forest Inventory (NFI) • Forest Management and Concession Areas (SNIF)
	INPE*	• Deforestation activity data (PRODES) • Land-Use activity data (TerraClass) • Degradation activity data (DETER) • Amazon emission and removal factors (CCST/EBA) • Amazon degradation emission and removal factors and emission and removal estimation • Deforestation emission and removal estimation for all biomes • Natural managed lands removal estimation • Support to regeneration removals estimate to PLANAVEG
	IPLF Network	• ILPF activity data, removal factors, and removal estimates
	MMA	• PLANAVEG activity data, removal factors, and removal estimates
	BACEN	• Areas financed by the ABC Program
	Rede Clima	• GIS team to intermediate processing
	LAPIG*	• Pasture Atlas
	Embrapa*	• AGROTAG, SATVEG, Carscan for ABC Plan estimation
	EmbrapaFlorestas*	• HWP activity data, emission and removal factors, and estimates
	UnB*	• Cerrado emission and removal factors, including degradation
	UFPE*	• Caatinga emission and removal factors • Mata Atlântica emission and removal factors (Northeast)
	ESALQ/USP*	• Mata Atlântica emission and removal factors (Southeast)
	UNICAMP*	• Mata Atlântica emission and removal factors (Southeast)
	UFPR*	• Mata Atlântica emission and removal factors (South)
	UFRGS*	• Pampa emission and removal factors
	Embrapa Pantanal*	• Pantanal emission and removal factors
	Embrapa solos*	• Soil carbon reference map • Removal and emission factors for pasture regeneration
	MAPA	• ABC plan activity data, emission and removal factors, and estimates, supported by Embrapa

*It should be part of the Rede Clima Land-Use subnet.; Source: own production.

Table SM2. 7. Official database improvements to achieve a complete and transparent environmental MRV to LULUCF mitigation actions.

Official database	Summary of methodology and data available	Possible technical and data availability improvements
Vegetation map	The better vegetation map available is from 2017 with a 1:250.000 scale, but it also considers anthropogenic areas.	To have a reference vegetation map of Brazil in a 1:250.000 scale
PRODES Amazonia	Experts' interpretation Minimum area 6.25 ha Annually from 1988 to 2022	The current methodology could be enhanced, considering automatization.
PRODES Cerrado	Experts' interpretation Minimum area 1 ha Biannually from 2001 to 2022	
PRODES Mata Atlântica	Experts' interpretation Minimum area 1 ha Biannually from 2001 to 2022	
PRODES Caatinga	Experts' interpretation Minimum area 1 ha Biannually from 2001 to 2022	Data from Cerrado, Mata Atlântica, Caatinga, Pampa, and Pantanal must be produced since 1990 to be applied to the National GHG Inventory.
PRODES Pampa	Experts' interpretation Minimum area 1 ha Biannually from 2001 to 2022	
PRODES Pantanal	Experts' interpretation Minimum area 1 ha Biannually from 2001 to 2022	
DETER	Experts' interpretation Minimum area 3 ha 2016, 2017, 2020, 2021	The historical series should begin in 1990 for the Amazon and Cerrado biomes.
TerraClass Amazonia	Experts' interpretation Minimum area 3ha 2004, 2008, 2010, 2012	The current methodology could be enhanced, considering automatization. Data must be produced biannually since 1990 for all biomes to be applied to the National GHG Inventory. Also, with this data, it would be possible to classify secondary vegetation by age, which is essential for PLANAVEG monitoring and removal estimation.
TerraClass Cerrado	Experts' interpretation Minimum area 3ha 2014 and 2018	
TerraClass Mata Atlântica, Caatinga, Pampa and Pantanal	Not available	
NFI carbon stock estimation	The database is now open access, and the reports must match the needs of the National GHG Inventory.	Carbon estimation should consider the same methodology as the 4th National GHG Inventory (IPCC, 2006).
Soil carbon map	The 4th National GHG Inventory is still applying a methodology that does not present the best information that we could have regarding carbon soil stocks.	Embrapa Solos could advance the preparation of a carbon soil stock map for reference in the following National GHG Inventories.

Source: own production

Table SM3. 1.REDD+ private projects in Pará.

Project	Carbon credits issued
Cercarbono	**9,223,377**
Carbono Verde Afforestation Project	5,188,727
Rio Jacareacanga REDD+ Project	4,034,650
VCS	**31,249,439**
ABC Norte REDD Project	421,51
Cikel Brazilian Amazon REDD APD Project Avoiding Planned Deforestation	2,823,810
Ecomapua Amazon REDD Project	2,071,291
Floresta Verde REDD+ Project	941,618
Jari/Pará REDD+ Project	900,752
Maísa REDD+ Project	634,948
Pacajai REDD+ Project	10,060,355
Rio Anapu-Pacaja REDD Project	6,307,759
RMDLT Portel - Para REDD Project	7,087,396
Total	**40,472,816**

Source: Verified Carbon Standard (VCS) e Cercarbono (2024), organized by UNDP (2024).

Table SM3. 2. Issued annual credit for REDD+ private projects in Pará.

Year	Carbon credits issued (tCO_2-e)		
	VCS	Cercarbono	Total
2012	100	0	100
2013	20	0	20
2014	14,5	0	14,5
2015	775,638	0	775,638
2016	593,634	0	593,634
2017	277,847	0	277,847
2018	803,559	0	803,559
2019	2,168,567	0	2,168,567
2020	7,031,710	0	7,031,710
2021	18,105,236	0	18,105,236
2022	588,078	0	588,078
2023	770,67	9,223,377	9,994,047
Total	**31,249,439**	**9,223,377**	**40,472,816**

Source: Verified Carbon Standard (VCS) e Cercarbono (2024), organized by UNDP (2024).