Land use transitions on degraded pasture lands in Brazil: balancing biomass-based mitigation and biodiversity protection

Framing of the Study

By reconciling **global conventions** with **Brazilian legislation**, we assess how the **restorative uses of degraded pasture lands** in Brazil can contribute to **ecosystem restoration, climate regulation and biomass production.**

Technical approach

- Spatially explicit crop growth modeling (CAT), life cycle assessment (LCA) following ISO standards, and carbon sequestration calculations based on biome-specific biomass accumulation curves.
- Quantification methods integrate satellite-based land cover maps, biodiversity prioritization tools, and carbon accounting to evaluate restoration and bioenergy scenarios.
- Finally, an integrated analysis of the results support a multifunctional landscape approach, balancing ecological restoration, biomass production, and sustainable development goals.

Data Acquisition

- **Degradation Assessment:** Pasturelands were classified by vegetative vigor (low = severely degraded, medium = less degraded) using MapBiomas 2023 data.
- **Spatial Data Sources:** Land use and vegetation maps from IBGE, MapBiomas, and public databases; Indigenous and Quilombo lands from FUNAI and INCRA; Protected Areas from CNUC; Priority biodiversity areas from MMA.
- **Deforestation & Riparian Zones:** Deforestation mapped as any native vegetation converted to pasture after 2008; riparian zones identified by buffering 500 meters from watercourses (ANA 2012).
- **Restoration Prioritization:** Priority areas for native vegetation restoration selected using PlanGea, a modeling platform maximizing biodiversity and climate benefits while minimizing costs.
- **Purpose:** To evaluate the distribution of degraded areas and propose multifunctional landscape recovery strategies, including but not limited to native vegetation restoration.

Policy and Regulatory Selection

1. Comprehensive review of Brazilian policy and regulatory documents.

2. Selection was guided by conventions and multilateral environmental agreements to which Brazil is a signatory (e.g., the Brazilian Biosafety Law).

3. Six key documents were chosen for their relevance to conservation, restoration, and biomass production:

- RenovaBio (Biofuels Law) – expands biofuels in the energy matrix.
- Forest Code – protects native vegetation.
- Ministry of Environment Ordinance – updates priority areas for biodiversity.
- System of Protected Areas – defines conservation units.
- Biosafety Law – restricts GMOs near protected areas.
- Plan for Native Vegetation Restoration – implements national restoration policy.

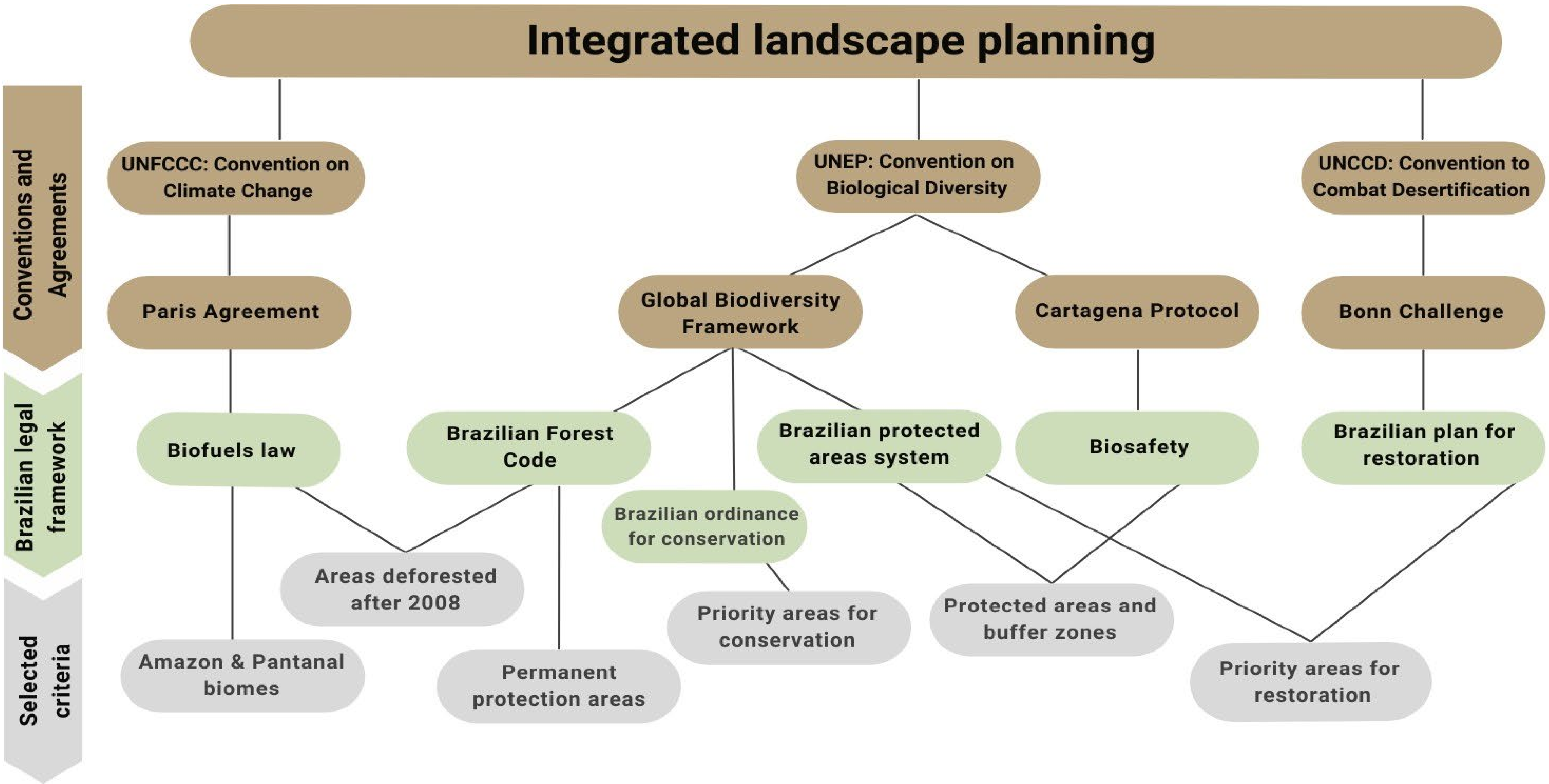
These documents form the legal backbone for identifying and managing degraded lands.

Legal Criteria for Land Designation

The following criteria were applied to select areas for native vegetation restoration:

- Native vegetation restoration is prioritized for areas with legal or illegal deforestation after 2008, aligning with the Forest Code and Soy Moratorium.
- Biomass production is only allowed on land deforested before 2017 (per RenovaBio), excluding Amazon and Pantanal biomes from certification.
- Protected Areas (PAs) include indigenous and quilombo territories, with a 3 km buffer zone as per CONAMA resolution.
- Environmental Protected Areas (APA) and Private Natural Heritage Reserves (RPPN) are excluded from buffer requirements and GMO restrictions.

This ensures that restoration and biomass production respect both national law and ecological priorities.


Integrated landscape planning
Conventions and Agreements
Brazilian legal framework
Selected criteria
UNFCCC: Convention on Climate Change
UNEP: Convention on Biological Diversity
UNCCD: Convention to Combat Desertification
Paris Agreement
Global Biodiversity Framework
Cartagena Protocol
Bonn Challenge
Biofuels law
Brazilian Forest Code
Brazilian protected areas system
Biosafety
Brazilian plan for restoration
Brazilian ordinance for conservation
Areas deforested after 2008
Priority areas for conservation
Protected areas and buffer zones
Amazon & Pantanal biomes
Permanent protection areas
Priority areas for restoration

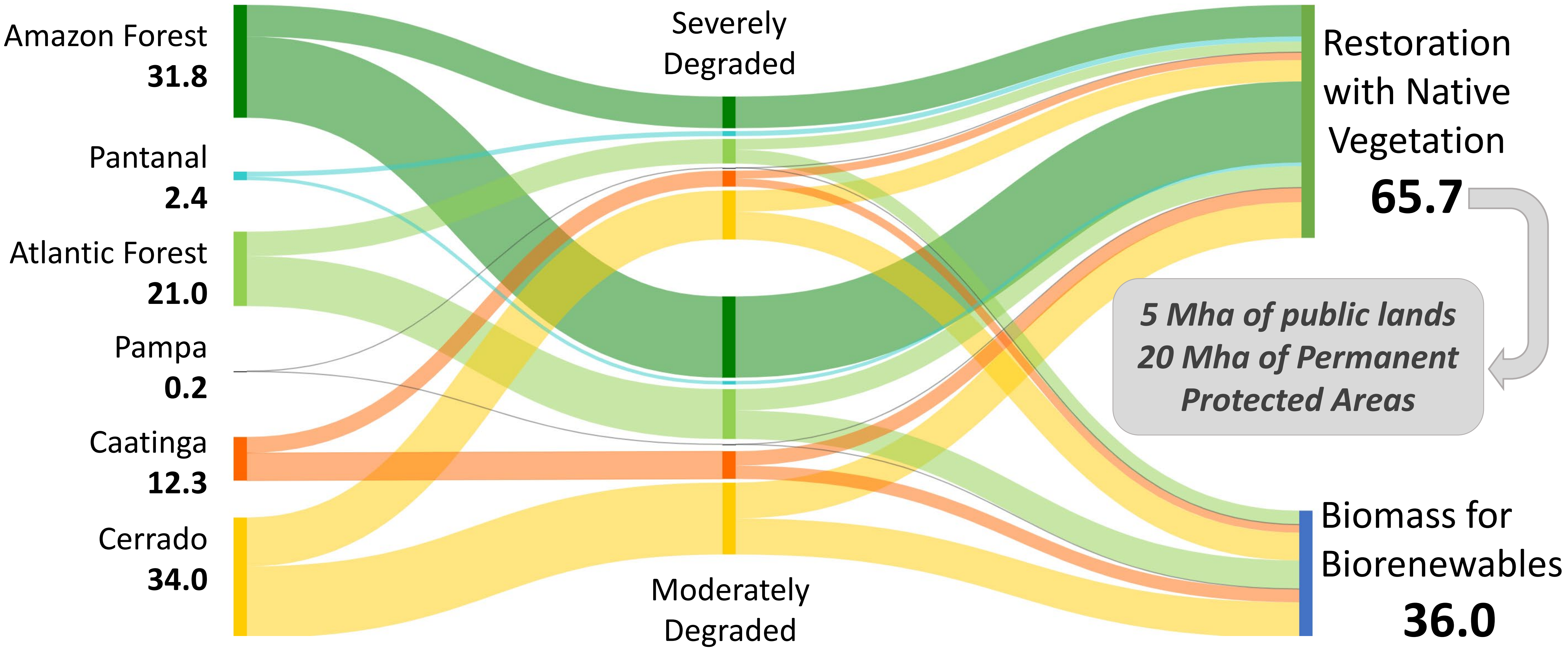
Carbon Sequestration Calculation

- **Restoration Assumption:** Restored native vegetation is considered similar to the surrounding remaining native vegetation.
- **Biomass Estimation:** Used data from Barros et al. (2023) to calculate average above and below ground biomass per hectare for each Brazilian biome.
- **Growth Modeling:** Biomass accumulation over time was projected using curves from Cook-Patton et al. (2020), with different models for each biome type (e.g., tropical moist forests, savannas, dry forests).
- **Recovery Timeline:** Assumed 95% of potential biomass is recovered after 100 years.
- **Carbon Content:** Estimated as 50% of total biomass; converted to CO_2 equivalent (1 tC = 3.67 tCO_2eq).
- **Application:** Potential carbon restored per hectare multiplied by total area targeted for restoration; restoration assumed to begin in 2025 for all biomes.

Bioenergy Case Study

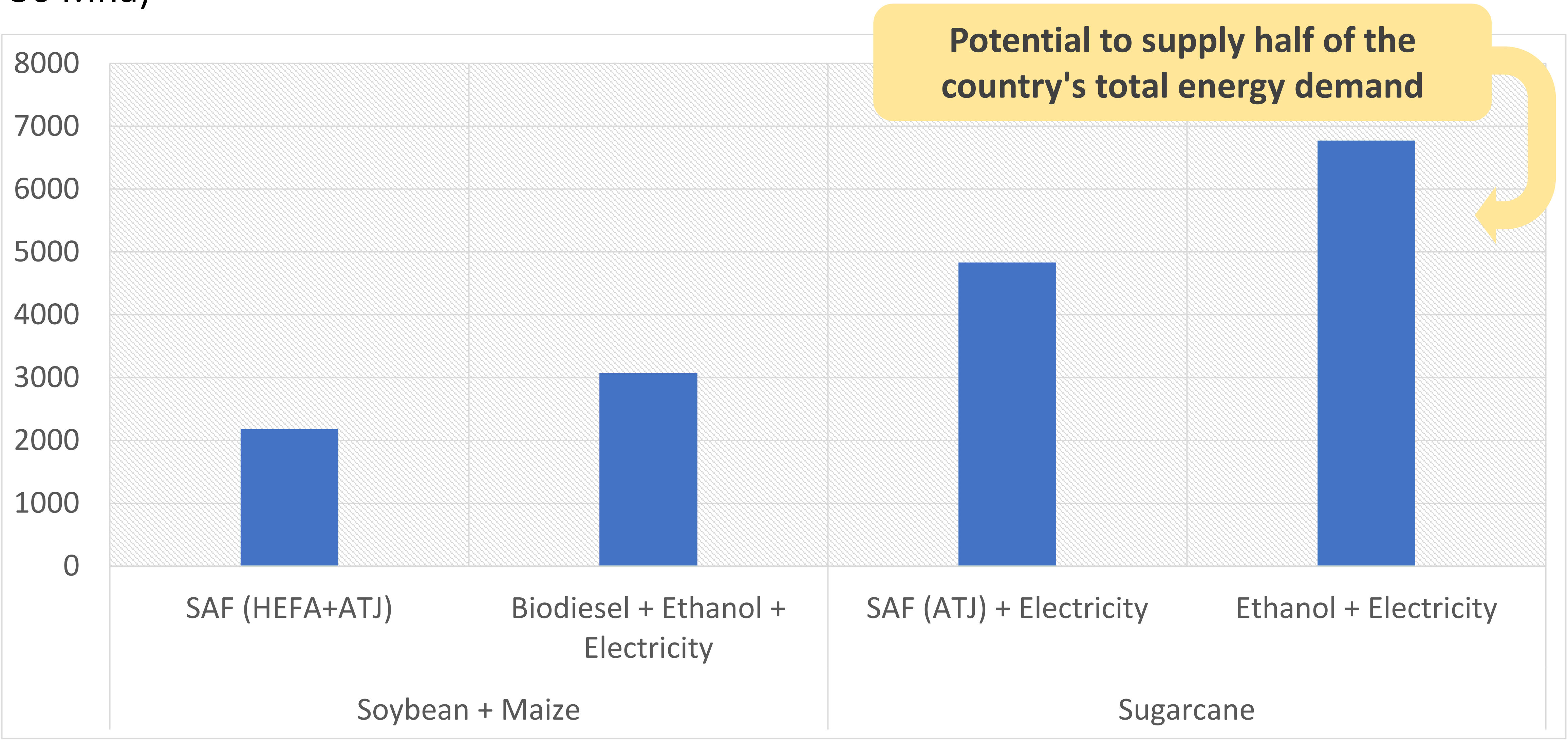
- **Four Scenarios Modeled:**
    - Sugarcane or soybean/maize double cropping,
    - Different conversion technologies and co-products (e.g., biodiesel, ethanol, SAF, electricity, DDGS, soybean meal, glycerol).
- **Crop Yield Estimation:**
    - Crop Assessment Tool (CAT) based on the Agroecological Zones method (FAO), incorporated daily climate data (0.25º resolution) for accurate yield projections.
- **GHG Emissions Assessment:**
    - Life cycle assessment (ISO 14040/44, ReCiPe 2016) for each scenario.
    - Compared emissions to fossil fuel substitutes (gasoline, kerosene, diesel, natural gas).
- **Land Use Change (LUC) Emissions:**
    - Calculated using IPCC guidelines, considering biomass and soil carbon stock changes.
    - LUC emissions amortized over 20 years and included in GHG accounting.

Achieved Outcomes



Potential Bioenergy Production

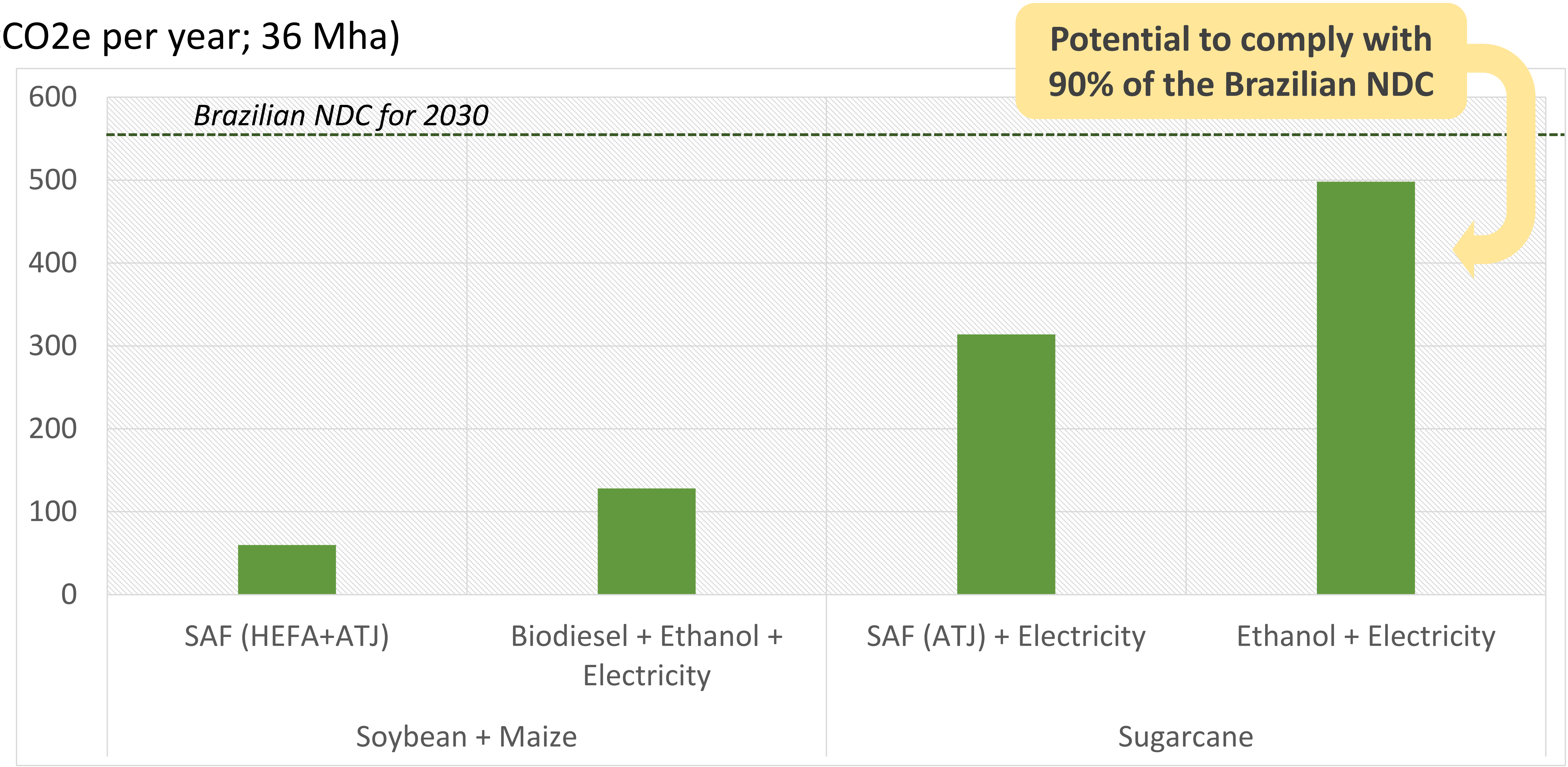
(PJ; 36 Mha)



Brazilian total energy demand in 2030: 13,700 PJ (EPE, 2024)

Bioenergy GHG Mitigation Potential*

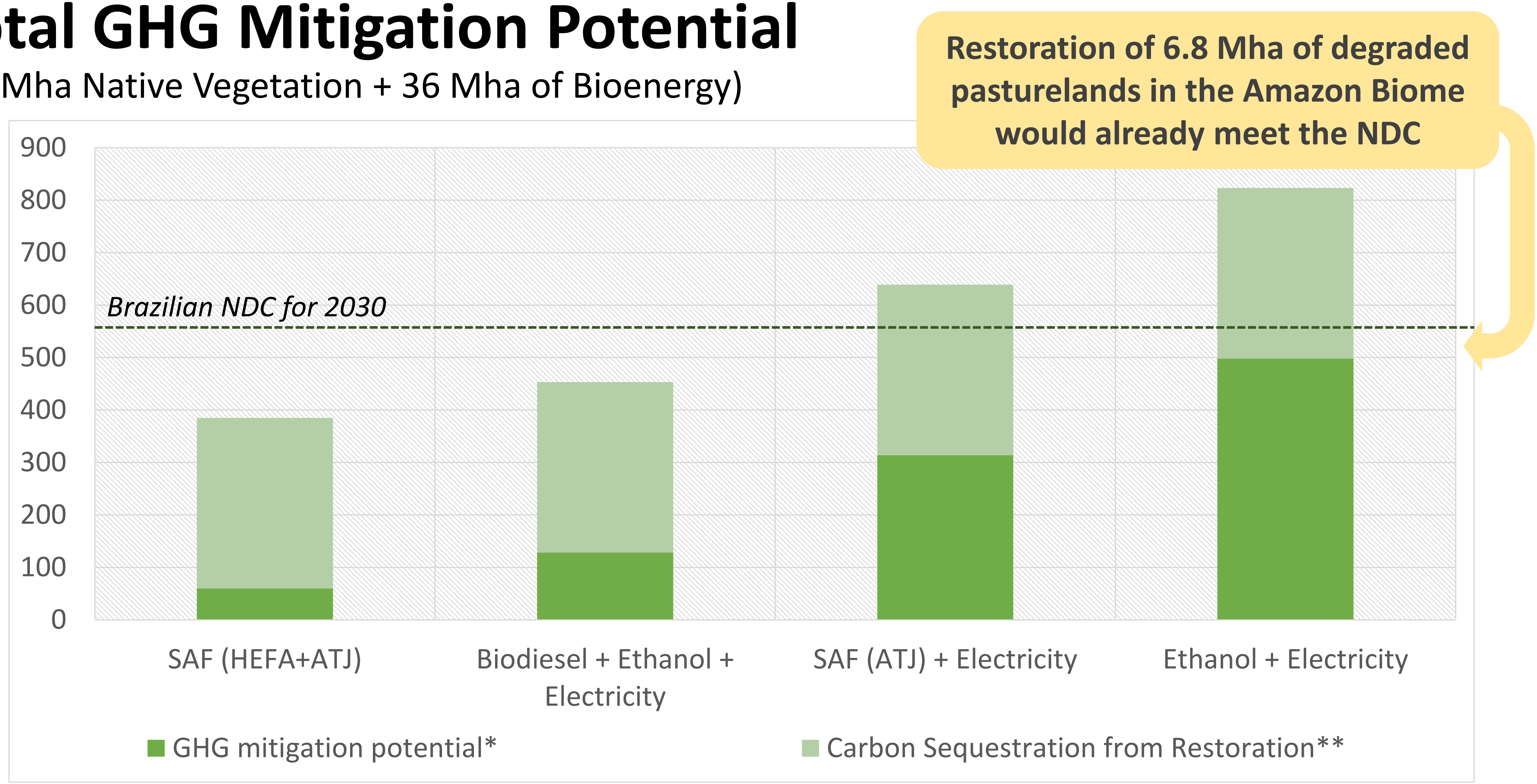
(MtCO2e per year; 36 Mha)



**Avoided emissions from fossil substitution + Carbon Stock Changes from LUC*

Total GHG Mitigation Potential

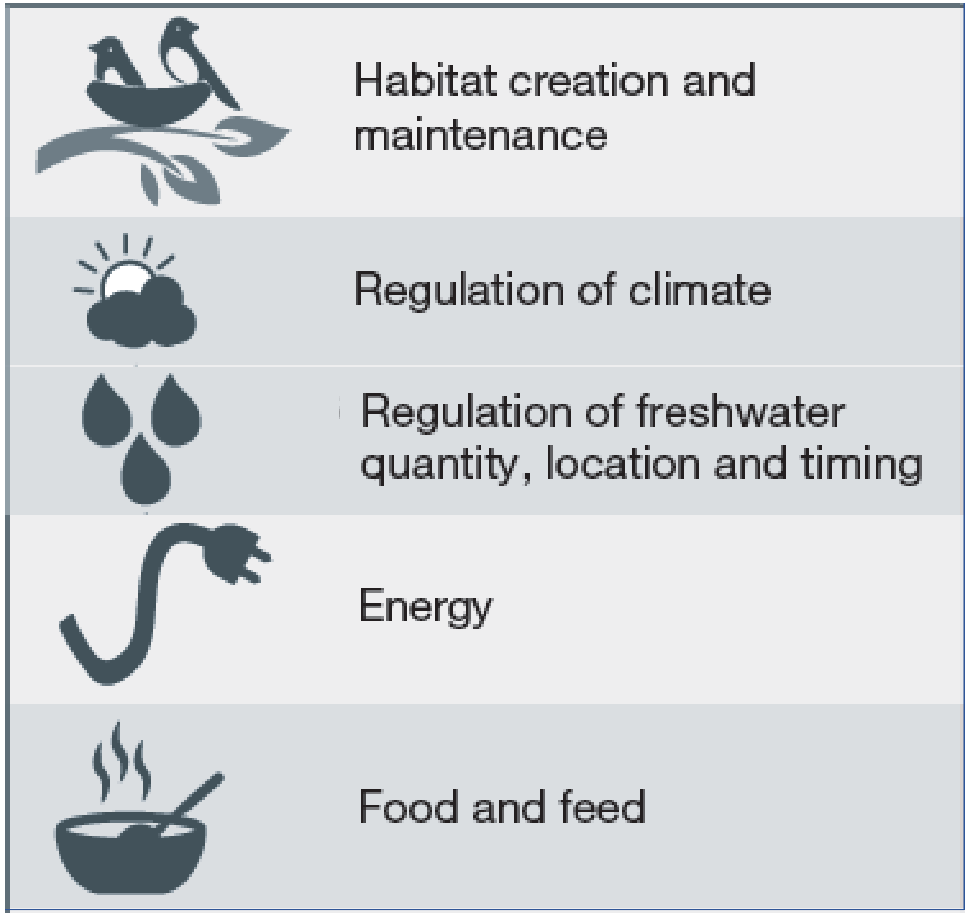
(66 Mha Native Vegetation + 36 Mha of Bioenergy)



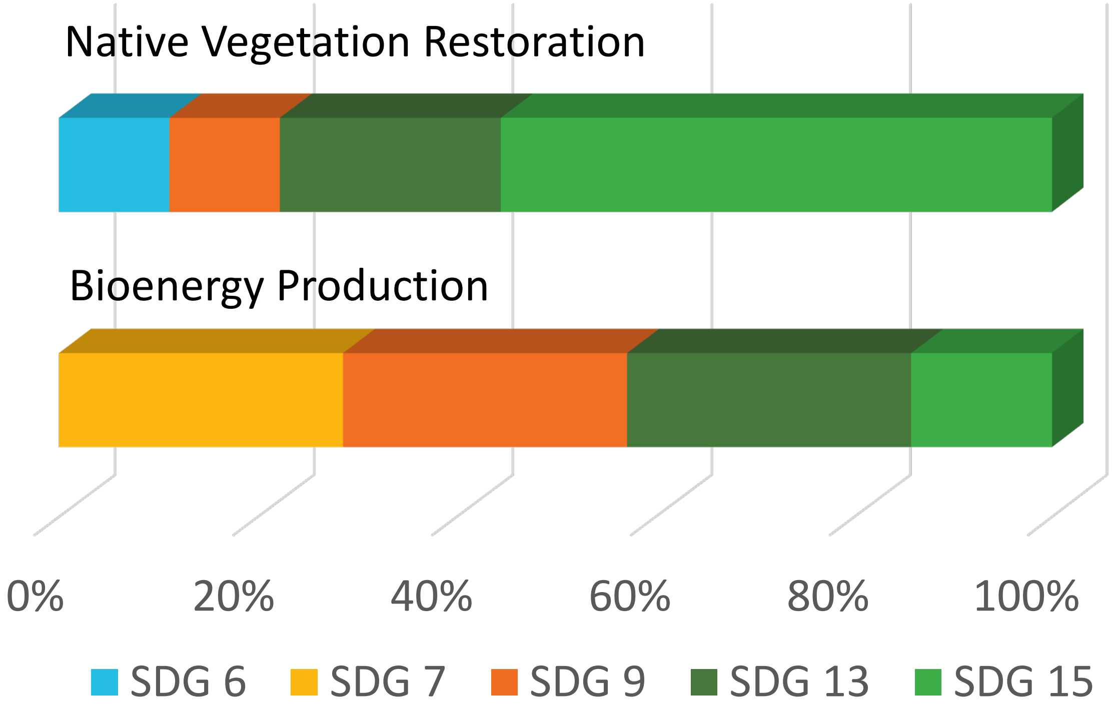
Avoided emissions from fossil substitution + Carbon Stock Changes from LUC (MtCO2e per year)

*** Average value of annualized carbon sequestration in native forest recovery (20 years; MtCO2e per year)*

Achieved Outcomes



Source: Diaz et al., 2018



Native Vegetation + Bioenergy: Beyond Regulation of Climate

Take-Home Messages

There is **enough area** for diversification of land use planning in **Brazil**

The restoration of **native vegetation** is essential not only for the conservation and restoration of **biodiversity**, but also for **compliance with the NDC**

An **integrated** framework that incorporates **diverse ecosystem services** from land use is paramount for **sustainable development**

Adaptive **management**, ongoing **monitoring**, and inclusive **governance** is essential for realize the **full potential of restoration and bioenergy strategies**