Potential expansion of agriculture with and without conversion of native vegetation to mitigate GHG emissions

November 2023

Objective

The objective of the present study is to quantify the area and the carbon stock of native vegetation with suitability for agriculture in South America.

In addition, the stock of pastureland with potential for agricultural expansion was evaluated in Brazil.

This study was developed by Agrosatélite

Scope

The following maps were produced to develop the analyses of the present study:

- Agriculture area and suitability for expansion

- Native Vegetation Carbon stock

- Pasture areas suitable for agricultural expansion

Agriculture

The map of agriculture for South America represent: 1) the areas of soybeans, corn and cotton cultivated as 1st crop during the season of 2022/23 in Brazil; 2) the area of corn cultivated as 2nd crop[1] in 2023 in Brazil; 3) the areas of soybeans and corn cultivated as 1st crop of 2022/23 in Paraguay; and 4) the areas of annual crops[2] cultivated as 1st crop during the season of 2022/23 for the remaining countries. The crop maps for Brazil and Paraguay were performed based on visual analyses of remote sensing images acquired from satellites (Landsat-8 and -9, and Sentinel 2A and 2B). For the other countries in South America, the crop maps were performed based on automatic image classification procedures using the Random Forest classifier and training samples from crop maps available at MapBiomas[3] , Agrosatélite[4] and CONAB[5].
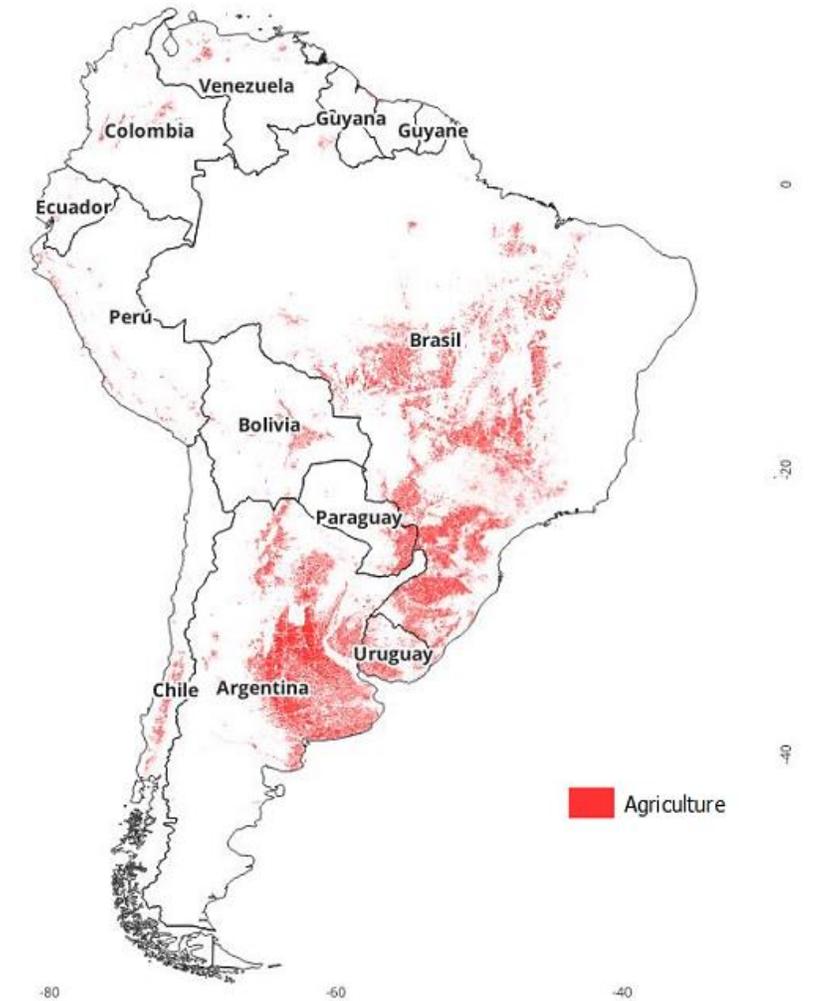
1. Mapping of 2nd crop of corn in 2023 for the following states: Paraná, São Paulo, Minas Gerais, Goiás, Distrito Federal, Mato Grosso e Mato Grosso do Sul.
2. This large class of agricultural crops, for the maps outside Brazil and Paraguay, should include soy, corn, cotton and other crops with similar calendar and growth cycle of seasonal crops. The figures of this analyses are less precise when compared to the visual analyses of satellite images and should not be used for crop forecast estimations but are good enough for the regional analyses to define risk and opportunity areas for crop expansion.
3. MapBiomas. 2023. Available at: https://brasil.mapbiomas.org/iniciativas-mapbiomas/
4. Agrosatélite. Maps Products. 2023. Available at: https://agrosatelite.com.br/produtos/maps
5. Companhia Nacional de Abastecimento. Mapeamentos agrícolas. 2023. Available at: https://portaldeinformacoes.conab.gov.br/mapeamentos-agricolas-downloads.html

Native Vegetation Carbon Stock

The map of carbon stocks per hectare (tC/ha) was obtained from official data of the IV National Inventory of Greenhouse Gas Emissions in Brazil[1], which includes average carbon stocks per hectare for biomass compartments above- and bellow-ground biomass, soil organic carbon, dead wood and litter. For the other countries of South America, global data on above-ground biomass from ESA CCI Biomass[2], below-ground biomass from NASA[3] and soil organic carbon from SOILGRIDS[4] were used. Carbon stocks from dead wood and litter, which correspond to less than 1% of the total value of carbon stocks in Brazil, were also not considered due to their low relevance.
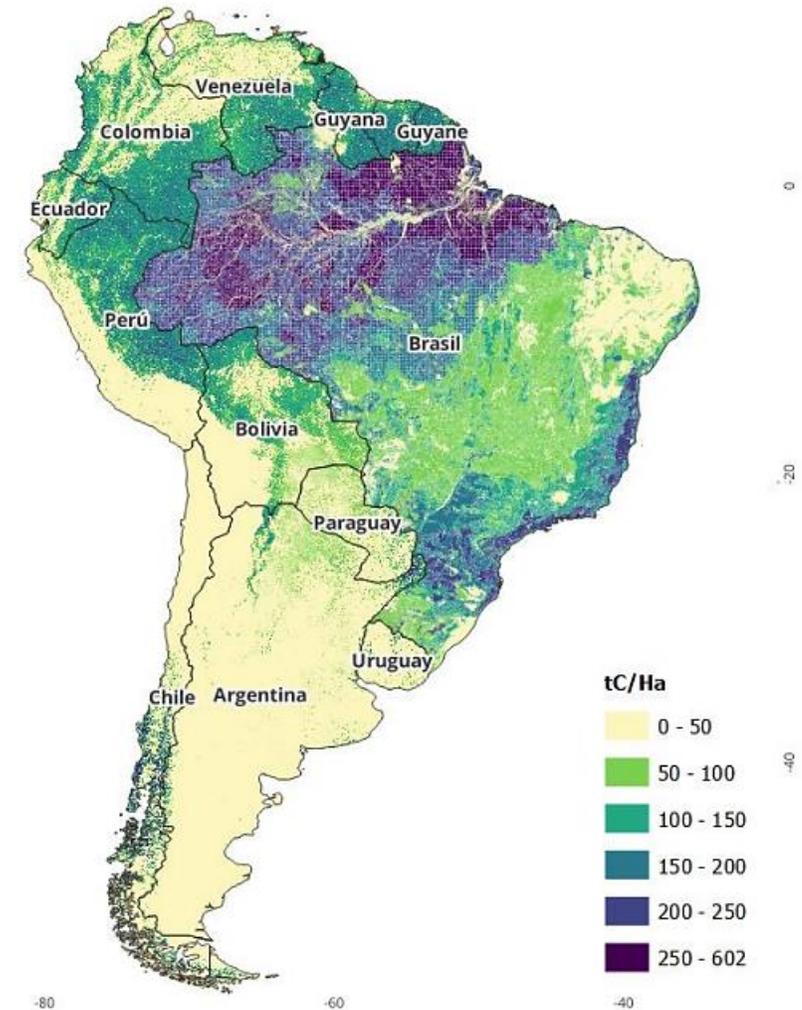
tC/Ha

▨	0 - 50
▨	50 - 100
▨	100 - 150
▨	150 - 200
▨	200 - 250
▨	250 - 602

1. Sistema Nacional de Registro de Emissões (SIRENE) - Relatórios de Referência Setorial. 2021. Available at: https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/sirene
2. ESA Biomass Climate Change Initiative (CCI). V4.0. 2020. Available at: https://data.ceda.ac.uk/neodc/esacci/biomass/data/agb/maps
3. Harmonized global maps of above and belowground biomass carbon density in the year 2010. 2010. Available at: https://www.nature.com/articles/s41597-020-0444-4
4. World Soil Information (SOILGRIDS). 2021. Available at: https://www.isric.org/explore/soilgrids/faq-soilgrids

Pasture areas suitable for agricultural expansion

The pasture map for Brazil was based on the 2022 pasture class from MapBiomas Brasil[1], Collection 8 and was refined by excluding the protected areas by law[2], the agricultural areas and the forested areas (treecover ≥ 10) that somehow overlayed with the pasture class from MapBiomas. The refined pasture map was then intersected with the agricultural suitability map to qualify the pasture areas with and without agricultural suitability. At last, the pasture map was intersected with the annual deforestation maps from the Deforestation Monitoring Project (PRODES/INPE)[3], being classified into 3 categories: pastures with deforestation date prior to 2008; pastures with deforestation date between 2008 and 2020; and pastures with deforestation date after 2020.


Pasture
- Suitable for soy
- Not suitable for soy

1. MapBiomas Brasil. 2023. Available at: https://brasil.mapbiomas.org/
2. See reference used to define the protected areas by law on slide "Definition of the main terms used in the study".
3. Instituto Nacional de Pesquisas Espaciais – INPE. Projeto de Monitoramento do Desmatamento – PRODES. 2023 Available at: http://terrabrasilis.dpi.inpe.br/

Native vegetation classified as Forest and Non-Forest, with and without suitability for soy + Agriculture
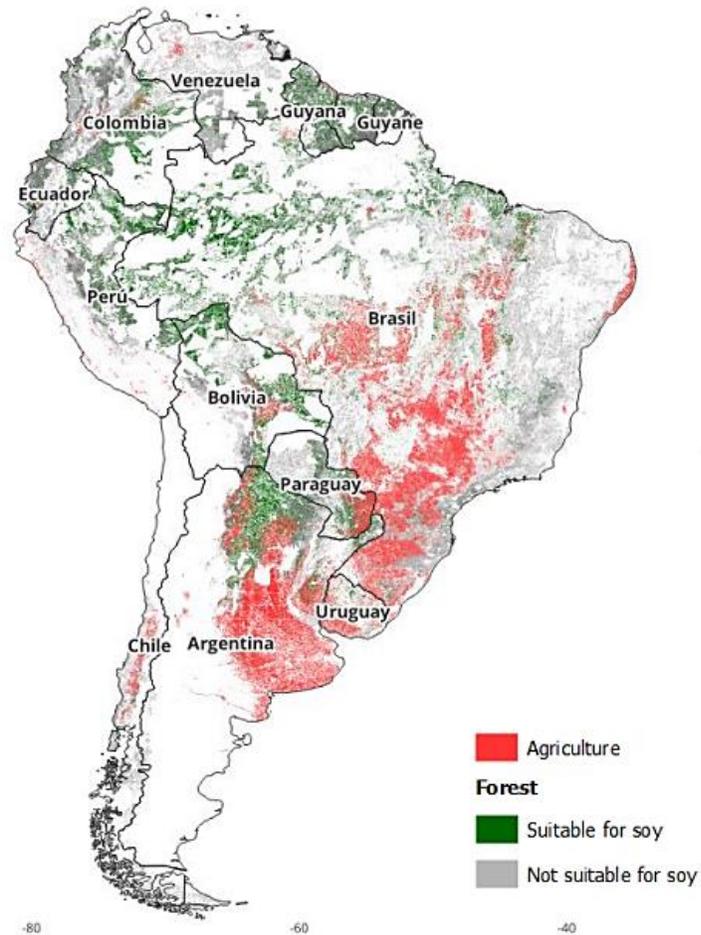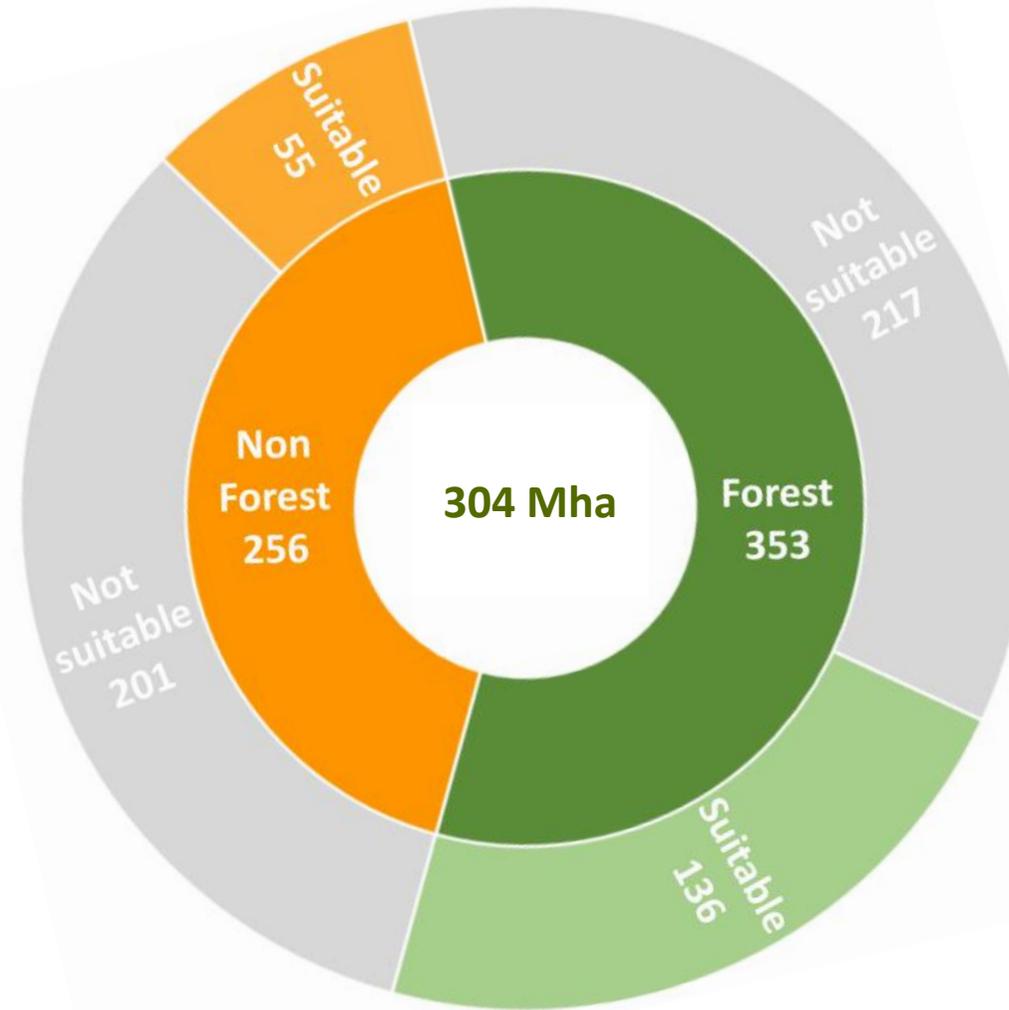
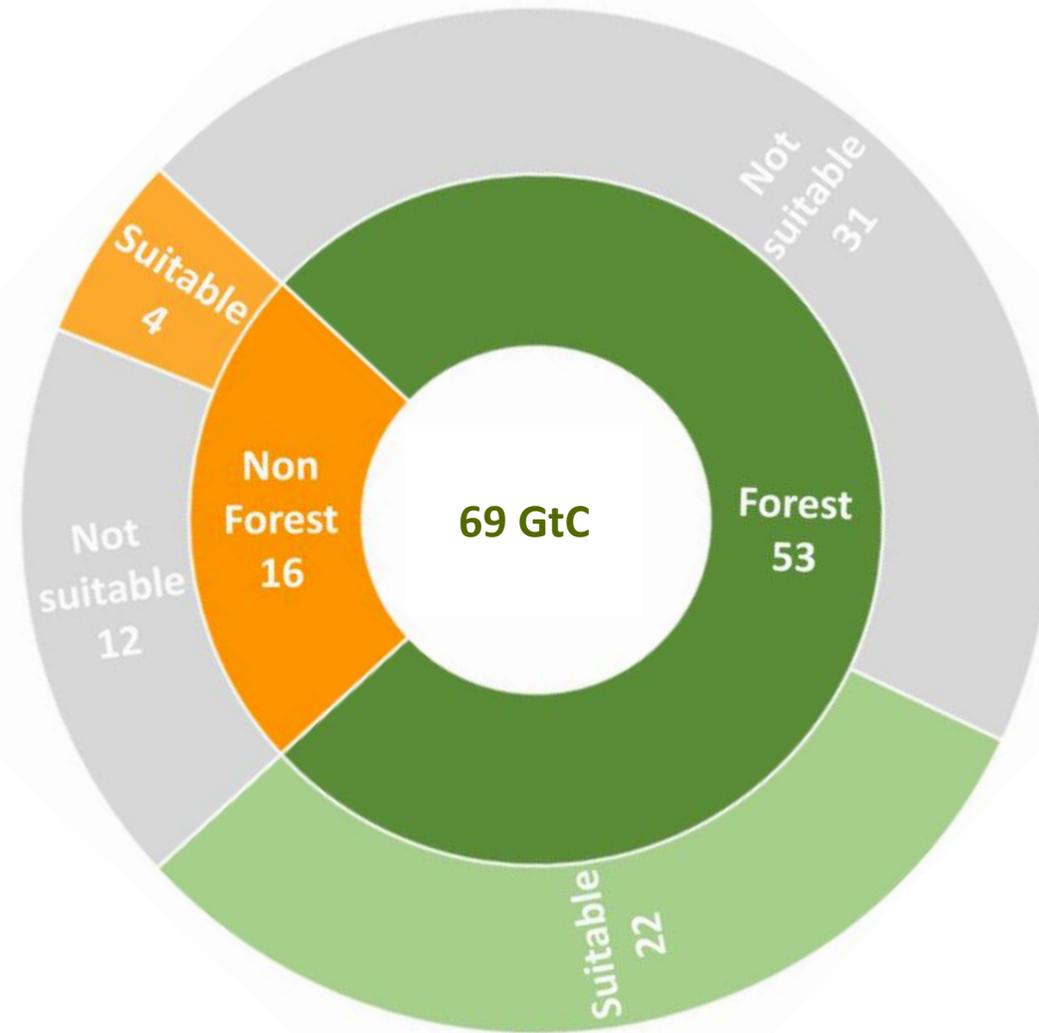Forest (TreeCover ≥ 10) with and without suitability
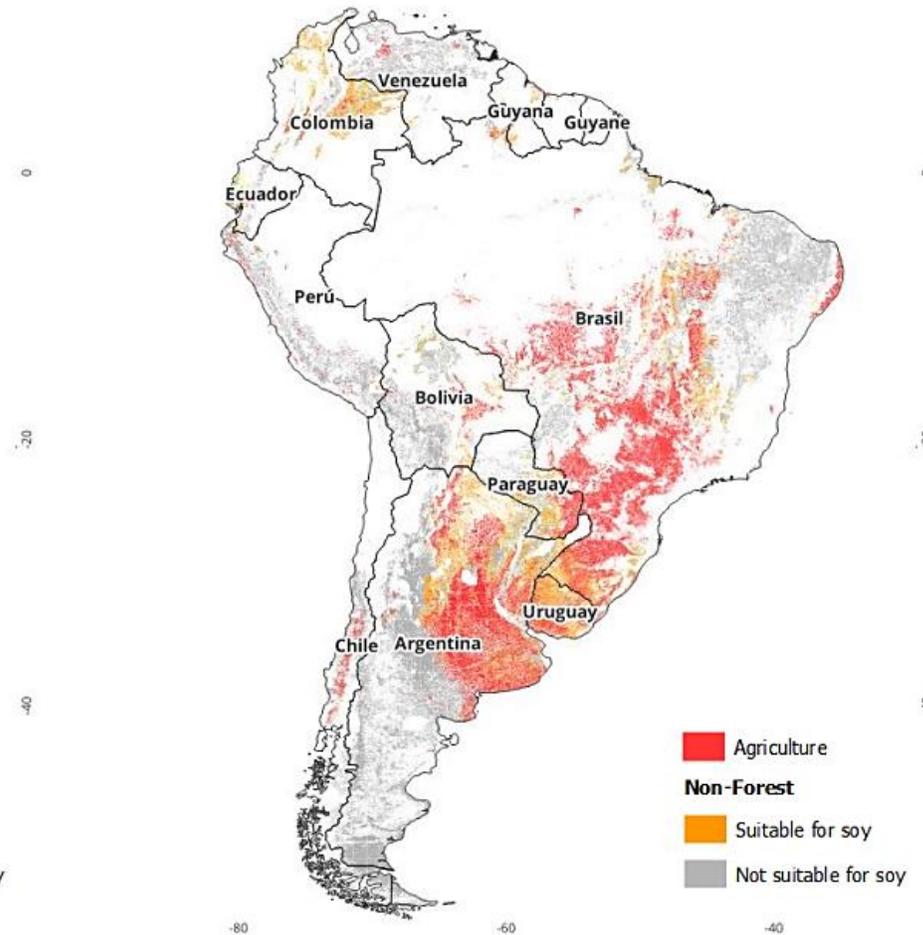
Non-Forest (TreeCover < 10) with and without suitability

Areas not included in the analyses: Conservation Units (except Environmental Protected Areas – APA) and Indigenous Territories (all countries), Military Areas (Brazil and Argentina). Quilombolas Territories, Legal Reserves and Permanent Protected Areas (Brazil).
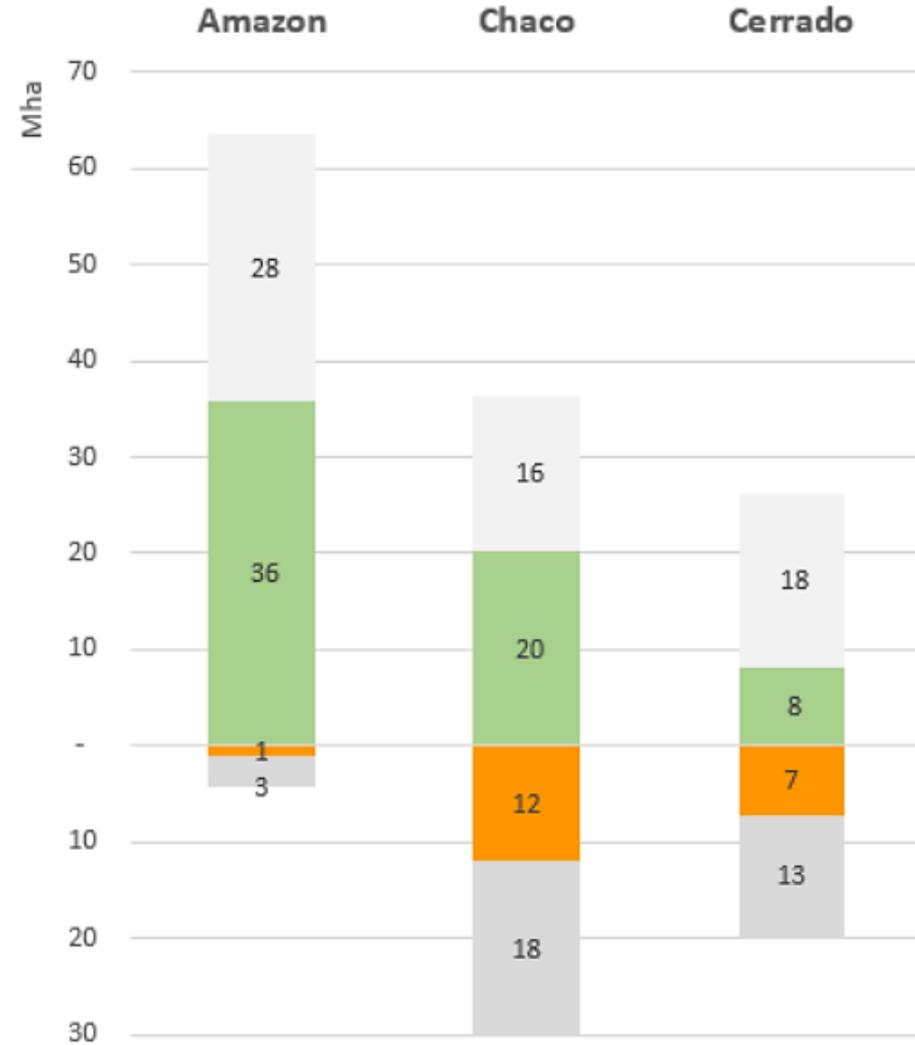
South America: Summary of the area (Mha) of forest and non-forest native vegetation eligible for legal land use conversion with and without suitability for agriculture
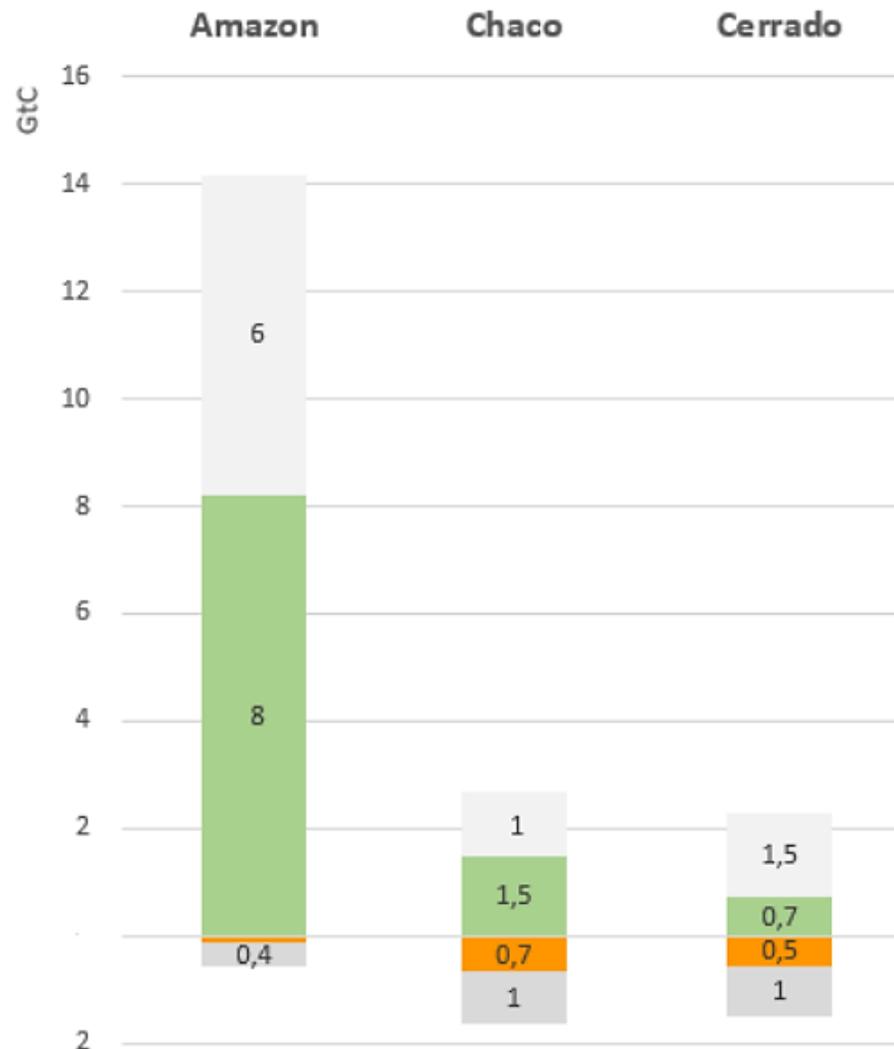
South America: Summary of the carbon stock (GtC) of forest and non-forest native vegetation eligible for legal land use conversion with and without suitability for agriculture

Area (Mha) of Forest and Non-Forest with and without suitability in high-risk biomes

Carbon stock (GtC) of Forest and Non-Forest with and without suitability in high-risk biomes

Legend:
- Forest (Suitable for soy) — green
- Forest (Not suitable for soy) — light grey
- Non-Forest (Suitable for soy) — orange
- Non-Forest (Not suitable for soy) — grey

Area (Mha) of Forest and Non-Forest with and without suitability in high-risk biomes
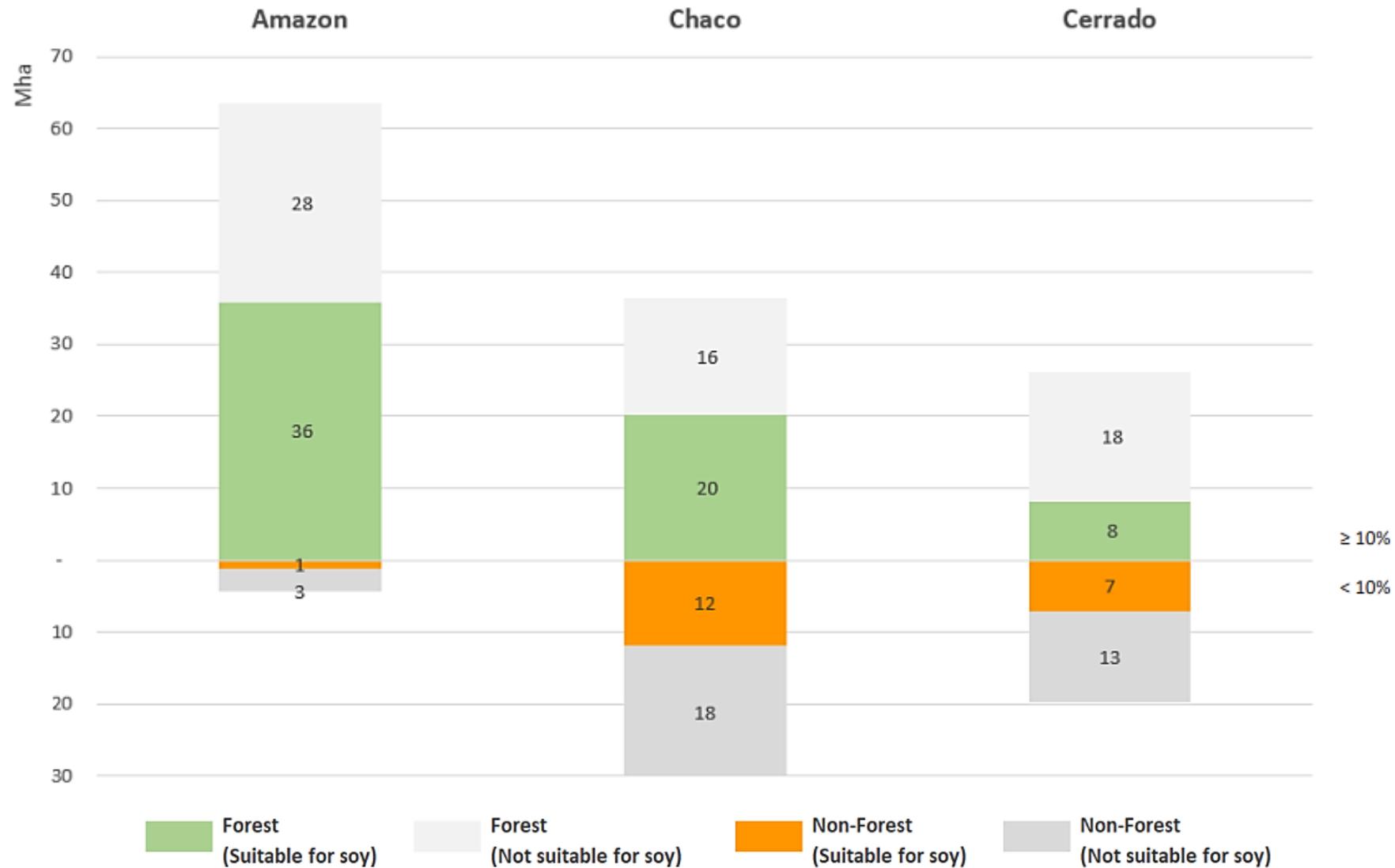
Carbon stock (GtC) of native vegetation in high-risk biomes and their suitability for agriculture
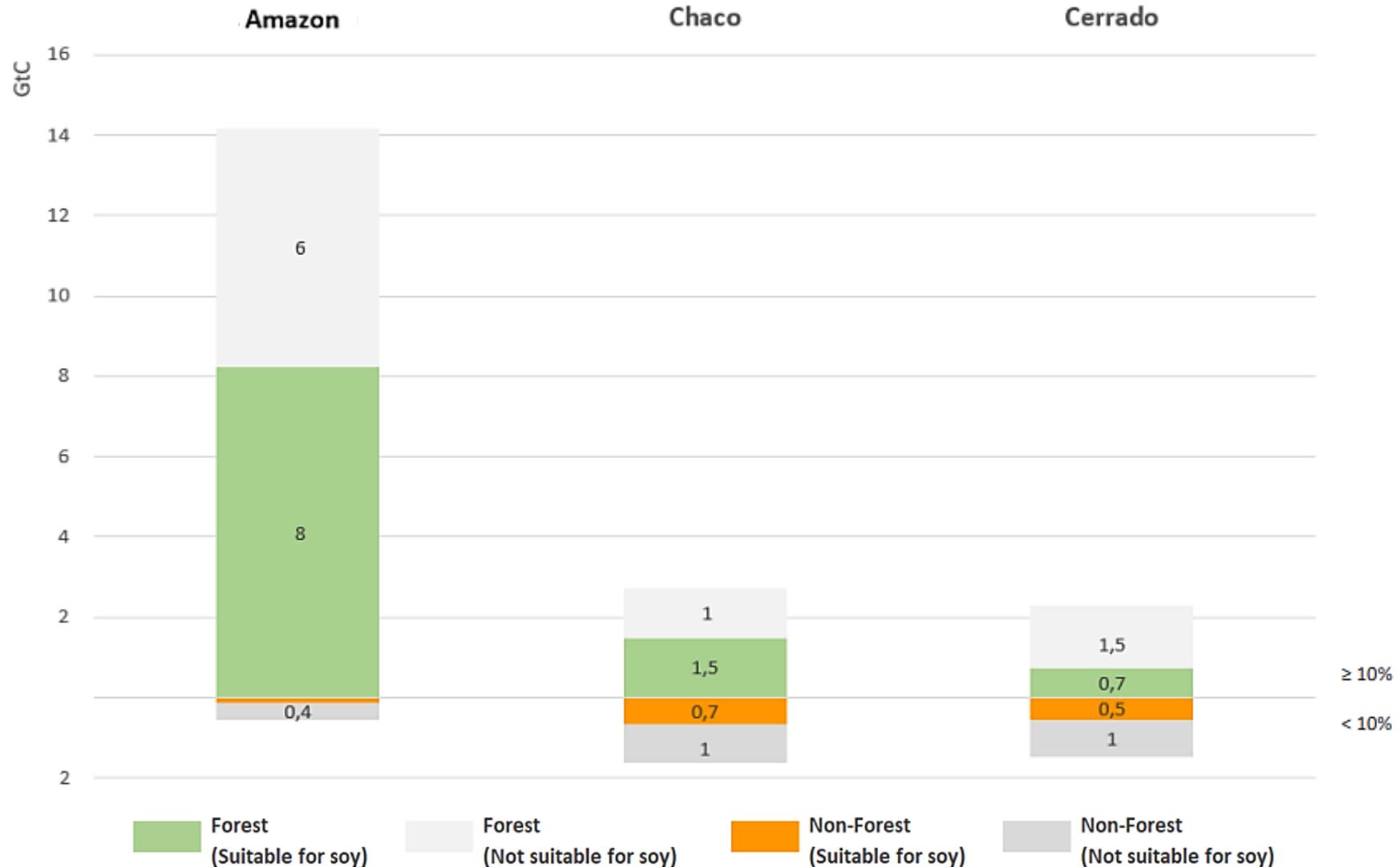
Suitability for agriculture expansion in existing pastureland (Mha)

Suitable for soy
- Deforested before 2008
- Deforested between 2008 and 2020
- Deforested after 2020

Not suitable for soy
- Deforested before 2008
- Deforested between 2008 and 2020
- Deforested after 2020
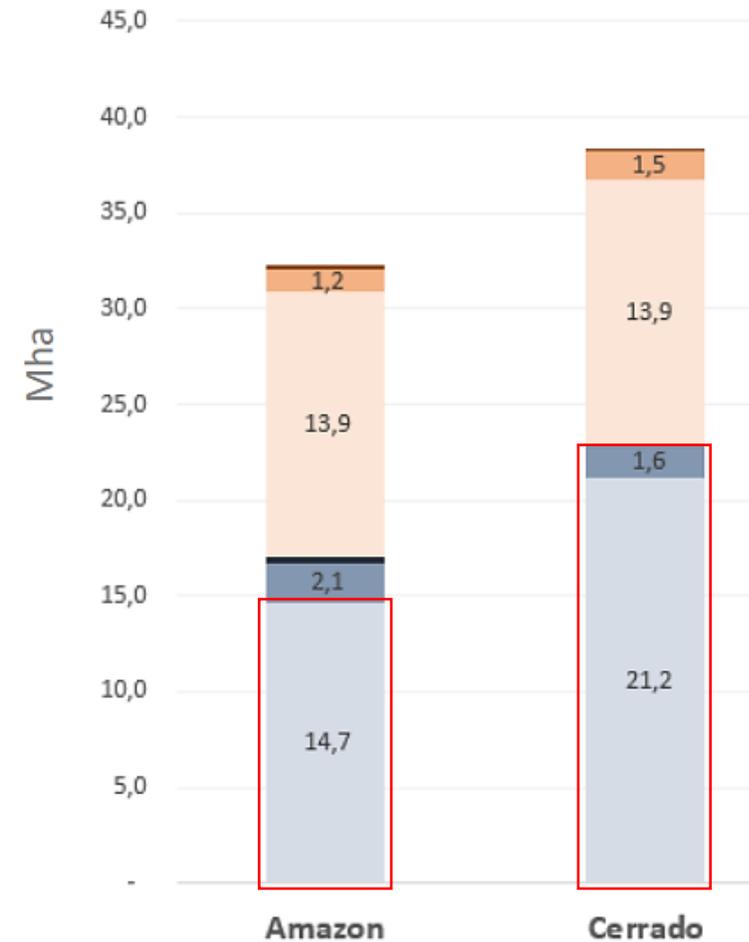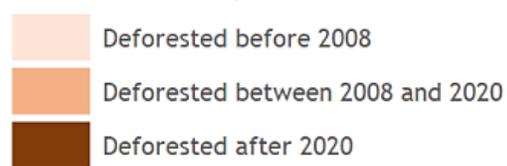
Potential agriculture expansion

The agriculture map of South America was used to create a hotspot map where it is most likely that agriculture expansion, mainly soy, will happen in the next years. A buffer with a radius of up to 20 km[1] was created around the areas of the agriculture map. The areas beyond the 20 km buffer were considered as peripheral for soy expansion. The hotspot and the peripheral maps were intersected with the map of non-forested vegetation with agricultural suitability for soybeans to quantify both area (ha) and the carbon stock (tC) of these maps, and to compare the potential expansion of soybeans within the hotspot map versus the peripheral map.

Legend:
- Agriculture
- Hotspots
  - 0 - 5 Km
  - 5 - 10 Km
  - 10 - 20 Km
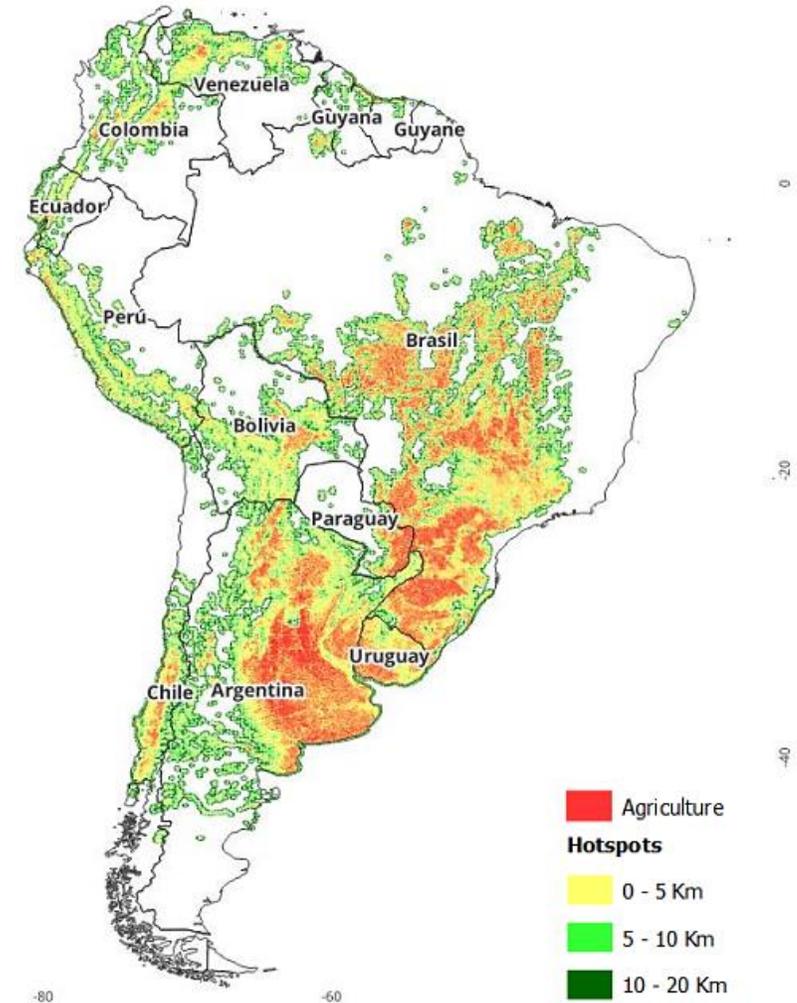
1. The 20 km buffer was defined based on the trend of soy expansion in the Cerrado and Amazon biomes from crop year 2016/17 to 2022/23. It was observed that 97% of the soy expansion during this period occurred within the buffer of 20 km of the soy map of crop year 2016/17. It was also observed that 80% of the soy expanded within a buffer of 5 km, 11% expanded within a buffer of 5 to 10 km, and 6% expanded within a buffer of 10 to 20 km. The analysis was also performed for the mentioned buffers as show in the figure above.

Definition of the main terms used in the study

- **Native Vegetation**: are the areas of native vegetation[1], within the analyzed regions, that can legally be converted to other uses and was classified as **Forest** and **Non-Forest** types. Non-Forest type includes natural grasses and other woody types of vegetation[2].
- **Forest Vegetation**: is the type of vegetation according to the definition of **forest by FAO** (2001)[3] in which an area is considered forest if it is **larger than 0.5 hectare** and has **trees over 5 meters** in height **covering ≥ 10% of the surface**. This data is obtained from the Global Forest Change-GFC for the year 2010 (tree cover 2010)[4].
- **Non-Forest Vegetation**: is the type of vegetation according to FAO[3] covering **< 10% of the surf**ace.
- **Agricultural suitability**: is the **area suitable for soybean cultivation** that was modeled based on data on: soil and climate (edaphoclimatic); crop calendar; slope and altitude; and risk to extreme events.
- **Carbon**: is the carbon stock (C) of the vegetation that is stored in the **aboveground and belowground biomass**, and in the **organic carbon** stock that is stored in **soil**.
- **Carbon Dioxide**: is the carbon value multiplied by its global warming potential, through a conversion factor from C to CO_2[5] equal to 3.67.

1. Areas not included in the analyses: Conservation Units (except Environmental Protected Areas – APA) and Indigenous Territories (all countries), Military Areas (Brazil and Argentina). Quilombolas Territories, Legal Reserves and Permanent Protected Areas (Brazil).
2. MapBiomas Brazil: Algorithm Theoretical Basis Document (ATBD). 2023. Available at: https://brasil.mapbiomas.org/wp-content/uploads/sites/4/2023/09/ATBDCollection-8-v1.1.docx.pdf
2. Sistema Nacional de Registro de Emissões (SIRENE) - Relatórios de Referência Setorial. 2021. Available at: https://www.gov.br/mcti/pt-br/acompanhe-omcti/sirene
3. FAO (2001) definition of forest. Global Forest Resources Assessment 2001. Rome, Italy. Available at: https://www.fao.org/3/ad652e/ad652e00.htm
4. Global Forest Watch. 2023. Available at: https://www.globalforestwatch.org/
4. Hansen, M. C., et al. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53. 2013. Available at: http://earthenginepartners.appspot.com/science-2013-global-forest
5. IPCC - Intergovernmental Panel on Climate Change. Guidelines for National Greenhouse Gas 20 Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Volume 4: 21 Agriculture, Forestry and Other Land Use, Chapter 4, Forestland, Eggleston H,S, et. al (eds), Published: IGES, Japan: 2006. Available at: https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

Classes of forest and non-forest

The Forest and Non-Forest classes were obtained from Global Forest Change (GFC)[1] data from Hansen et al. (2013)[2] available for the entire globe.

The GFC map named *Tree canopy cover for year 2010* (tree cover 2010) represents the tree cover for the year 2010, being defined as the percentage of native vegetation canopy cover, in such a way that it allows establishing the percentages according to the FAO (2001)[3] definition of Forest (≥ 10% coverage) and, consequently, Non-Forest (< 10% coverage). The Non-Forest class of the GFC map was complemented with data from MapBiomas[5] available in South America and from GLAD[6] for the portions that were not part of MapBiomas to improve the GFC map that underestimates the Non-Forest class.

The GFC map named *Year of gross forest cover loss event* (loss year) represents the loss of annual tree cover from 2011 to 2022 and was used to update the tree cover map from 2010 (tree cover 2010) to 2022. Additionally, the deforestation mapped by the Deforestation Monitoring Project (PRODES) from 2011 to 2022 in Brazil4 was used to complement the losses of native vegetation not captured in the GFC "loss year".

From the Forest and Non-Forest maps we excluded the following areas: Legal Reserve and Areas of Permanent Protection of CAR[7], Protected Areas[10] (except of Environmental Protection Areas-APA), planted forests (MapBiomas and GFW TreePlantations[8]), and seasonal, perennial and semi-perennial crops (maps of Agrosatélite[9]) that eventually intersected with the native vegetation map.

1. Global Forest Watch. 2023. Available at: https://www.globalforestwatch.org/
2. 2. Hansen, M. C., et al. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53. 2013. Available at: http://earthenginepartners.appspot.com/science-2013-global-forest

3. A FAO (2001) define floresta como, áreas as quais apresentam uma cobertura de copa igual ou superior a 10%, área maior de 0,5ha e árvores maiores do que 5 metros de altura. FAO, 2001. Global Forest Resources Assessment 2001. Rome, Italy. Available at: https://www.fao.org/3/ad652e/ad652e00.htm

Area and stock of C in forest and non-forest native vegetation with agricultural suitability

The maps of the classes of Forest and Non-Forest were intersected with the maps of agricultural suitability and average carbon stock per hectare (C/ha), allowing to calculate the areas in hectares and the C[11] stocks for the Forest and Non-Forest classes, both with and without agricultural suitability for soybeans.
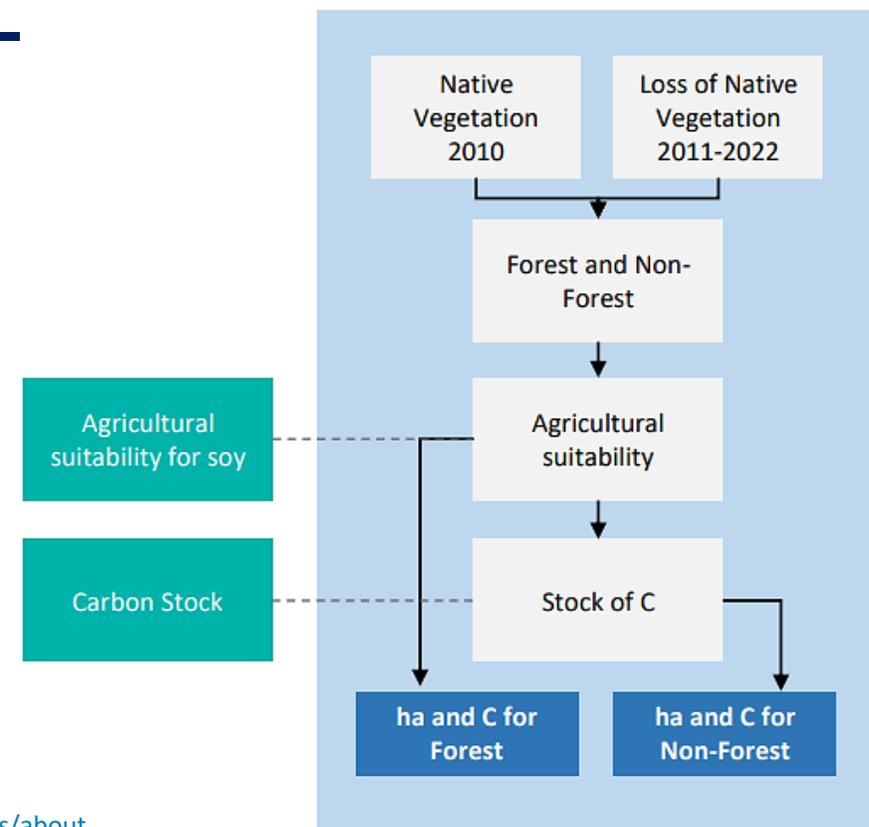
4. Projeto de Monitoramento do Desmatamento – PRODES. 2023. Available at: http://terrabrasilis.dpi.inpe.br//

5. Iniciativas MapBiomas. 2023. Available at: https://brasil.mapbiomas.org/iniciativasmapbiomas/

6. Global Land Cover and Land Use Change 2000-2020 - GLAD. 2023. Available at: https://glad.earthengine.app/

7. Sistema Nacional de Cadastro Ambiental Rural – SICAR. Available at: https://www.car.gov.br/#/

8. Global Forest Watch – Tree Plantations. 2023. Available at: https://data.globalforestwatch.org/datasets/gfw::tree-plantations/about

9. Agrosatélite Geotecnologia Aplicada – Produtos Linha Maps. 2023. Available at: https://agrosatelite.com.br/produtos/maps

10. Cadastro Nacional de Unidades de Conservação – CNUC. 2023. Available at: https://cnuc.mma.gov.br/map

10. Ministério do Meio Ambiente – MMA. 2023. Available at: http://mapas.mma.gov.br/i3geo/datadownload.htm?ucstodas

10. Instituto Chico Mendes de Conservação da Biodiversidade – ICMBio. 2023. Available at: https://www.gov.br/icmbio/pt-br/assuntos/dados_geoespaciais/

10. Fundação Nacional do Índio – FUNAI. 2023. Available at: https://geoserver.funai.gov.br/

10. Instituto Nacional de Colonização e Reforma Agrária – INCRA. Territórios Quilombolas. 2023. Available at: https://certificacao.incra.gov.br/csv_shp/export_shp.py

10. Serviço Florestas Brasileiro – SFB. Florestas Públicas. 2023. Available at: https://www.gov.br/agricultura/pt-br/assuntos/servico-florestal-brasileiro/cadastro-nacional-de-florestas-publicas

10. Rede Amazônica de Informação Socioambiental – RAISG. Dados Cartográficos de Áreas Protegidas. 2023. Available at: https://www3.socioambiental.org/geo/RAISGMapaOnline/

10. UNEP-WCMC and IUCN (2023), Protected Planet: The World Database on Protected Areas (WDPA) and World Database on Other Effective Area-based Conservation Measures (WD-OECM) [Online], August 2023, Cambridge, UK: UNEP-WCMC and IUCN. Available at: https://www.protectedplanet.net/en

10. Sistema Federal de Áreas Protegidas de Argentina - SIFAP. Available at: https://www.argentina.gob.ar/ambiente/areas-protegidas/sifap

10. Mapa de las Tierras Indígenas del Paraguay. Available at: https://www.tierrasindigenas.org/Mapa

11. IPCC - Intergovernmental Panel on Climate Change. Guidelines for National Greenhouse Gas 20 Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Volume 4: 21 Agriculture, Forestry and Other Land Use, Chapter 4, Forestland, Eggleston H,S, et. al (eds), Published: IGES, Japan: 2006. Available at: https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html.