Technical Note

Potential impacts of due diligence criteria on the protection of threatened South American non-forest natural ecosystems

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Abstract

- A new regulation currently under discussion in the European Union restricts the import of several agricultural commodities produced in deforested areas.

- The definition of "deforestation" in the proposed European regulation is based on the FAO definition of forest. **This leaves aside relevant areas of natural ecosystems and biomes in South America, where extensive areas are being converted to farming, such as in the Cerrado and Pampa biomes.**

- In this technical note, we use MapBiomas' land cover and land use data in the Amazon, Atlantic Forest, Chaco, Cerrado, Caatinga, Pampa and Pantanal biomes to assess the percentage of natural ecosystems that would not be protected by EU regulation in South America, if the FAO's definition of forest is the only one considered.

- Considering a total of 1,073 Mha of natural remnants of the seven biomes, covering all of Brazil, the Amazon, Atlantic Forest, Chaco and Pampa biomes, the FAO Forest definition criterion would only include 745.5 Mha, 69.5% of the natural ecosystems in these biomes.

- **327.1 Mha natural ecosystems are not included in the FAO definition. This implies that 30.5% of the natural ecosystems in these biomes would not be protected, corresponding to more than five times the size of France. Those would be left unprotected by the European regulation and thus not guaranteeing that commodities are free of conversion on those ecosystems.**

- The proportion of unprotected natural ecosystems is unevenly distributed. **The FAO definition covers a large proportion of only three of the seven mapped biomes**: the Amazon (84%), Chaco (75%) and Atlantic Forest (71%). **In Caatinga, Pampa, Pantanal and Cerrado only a small portion is covered by the definition** (10% of the remaining Caatinga, 11% of the Pampa, 24% of the Pantanal, and 26% of the Cerrado). **All of them are now under intense pressure by large-scale agriculture expansion.**

Summary

1. Introduction

1.1 European Union legislation and the FAO definition of forest

This technical note assesses the scope of a regulation proposed by the European Commission that restricts the import of commodities produced in recently deforested areas, using the FAO definition of forest as reference for due diligence to be carried out by importers.

The aim of this analysis is to **evaluate whether the FAO definition of forest covers all or most of the large-scale natural ecosystem conversion to commodities production in the South America**, based on the land cover and land use data of the MapBiomas initiatives.

According to FAO, "Forest" is defined as: *"land with a tree canopy cover of more than 10 percent and area of more than 0.5 ha. The trees should be able to reach a minimum height of 5 m at maturity in situ"*.

Kate Evans/CIFOR

IPAM

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1. Introduction

1.2 MapBiomas land cover and land use data

MapBiomas is a collaborative network of NGOs, universities and technology companies dedicated to mapping land cover and land use changes throughout South America and Indonesia.

All MapBiomas processing is done on Google Earth Engine platform, using artificial intelligence and cloud computing to perform a pixel-by-pixel classification of land cover and land use over a time series.

MapBiomas has started in Brazil in 2015 where its currently mapping 25 classes of land cover and land use of all Brazilian biomes from 1985 to the present. The initiative has expanded to other regions, such as the Amazon, Chaco, Atlantic Forest and Pampa biomes, and most recently Indonesia.

All MapBiomas data and maps of land cover and land use are freely available and transparent in platforms (https://mapbiomas.org/).

2. Method

2.1 Scope

The analyses included areas already mapped by the MapBiomas network in South America for land cover and land use which includes:

- **Amazon Biome** - covering parts of Brazil, Bolivia, Colombia, Ecuador, Guyana, French Guiana, Peru, Suriname and Venezuela;
- **Atlantic Forest Biome** - covering parts of Brazil, Argentina and Paraguay;
- **Chaco Biome** - covering parts of Paraguay, Argentina and Bolivia;
- **Pampa Biome** - covering parts of Brazil, Argentina and Uruguay;
- Other Biomes in Brazil: **Caatinga, Cerrado, and Pantanal.**
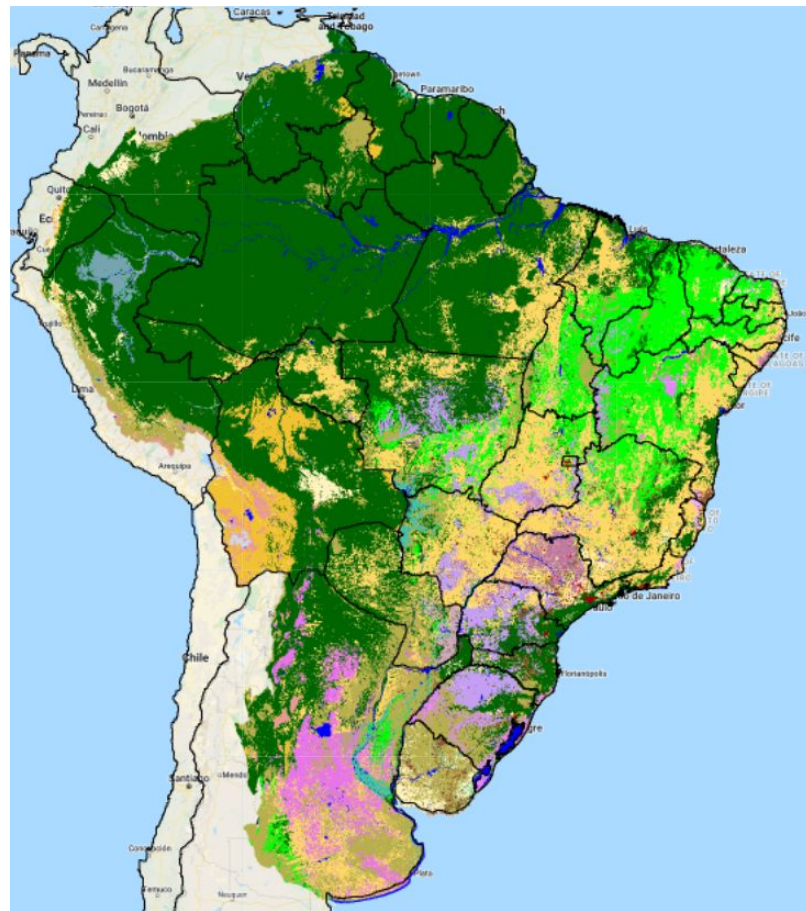
2. Method

2.1 Scope

Amazon

The Amazon is the largest remaining tropical rainforest in the world, housing a large part of Earth's biodiversity. Despite being covered predominantly by tropical forest, several other vegetation types are present, such as savannas and grasslands (Devecchi et al. 2020). The biome is threatened by the growing incidence of fires and deforestation in the region (Silva Jr. et al. 2021), which are enhanced by the weakening of environmental agencies (Coelho-Junior et al. 2022).

83% of the Amazon are covered with native vegetation, whereas the non-forest natural ecosystems represent 13% of the biome.


Native Vegetation
- Forest by FAO
- Non forest by FAO

0   250   500 km

Barbosa & Miranda 2004
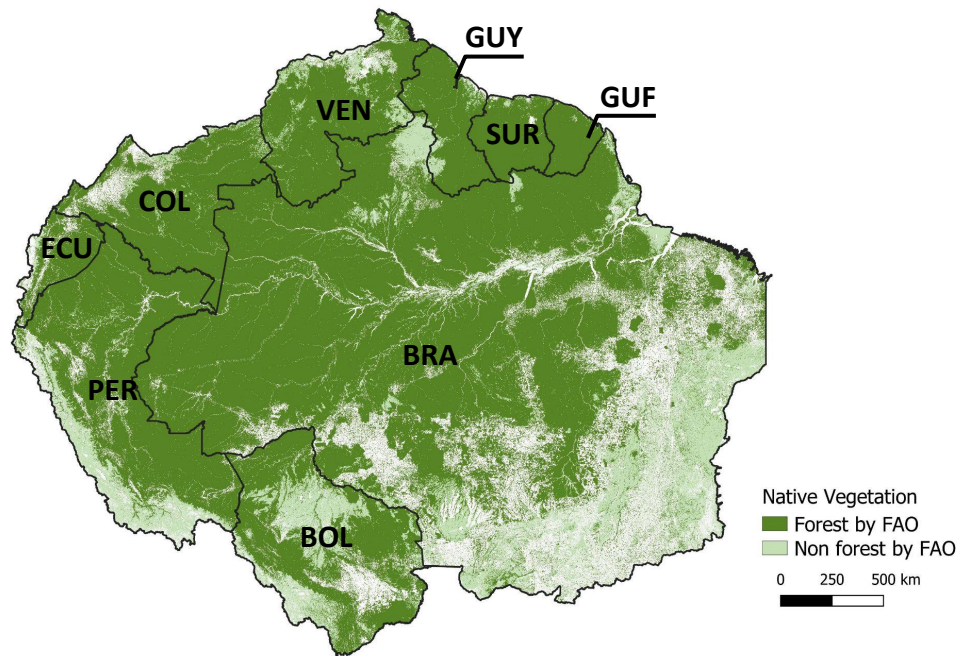
2. Method

2.1 Scope

Cerrado

The Cerrado is one of the world's biodiversity hotspots (Myers et al. 2000), and also one of the hottest agriculture expansion frontiers (Spera et al. 2016). The biome has already lost almost half of its original extension (mainly to cattle and soy) (Alencar et al. 2020). It has a highly specialized unique vegetation with gradients of forest, savannas and grasslands (Ribeiro & Walter, 2008), but only 6.5% of its territory are legally protected areas (Françoso et al. 2015).

55% of the Cerrado biome are native vegetation, whereas the non-forest natural ecosystems represent 41% of the biome.


Native vegetation
- Forest by FAO
- Non forest by FAO

0   250   500 km
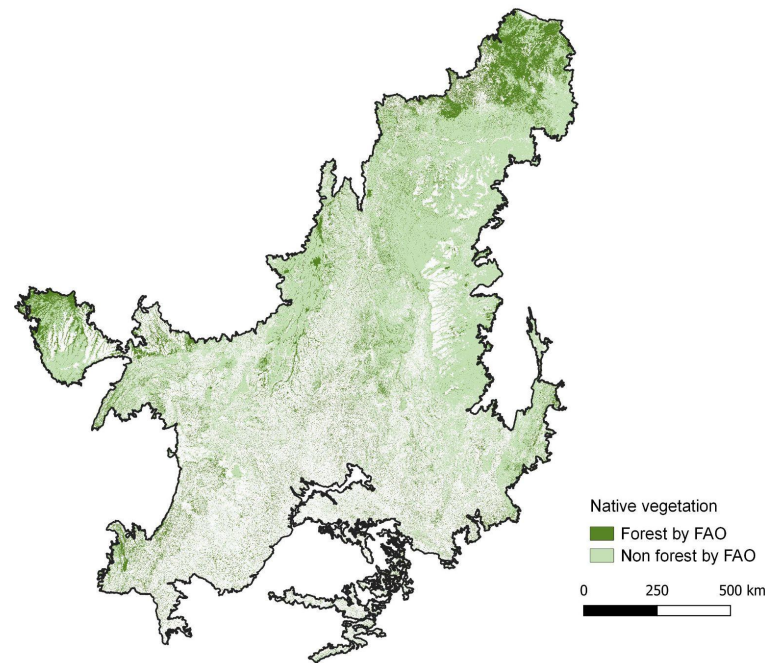
2. Method

2.1 Scope

Caatinga

The Caatinga biome occurs exclusively in Brazil. It is a vast semi-arid region dominated by deciduous and xerophytic woodlands (Da Costa et al. 2007). Around 35% of its extension has been converted to farming, of which 15% suffers desertification (Leal et al. 2005). The main drivers of conversion are cattle ranching, smallholder livestock production, non-timber forestry, and large-scale irrigated agriculture.

64% of the Caatinga biome are covered with native vegetation, whereas the non-forest natural ecosystems represent 58% of the biome.
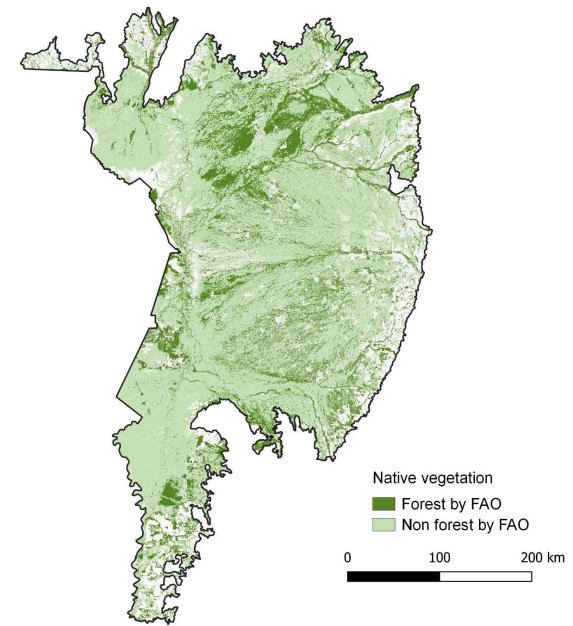

Native vegetation
- Forest by FAO
- Non forest by FAO

0   250   500 km

Diego Pereira Costa

Diego Pereira Costa
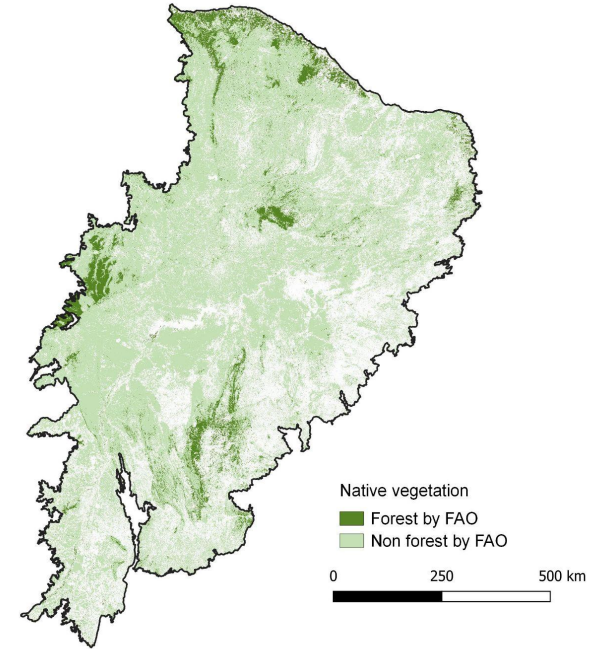
2. Method

2.1 Scope

Pantanal

The Pantanal is the world's largest tropical wetland. Its overall vegetation cover is still preserved (Souza Jr. et al. 2020), but under high conversion pressure due to cattle ranching (Seidl et al. 2001). The worst impacts are on the water system, where Cerrado deforestation upstream stilts the riverbeds and reduces the water flows (Bergier, 2013).

80% of the Pantanal biome are native vegetation, whereas the non-forest natural ecosystems represent 61% of the biome.


Native vegetation
- Forest by FAO
- Non forest by FAO

0   100   200 km

SOS Pantanal

2. Method

2.1 Scope

Chaco

The Chaco is the largest forest in South America after the Amazon rainforest. It is a semi-arid lowland covered by mixed dry forests, grasslands and wetlands. **With 81% of its native vegetation still preserved**, it has nonetheless one of the world's highest conversion rates, due to large scale cattle and soy expansion. **The non-forest natural ecosystems represent 20% of the Chaco biome.**
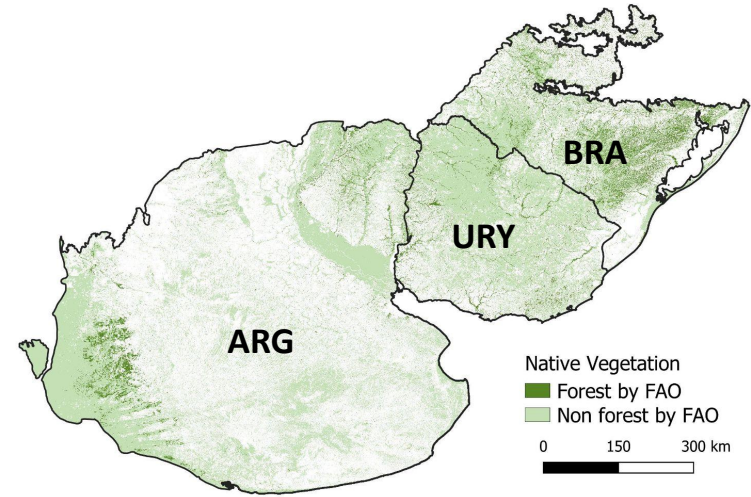

BOL

PAR

ARG

Native Vegetation
Forest by FAO
Non forest by FAO

0   250   500 km

Lidia Núñez

Mário Barroso
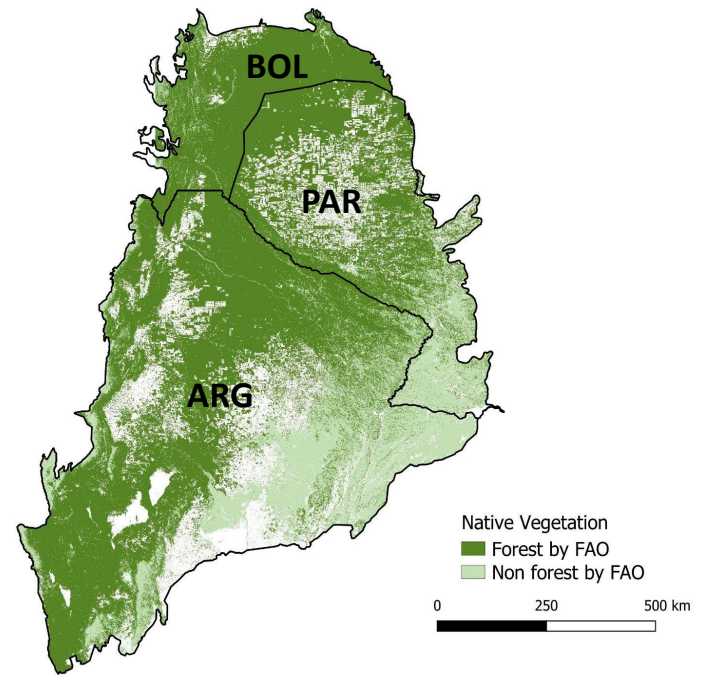
2. Method

2.1 Scope

Pampa

The Pampa is a vast region dominated by natural grasslands (Andrade et al. 2018). Nearly half of it has already been converted to large-scale crop production and cattle ranching. At the same time, protected areas are less than 0.5% of the biome (Overbeck et al. 2007). Most of the conversion occurs on the natural grasslands, with almost 17% increase of farming cover since the year 2000.

**43% of the Pampa biome are under native vegetation, where the non-forest natural ecosystems represent 38% of the biome.**

Native Vegetation
- Forest by FAO
- Non forest by FAO

0   150   300 km

Eduardo Vélez-Martin

Eduardo Vélez-Martin

2. Method

2.1 Scope

Atlantic Forest

The Atlantic Forest occupies 8% of South America, of which 6% is in Paraguay, 2% in Argentina and 92% in Brazil. Native vegetation now covers 37% of the biome's extent, with a high rate of secondary vegetation and many fragmented areas (Rosa et al. 2021). In Brazil, the Atlantic Forest covers about 15% the territory and is home to 72% of the population, concentrating 70% of the national GDP. It provides many essential services, such as water supply, climate regulation, agriculture, fisheries, energy production and tourism (www.sosma.org.br).

37% of the Atlantic Forest biome are native vegetation, whereas the non-forest natural ecosystems represent 11% of the biome.
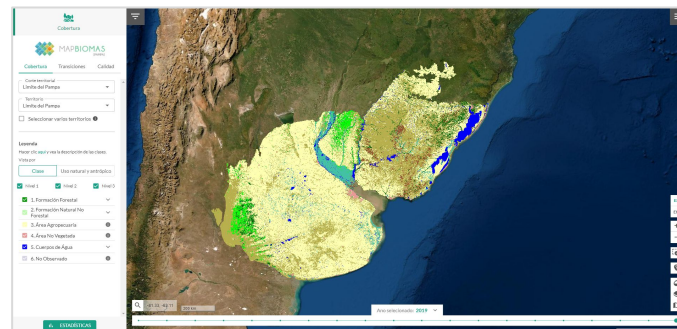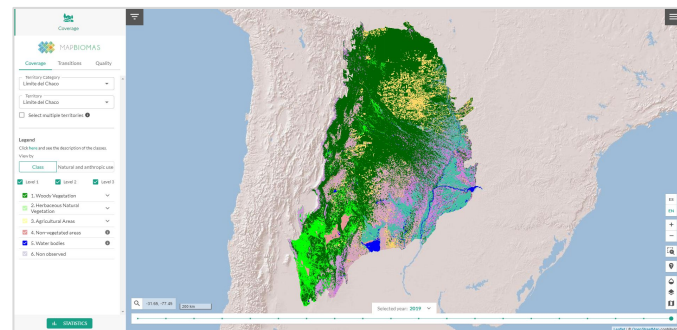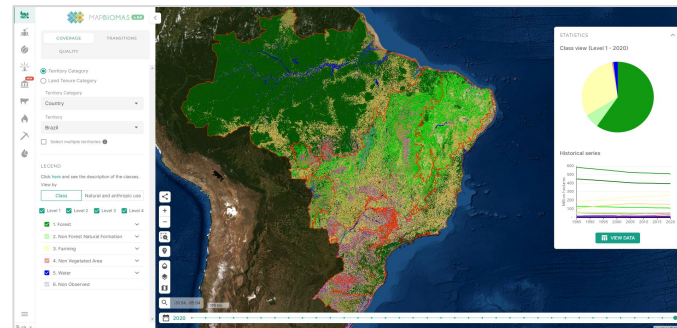

Native Vegetation
- Forest by FAO
- Non forest by FAO

0 250 500 km

PRY
BRA
ARG

SVMA 2020

13
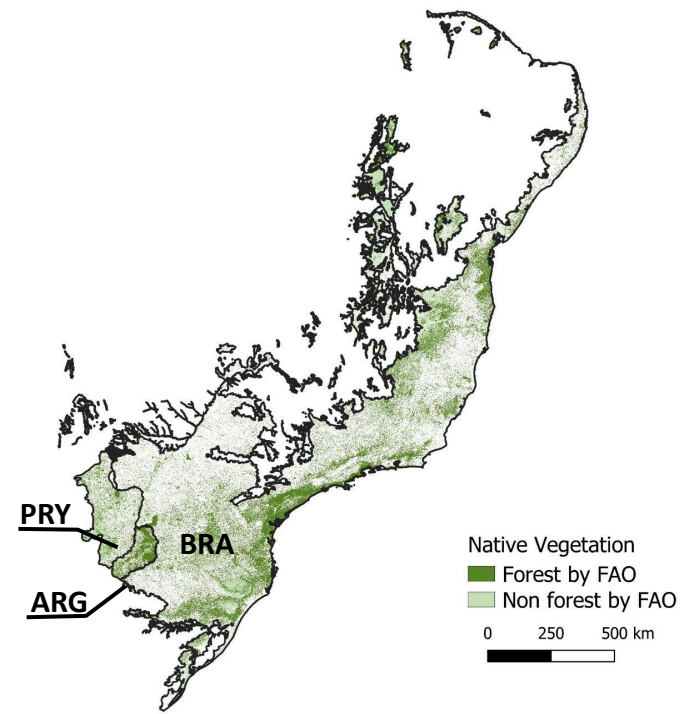
2. Methods

2.2 MapBiomas land cover and land use data

The proportion of the natural ecosystems detected by MapBiomas that would fit the FAO definition of forest was calculated, as well as the non-forest natural ecosystems that do not meet the FAO definition.

MapBiomas data for the Amazon, Atlantic Forest, Chaco, Pampa and for the Brazilian biomes Caatinga, Cerrado and Pantanal from 2000 to 2019 were used in this analysis.

INITIATIVE	COLLECTION Nº	PERIOD	Nº CLASSES
BRAZIL - https://mapbiomas.org/ (Cerrado, Caatinga and Pantanal)	6	1985-2020	25
CHACO - https://chaco.mapbiomas.org/	2	2000-2019	15
PAMPA - https://pampa.mapbiomas.org/	1	2000-2019	8
AMAZON - https://amazonia.mapbioma.osrg/	3	1985-2020	15
ATLANTIC FOREST https://bosqueatlantico.mapbiomas.org/	1	2000-2019	13

2. Methods

2.3. Legend correspondence between MapBiomas and FAO

The MapBiomas classes of native vegetation cover corresponding to FAO definition of forest in the seven mapped biomes (Amazon, Chaco, Atlantic Forest, Cerrado, Pantanal, Pampa and Caatinga) were clustered into two categories:

1. Correspondence to the FAO definition of Forest: Forest, Flooded Forest, Mangroves and Natural Woodlands;

2. Non-forest natural ecosystems not corresponding to the FAO definition of Forest: Savannas, Open Woodlands, Grasslands, Wetlands and Other Non-Forest Natural Formation.

This correspondence between MapBiomas classes and FAO definition of forest was based on the MapBiomas ATBDs and FAO (2012).

BRAZIL Collection 6	AMAZON Collection 3	ATLANTIC FOREST Collection 1	CHACO Collection 2	PAMPA Collection 1	FAO
1. Forest (1)	**1. Forest (1)**	**1.1 Natural Forest (2)**	**1.1. Woody Natural Vegetation (2)**	**1. Natural Forest (2)**	**Forest**
1.1. Forest Formation (3)	1.1. Forest Formation (3)	1.1.1 Forest Formation (3)	1.1.1. Closed Natural Woodlands (3)	1.1.1. Forest Formation (3)	Forest by FAO
			1.1.2. Open Natural Woodlands (4)		Forest by FAO
1.3. Mangrove (5)	1.3. Mangrove (5)				Forest by FAO
1.4. Wooded Restinga (49)					Forest by FAO
	1.4. Flooded Forest (6)		1.1.4. Flooded Natural Woodlands (6)		Forest by FAO
1.2. Savanna Formation (4)	1.2. Savanna Formation (4)	1.1.2 Savanna Formation (4)	1.1.3. Sparse Natural Woodlands (45)	1.1.2. Savanna Formation (4)	**Non-Forest by FAO**
2. Non Forest Natural Formation (10)	**2. Non Forest Natural Formation (10)**	**2. Non Forest Natural Formation (10)**	**2. Herbaceous Natural Vegetation (10)**	**2. Non Forest Natural Formation (10)**	**Non-Forest by FAO**
2.1. Flooded Grassland and Swamped Area (11)	2.1. Flooded Grassland and Swamped Area (11)	2.1. Flooded Grassland and Swamped Area (11)	2.1. Grassland (12)	2.1. Wetland (11)	
2.2. Grassland (12)	2.2. Grassland (12)	2.2. Grassland (12)	2.1. Grassland (12)	2.2. Grassland (12)	
2.3. Salt Flat (32)			2.1.1. Open Grassland (42)		**Non-Forest by FAO**
2.4. Rocky Outcrop (29)	2.3. Rocky Outcrop (29)	2.4. Rocky Outcrop (29)	2.1.2. Closed Grassland (43)		
2.6. Other non Forest Formations (13)	2.4. Other non Forest Formations (13)	2.5. Other non Forest Formations (13)	2.1.3. Sparse Grassland (44)		
			2.1.4. Flooded Grassland (11)		

3. RESULTS

3.1 Main Findings

- From a total of **1,073 Mha** of native vegetation remnants from the seven biomes, covering all Amazon, Atlantic Forest, Chaco, Pampa, Caatinga, Cerrado and Pantanal biomes, **the FAO forest definition criterion would only include 745.5 Mha, 69.5% of the natural ecosystems in these biomes.**

- **327.1 Mha of non-forest natural ecosystems are not included in the FAO definition. 30.5% of these natural ecosystems would not be protected by the EU regulation, corresponding to more than 5 times the size of France.**

Area of Forest and Non-Forest Natural Ecosystems by FAO definition in 2019 (MapBiomas)				
Biomes	**Forest by FAO (ha)**	**Non-Forest by FAO (ha)**	**Non-Forest by FAO (%)**	**Total**
Amazon	593,715,426	109,296,330	15.6%	703,011,755
Cerrado*	28,271,277	80,733,503	74.1%	109,004,780
Chaco	73,428,428	24,025,433	24.7%	97,453,861
Caatinga*	5,321,260	50,014,725	90.4%	55,335,985
Pampa	4,917,207	38,566,667	88.7%	43,483,874
Atlantic Forest	36,928,649	15,310,601	29.3%	52,239,250
Pantanal*	2,920,368	9,150,443	75.8%	12,070,811
Total	**745,502,615**	**327,097,702**	**30.5%**	**1,072,600,317**

Non-Forest by FAO
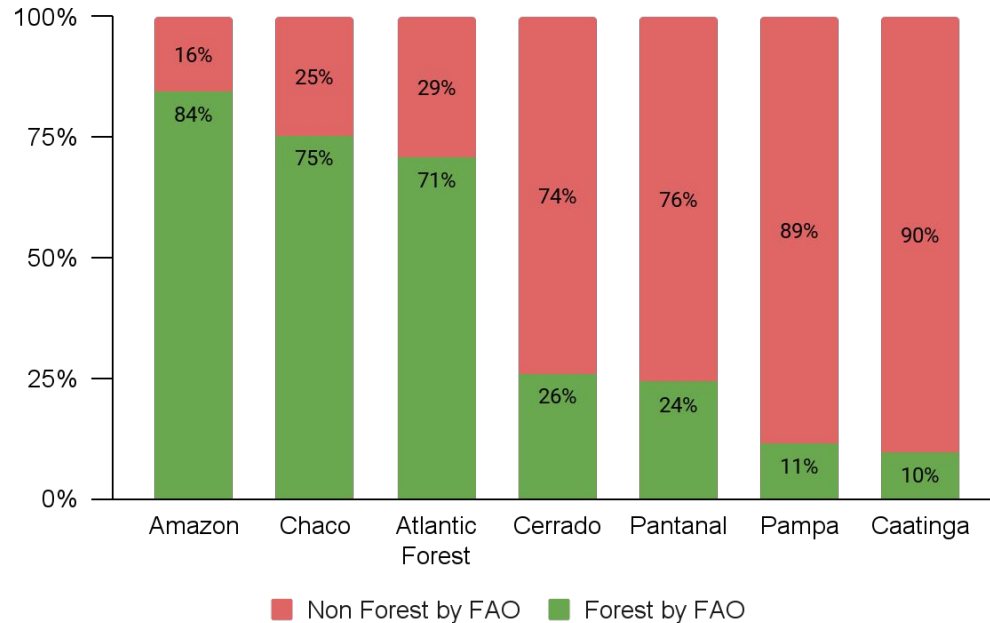30.5%

Forest by FAO
69.5%
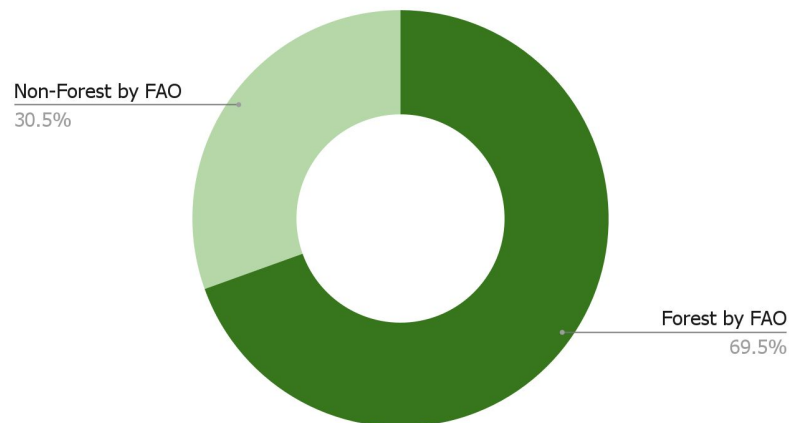
* Cerrado, Caatinga and Pantanal were considered only in the Brazilian territory.

3. RESULTS

3.1 Main findings
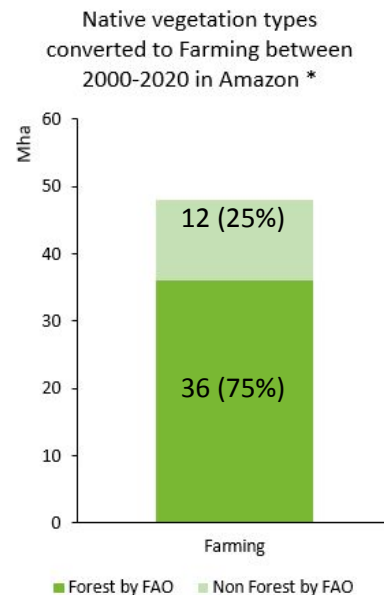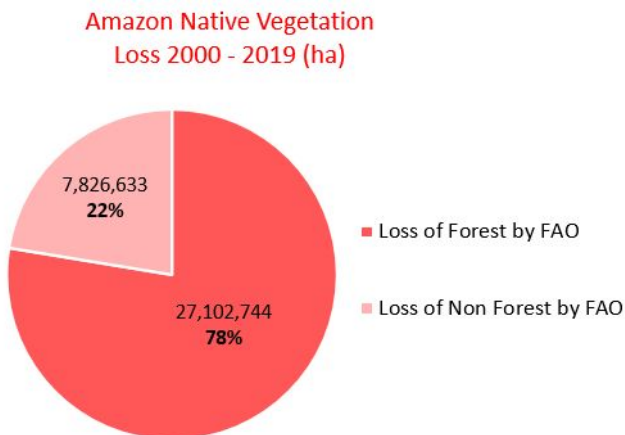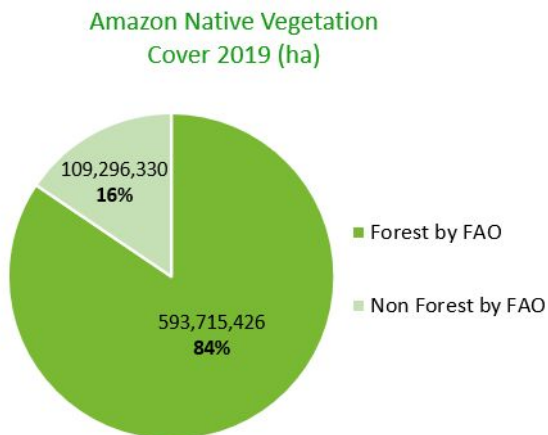
Native vegetation cover according to FAO definition

- The FAO forest definition covers mostly three of the seven mapped biomes: the **Amazon (84%), the Chaco (75%) and the Atlantic Forest (71%).**

- The **Caatinga, Pampa, Pantanal and Cerrado showed the largest gaps** (only 10% forest in Caatinga, 11% in Pampa, 24% in Pantanal, 26% in the Cerrado).

3. RESULTS

3.2 Amazon
(BRA, BOL, COL, ECU, GUY, GUF, PER, SUR, VEN)

- **16% of the Amazon native vegetation would not be protected by the FAO definition, an area twice the size of Spain.**

- 22% of native vegetation loss between 2000 and 2019 were in non-forest natural ecosystems.

- 12 Mha of non-forest vegetation were converted to farming lands in the last 20 years, representing 25% of native vegetation loss to farming.

Amazon Native Vegetation Cover 2019 (ha)

- 109,296,330 **16%** — Non Forest by FAO
- 593,715,426 **84%** — Forest by FAO

Amazon Native Vegetation Loss 2000 - 2019 (ha)

- 7,826,633 **22%** — Loss of Non Forest by FAO
- 27,102,744 **78%** — Loss of Forest by FAO

Native vegetation types converted to Farming between 2000-2020 in Amazon *

- 12 (25%) Non Forest by FAO
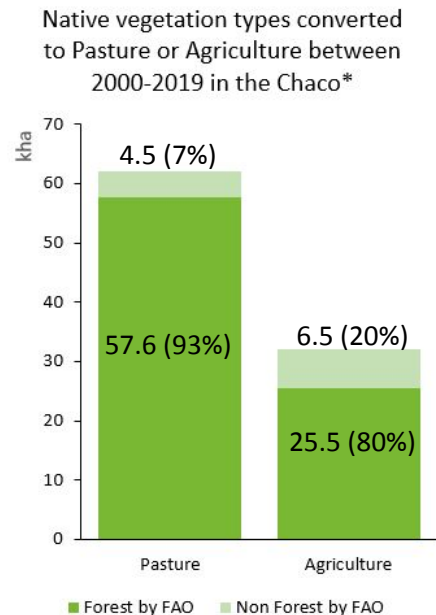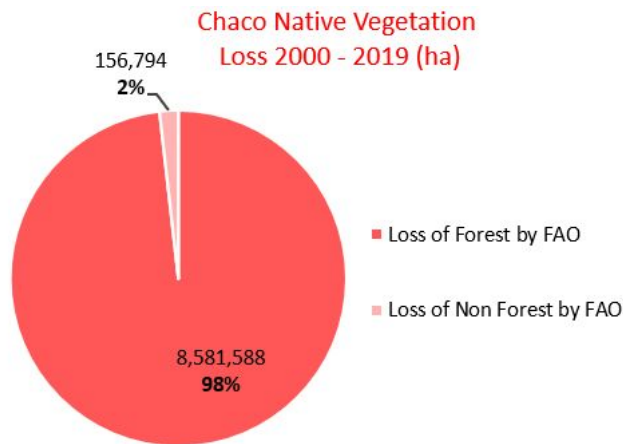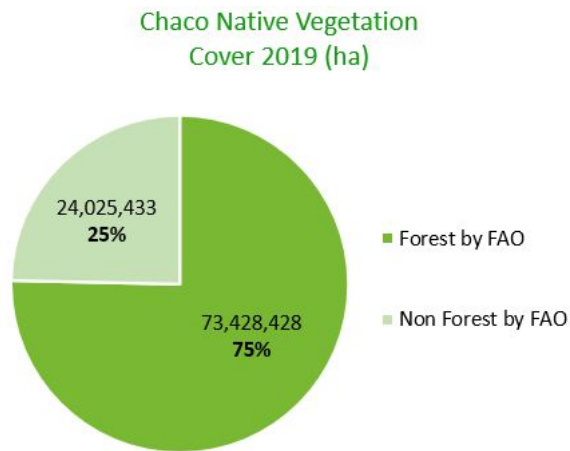- 36 (75%) Forest by FAO

* It is not necessarily a direct conversion, other land uses and land covers could be present between the 2000 and 2020.

3. RESULTS

3.3 Chaco
(ARG, BOL, PAR)

- **25% of the Chaco native vegetation would not be protected by the FAO definition, an area nearly the size of United Kingdom.**

- 2% of native vegetation loss between 2000 and 2019 were in non-forest natural ecosystems.

- 4.5k ha of non-forest vegetation was converted to pasture, and 6.5k ha to agriculture, where 7% and 20% of native vegetation conversion to pasture and agriculture, respectively, were in non-forest natural ecosystems.

Chaco Native Vegetation Cover 2019 (ha)

24,025,433
25%

73,428,428
75%

- Forest by FAO
- Non Forest by FAO

Chaco Native Vegetation Loss 2000 - 2019 (ha)

156,794
2%

8,581,588
98%

- Loss of Forest by FAO
- Loss of Non Forest by FAO

Native vegetation types converted to Pasture or Agriculture between 2000-2019 in the Chaco*

kha

4.5 (7%)

57.6 (93%)

6.5 (20%)

25.5 (80%)

Pasture   Agriculture

- Forest by FAO
- Non Forest by FAO

* It is not necessarily a direct conversion, other land uses and land covers could be present between the 2000 and 2019.
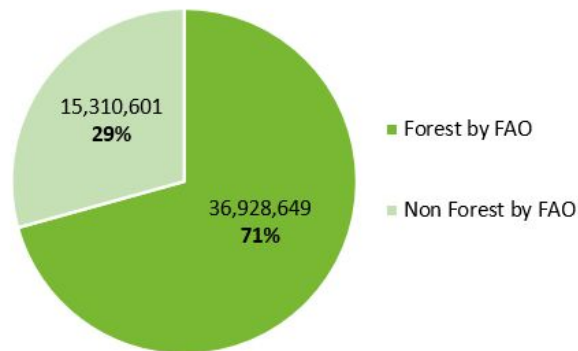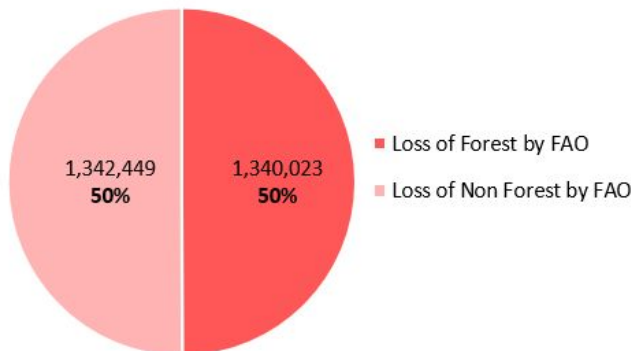
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3. RESULTS

3.4 Atlantic Forest
(BRA, ARG, PAR)

- **29% of the Atlantic Forest native vegetation would not be protected by the FAO definition, an area larger than Greece.**

- 50% of native vegetation loss between 2000 and 2019 were in non-forest natural ecosystems.

- 12.1k ha of non-forest vegetation was converted to pasture, and 7.8k ha to agriculture, where 60% and 48% of native vegetation conversion to pasture and agriculture, respectively, were in non-forest natural ecosystems.
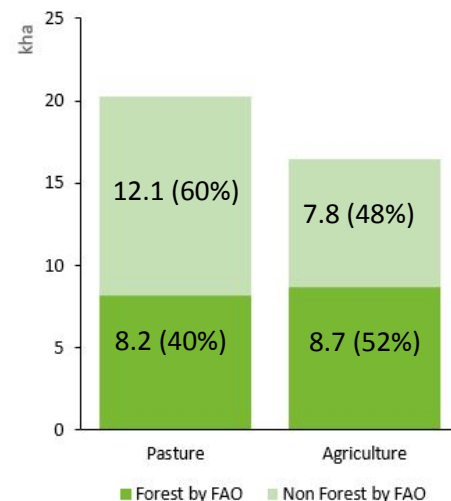

Atlantic Forest Native Vegetation Cover 2019 (ha)

- 15,310,601 **29%** — Non Forest by FAO
- 36,928,649 **71%** — Forest by FAO

Atlantic Forest Native Vegetation Loss 2000 - 2019 (ha)

- 1,342,449 **50%** — Loss of Non Forest by FAO
- 1,340,023 **50%** — Loss of Forest by FAO

Native vegetation types converted to Pasture or Agriculture between 2000-2019 in the Atlantic Forest*

Pasture: 12.1 (60%) Non Forest by FAO; 8.2 (40%) Forest by FAO
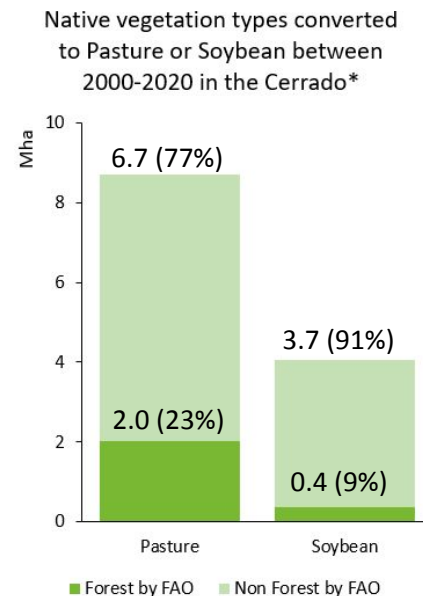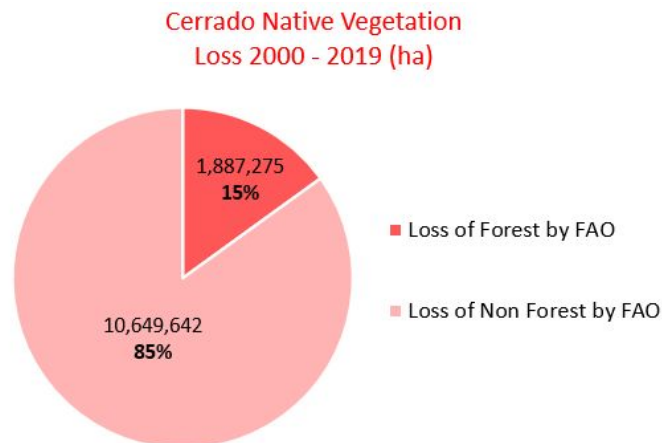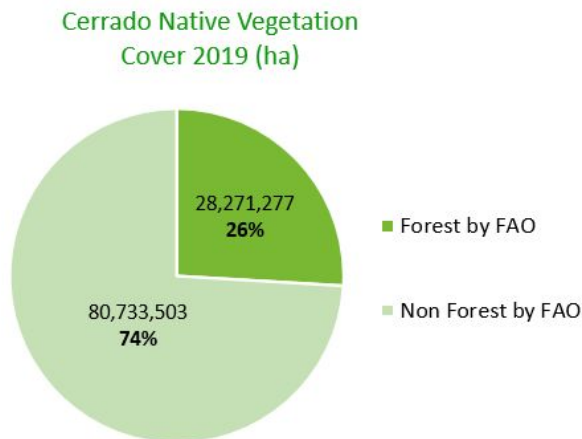Agriculture: 7.8 (48%) Non Forest by FAO; 8.7 (52%) Forest by FAO

* It is not necessarily a direct conversion, other land uses and land covers could be present between the 2000 and 2019.

3. RESULTS

3.5 Cerrado (BRA)

- 74% of the Cerrado native vegetation would not be protected by the FAO definition, an area nearly the size of Ukraine and Belarus combined.

- 85% of native vegetation loss between 2000 and 2019 were in non-forest natural ecosystems.

- 6.7 Mha of non-forest vegetation was converted to pasture, and 3.7 Mha to soybean, representing, respectively.

- 77% of native vegetation conversion to pasture were in non-forest natural ecosystems, in the case of soybean the proportion is even higher - 91%.

Cerrado Native Vegetation Cover 2019 (ha)

- 28,271,277 **26%** — ■ Forest by FAO
- 80,733,503 **74%** — ■ Non Forest by FAO

Cerrado Native Vegetation Loss 2000 - 2019 (ha)

- 1,887,275 **15%** — ■ Loss of Forest by FAO
- 10,649,642 **85%** — ■ Loss of Non Forest by FAO

Native vegetation types converted to Pasture or Soybean between 2000-2020 in the Cerrado*

- Pasture: 6.7 (77%), 2.0 (23%)
- Soybean: 3.7 (91%), 0.4 (9%)

■ Forest by FAO ■ Non Forest by FAO

* It is not necessarily a direct conversion, other land uses and land covers could be present between the 2000 and 2020.
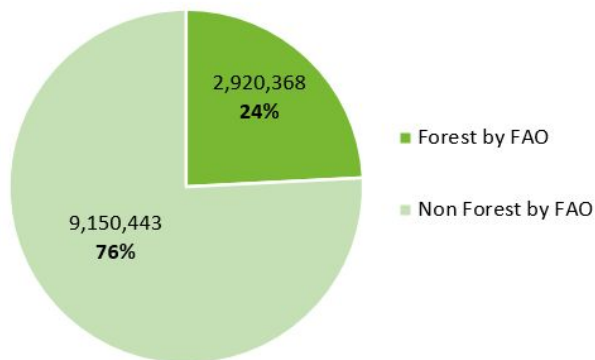
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3. RESULTS

3.6 Pantanal (BRA)

- **76% of the Pantanal native vegetation would not be protected by the FAO definition, an area roughly the size of Portugal.**
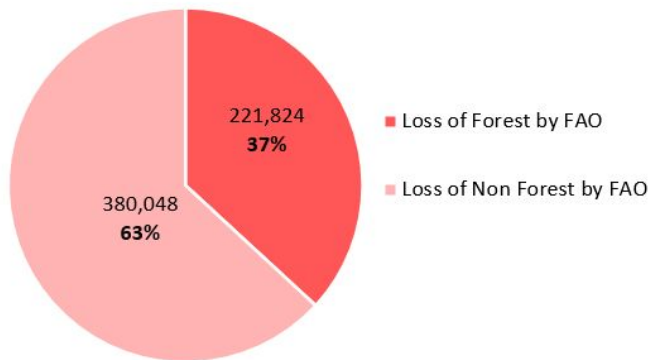
- 63% of native vegetation loss between 2000 and 2019 were in non-forest natural ecosystems.

- 777k ha of non-forest vegetation was converted to farming lands in the last two decades; more than two times the forest lost.

- 73% of native vegetation conversion to farming lands were in non-forest natural ecosystems.
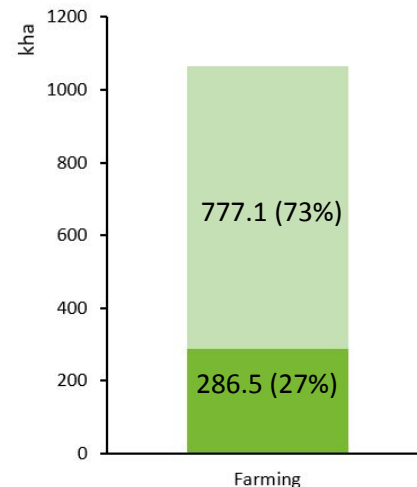
Pantanal Native Vegetation Cover 2019 (ha)

- 2,920,368 **24%** — Forest by FAO
- 9,150,443 **76%** — Non Forest by FAO

Pantanal Native Vegetation Loss 2000 - 2019 (ha)

- 221,824 **37%** — Loss of Forest by FAO
- 380,048 **63%** — Loss of Non Forest by FAO

Native vegetation types converted to Farming between 2000-2020 in Pantanal*

- kha
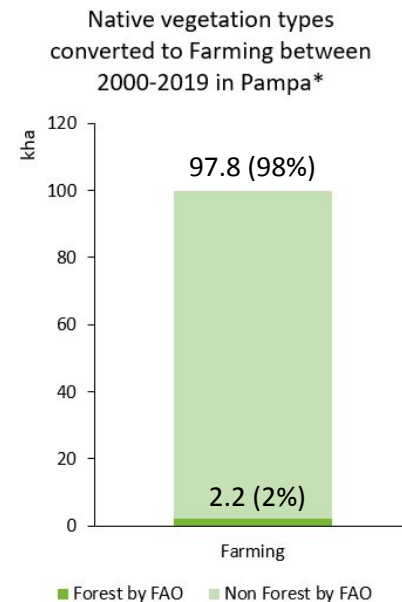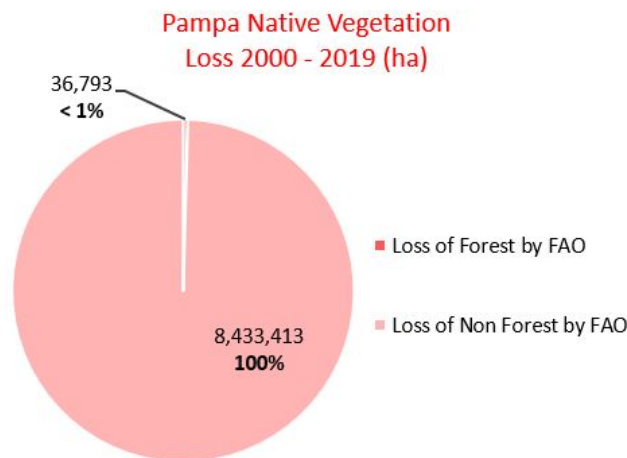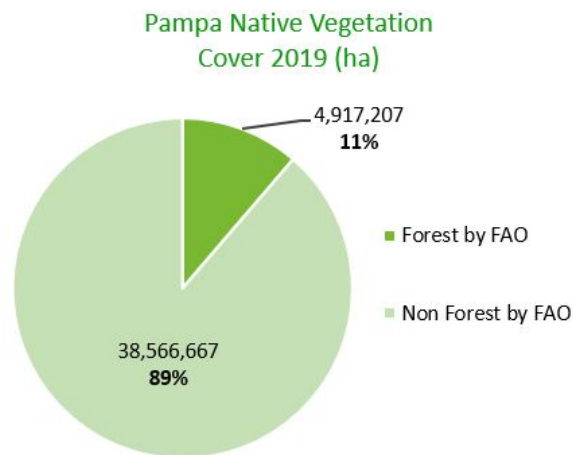- 777.1 (73%)
- 286.5 (27%)
- Farming

* It is not necessarily a direct conversion, other land uses and land covers could be present between the 2000 and 2020.

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3. RESULTS

3.7 Pampa
(BRA, ARG, URY)

- **89% of the Pampa native vegetation would not be protected by the FAO definition, an area larger than Norway.**

- Almost 100% of native vegetation loss between 2000 and 2019 happened in non-forest natural ecosystems.

- 97.8k ha of non-forest vegetation was converted to farming lands between 2000-2019, representing 98% of native vegetation conversion to farming lands.

Pampa Native Vegetation Cover 2019 (ha)

4,917,207 **11%**

38,566,667 **89%**

- Forest by FAO
- Non Forest by FAO

Pampa Native Vegetation Loss 2000 - 2019 (ha)

36,793 **< 1%**

8,433,413 **100%**

- Loss of Forest by FAO
- Loss of Non Forest by FAO

Native vegetation types converted to Farming between 2000-2019 in Pampa*

97.8 (98%)

2.2 (2%)

Farming

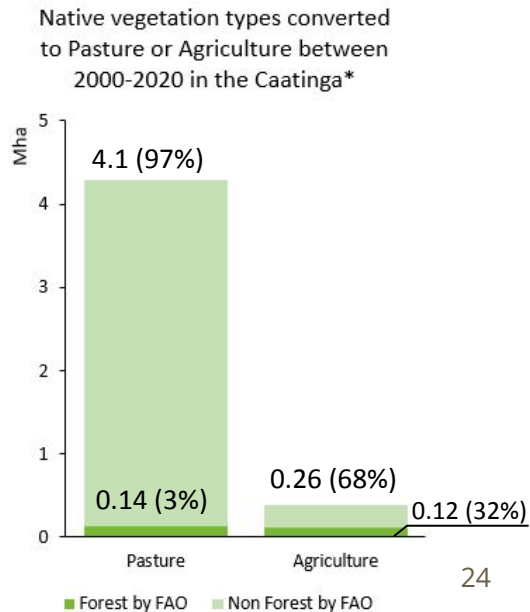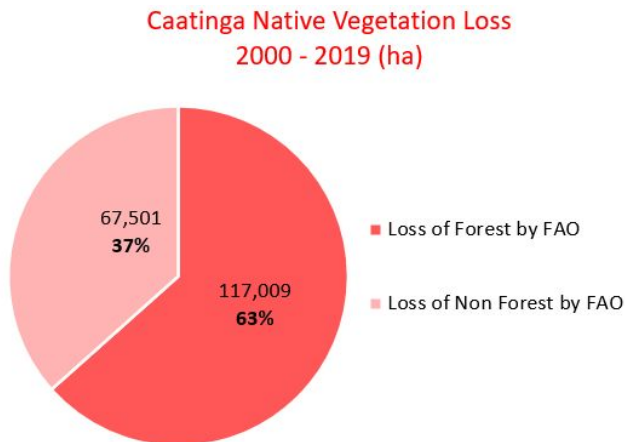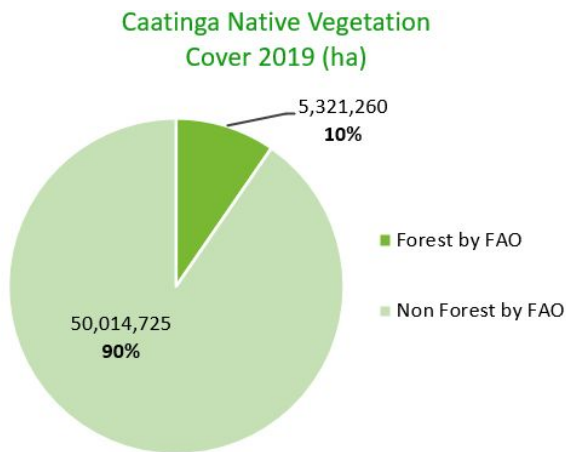- Forest by FAO
- Non Forest by FAO

* It is not necessarily a direct conversion, other land uses and land covers could be present between the 2000 and 2019.

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3. RESULTS

3.8 Caatinga (BRA)

- **90% of the Caatinga native vegetation would not be protected by the FAO definition, an area nearly the size Spain.**

- 37% of native vegetation loss between 2000 and 2019 happened in non-forest natural ecosystems.

- 4.1 Mha of non-forest vegetation was converted to pasture, and 0.26 Mha to agriculture; more than 16 times the forest lost.

- 97% and 68% of native vegetation conversion to pasture and agriculture, respectively, were in non-forest natural ecosystems.

Caatinga Native Vegetation Cover 2019 (ha)

5,321,260 **10%**
50,014,725 **90%**

- Forest by FAO
- Non Forest by FAO

Caatinga Native Vegetation Loss 2000 - 2019 (ha)

67,501 **37%**
117,009 **63%**

- Loss of Forest by FAO
- Loss of Non Forest by FAO

Native vegetation types converted to Pasture or Agriculture between 2000-2020 in the Caatinga*

4.1 (97%)
0.14 (3%)
0.26 (68%)
0.12 (32%)

- Forest by FAO
- Non Forest by FAO

* It is not necessarily a direct conversion, other land uses and land covers could be present between the 2000 and 2020.

4. Concluding remarks

4.1 The natural ecosystems threatened in South American biomes

- The adoption of FAO definition of forest as a criteria for **EU regulation of deforestation free commodities will leave unprotected 30.5% of the natural ecosystems' remnants in seven biomes of South America** (in Amazon, Cerrado, Chaco, Atlantic Forest, Chaco, Pampa and Pantanal) which represents **327.1 million hectares**, corresponding to more than 5 times the size of France. Those would not be covered by the European regulation and thus there would be no assurance that commodities produced in those areas would be free of conversion.

- **Most of the natural ecosystems' remnants in Caatinga, Pampa, Pantanal and Cerrado biomes are categorized as non-forest natural ecosystem as per FAO and thus will not be covered by European regulation.**

- **The Cerrado savannas and grasslands are being converted mostly by pasture and soybean expansion. The Pantanal non-forest natural ecosystems are also critically threatened by pasture expansion.**

- **The Pampa and Caatinga biomes are proportionally the ones with more non-forest natural ecosystems.** In the Pampa biome, grasslands are threatened by farming, while in Caatinga, non-forest natural ecosystems are converted into planted pastures.

  The biomes show different levels of conservation. The Amazon, Chaco and Pantanal still have significant remnants of native vegetation, while the Atlantic Forest, Cerrado, Caatinga and Pampa are already highly impacted. But **all of them under process of deforestation and conversion of natural ecosystems to farming.**

4. Concluding remarks

4.2 Land cover mapping to decision making

- The natural ecosystems dynamics and its conversion to other land uses can be monitored and mapped over the time series using remote sensing, machine learning and local institution collaboration network.

- The MapBiomas network is now mapping all the South American biomes, as well as Indonesia. The MapBiomas approach would allow to efficiently and rapidly generate similar monitoring information where needed, including forest and non-forest natural ecosystems.

- All MapBiomas data and maps of land use and land cover are freely available and transparent in platforms and this knowledge could be taken into account for building legislation, public policy and decision making to evaluate the impacts on these biomes for their long-term protection.

Contact us

Write to us on contato@mapbiomas.org , access our social networks or participate in the MapBiomas Forum, where the user community interacts with the MapBiomas teams on the different technical and scientific aspects of the project.

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References

Alencar, A., Z. Shimbo, J., Lenti, F., Balzani Marques, C., Zimbres, B., Rosa, M., Arruda, V., Castro, I., Fernandes Márcico Ribeiro, J. P., Varela, V., Alencar, I., Piontekowski, V., Ribeiro, V., M. C. Bustamante, M., Eyji Sano, E., Barroso, M. (2020) . Mapping Three Decades of Changes in the Brazilian Savanna Native Vegetation Using Landsat Data Processed in the Google Earth Engine Platform. Remote Sensing, 12(6), 924. https://doi.org/10.3390/rs12060924.

Andrade, B. O., Bonilha, C. L., Overbeck, G. E., Vélez-Martin, E., Rolim, R. G., Bordignon, S. A. L., Schneider, A. A., Ely, C. V., Lucas, D. B., Garcia, E. N., dos Santos, E. D., Torchelsen, F. P., Vieira, M. S., Silva Filho, P. J. S., Ferreira, P. M. A., Trevisan, R., Hollas, R., Campestrini, S., Pillar, V. D., Boldrini, I. I. (2019). Classification of South Brazilian grasslands: Implications for conservation. Applied Vegetation Science, 22(1), 168-184. http://dx.doi.org/10.1111/avsc.12413

Barbosa, R. I., Miranda, I. S. (2004). Fitofisionomias e diversidade vegetal das savanas de Roraima. In: Savanas de Roraima - Etnoecologia, Biodiversidade e Potencialidades Agrossilvipastoris. Ed.: Barbosa, R. I., Xaud, H. A. M., Costa e Souza, J. M. FEMACT, Roraima.

Bergier, I. (2013). Effects of highland land-use over lowlands of the Brazilian Pantanal. Science of the Total Environment, 463, 1060-1066. https://doi.org/10.1016/j.scitotenv.2013.06.036

Coelho-Junior, M. G., Valdiones, A. P., Shimbo, J. Z., Silgueiro, V., Rosa, M., Marques, C. D. L., Oliveira, M., Araújo, S., Azevedo, T. (2022). Unmasking the impunity of illegal deforestation in the Brazilian Amazon: a call for enforcement and accountability. Environmental Research Letters, 17(4), 041001. https://doi.org/10.1088/1748-9326/ac5193

da Costa, R. C., de Araújo, F. S., Lima-Verde, L. W. (2007). Flora and life-form spectrum in an area of deciduous thorn woodland (caatinga) in northeastern, Brazil. Journal of Arid Environments, 68(2), 237-247. https://doi.org/10.1016/j.jaridenv.2006.06.003

de Oliveira, G., Araújo, M. B., Rangel, T. F., Alagador, D., Diniz-Filho, J. A. F. (2012). Conserving the Brazilian semiarid (Caatinga) biome under climate change. Biodiversity and Conservation, 21, 2913–2926. https://doi.org/10.1007/s10531-012-0346-7

Devecchi, M. F., Lovo, J., Moro, M. F., Andrino, C. O., Barbosa-Silva, R. G., Viana, P. L., Giulietti, A. M., Antar, G., Watanabe, M. T. C., Zappi, D. C. (2020). Beyond forests in the Amazon: biogeography and floristic relationships of the Amazonian savannas. Botanical Journal of the Linnean Society, 193(4), 478–503. https://doi.org/10.1093/botlinnean/boaa025

FAO (2012). Manual for integrated field data collection. Rome: FAO.

Françoso, R. D., Brandão, R., Nogueira, C. C., Salmona, Y. B., Machado, R. B., Colli, G. R. (2015). Habitat loss and the effectiveness of protected areas in the Cerrado Biodiversity Hotspot. Natureza & Conservação, 13 (1), 35-40. https://doi.org/10.1016/j.ncon.2015.04.001

Leal, I. R., Da Silva, J. M. C., Tabarelli, M., & Lacher Jr, T. E. (2005). Changing the course of biodiversity conservation in the Caatinga of northeastern Brazil. Conservation Biology, 19(3), 701-706. http://dx.doi.org/10.1111/j.1523-1739.2005.00703.x

MapBiomas Project (2022). MapBiomas General "Handbook" - Algorithm Theoretical Basis Document (ATBD), Collection 6, Version 1.0 , accessed on April 2022 through the link: https://mapbiomas-br-site.s3.amazonaws.com/Metodologia/ATBD_Collection_6_v1_January_2022.pdf

MapBiomas Project (2021). MapBiomas Amazon "Handbook" - Algorithm Theoretical Basis Document (ATBD) - RAISG - MapBiomas Amazonía, Collection 3, Version 1.0 , accessed on April 2022 through the link: https://s3.amazonaws.com/amazonia.mapbiomas.org/atbd/atbd%20general/ATBD_Geral_MapBiomas_Amazonia_3.0.en_proceso_de_elaboraci%C3%B3n.pdf

References

MapBiomas Project (2020). MapBiomas Chaco"Handbook" - Algorithm Theoretical Basis Document (ATBD), Collection 2, Version 1.0 , accessed on April 2022 through the link:
https://mapbiomas-br-site.s3.amazonaws.com/MapBiomas%20CHACO/Colecao_2/ATBD/ATBD_-_MapBiomas_Chaco_Collection2.pdf

MapBiomas Project (2021). MapBiomas Atlantic Forest Trinational "Handbook" - Algorithm Theoretical Basis Document (ATBD), Collection 1, Version 1.0 , accessed on April 2022 through the link:
https://mapbiomas-tri-mataatlantica-site.s3.amazonaws.com/download/Cole%C3%A7%C3%A3o_1/ATDB_Atlantic-Forest-Trinational.pdf

MapBiomas Project (2021). MapBiomas Trinational Pampa "Handbook" - Algorithm Theoretical Basis Document (ATBD), Collection 1, Version 1.1 , accessed on April 2022 through the link:
https://mapbiomas-tri-pampa-site.s3.amazonaws.com/ATBD_Collection_1_PampaTrinational_v1.1__1_.pdf

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B., Kent, J. (2000). Biodiversity hotspots for conservation priorities. Nature, 403, 853-858. https://doi.org/10.1038/35002501

Overbeck, G. E., Müller, S. C., Fidelis, A., Pfadenhauer, J., Pillar, V. D., Blanco, C. C., Boldrini, I. I., Both, R., Forneck, E. D. (2007). Brazil's neglected biome: the South Brazilian Campos. Perspectives in Plant Ecology, Evolution and Systematics, 9(2), 101-116. https://doi.org/10.1016/j.ppees.2007.07.005

Ribeiro, J. F., Walter, B. M. T. (2008). As principais fitofisionomias do bioma Cerrado. In: Sano, S. M., Almeida, S. P., Ribeiro, J. F. (Eds.), Cerrado: ecologia e flora (2nd ed., 151–212). Embrapa Informação Tecnológica.

Rosa, M. R., Brancalion, P. H., Crouzeilles, R., Tambosi, L. R., Piffer, P. R., Lenti, F. E., Hirota, M., Santiami, E., Metzger, J. P. (2021). Hidden destruction of older forests threatens Brazil's Atlantic Forest and challenges restoration programs. Science advances, 7(4), eabc4547. https://doi.org/10.1126/sciadv.abc4547

Seidl, A. F., de Silva, J. D. S. V., Moraes, A. S. (2001). Cattle ranching and deforestation in the Brazilian Pantanal. Ecological Economics, 36, 413–425. https://doi.org/10.1016/S0921-8009(00)00238-X

Silva Junior, C. H., Pessoa, A., Carvalho, N. S., Reis, J. B., Anderson, L. O., Aragao, L. E. (2021). The Brazilian Amazon deforestation rate in 2020 is the greatest of the decade. Nature ecology & evolution, 5(2), 144-145. https://doi.org/10.1038/s41559-020-01368-x

Souza Jr., C. M., Z. Shimbo, J., Rosa, M. R., Parente, L. L., A. Alencar, A., Rudorff, B. F. T., Hasenack, H., Matsumoto, M., G. Ferreira, L., Souza-Filho, P. W. M., de Oliveira, S. W., Rocha, W. F., Fonseca, A. V., Marques, C. B., Diniz, C. G., Costa, D., Monteiro, D., Rosa, E. R., Vélez-Martin, E., Weber, E. J., Lenti, F. E. B., Paternost, F. F., Pareyn, F. G. C., Siqueira, J. V., Viera, J. L., Neto, L. C. F., Saraiva, M. M., Sales, M. H., Salgado, M. P. G., Vasconcelos, R., Galano, S., Mesquita, V. V., Azevedo, T. (2020). Reconstructing Three Decades of Land Use and Land Cover Changes in Brazilian Biomes with Landsat Archive and Earth Engine. Remote Sensing, 12, 2735. https://doi.org/10.3390/rs12172735

Spera, S. A., Galford, G. L., Coe, M. T., Macedo, M. N., Mustard, J. F. (2016). Land-use change affects water recycling in Brazil's last agricultural frontier. Global Change Biology, 22(10), 3405-3413. https://doi.org/10.1111/gcb.13298

SVMA, Secretaria do Verde e do Meio Ambiente (2020). Mapeamento Digital da Cobertura Vegetal do Município de São Paulo. Relatório Final. Available on:
https://www.prefeitura.sp.gov.br/cidade/secretarias/upload/meio_ambiente/RelCobVeg2020_vFINAL_compressed(1).pdf

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