Panorama of Brazil's Forest Code

2ª ed.

CSR
CENTRO DE SENSORIAMENTO REMOTO

LAGESA
laboratório de gestão de serviços ambientais

UFMG
UNIVERSIDADE FEDERAL DE MINAS GERAIS

CIT
Centro de Inteligência Territorial

OBSERVATÓRIO DO CÓDIGO FLORESTAL

NICFI
Norway's International Climate and Forest Initiative

JULY | 2023

Policy brief

Centro de Sensoriamento Remoto – CSR/UFMG
Laboratório de Gestão de Serviços Ambientais – LAGESA/UFMG
Universidade Federal de Minas Gerais – UFMG

2ª edition
November 2022
Belo Horizonte/MG, Brazil

Contact: cf@csr.ufmg.br

CSR
CENTRO DE SENSORIAMENTO REMOTO

LAGESA
laboratório de gestão de serviços ambientais

UFMG
UNIVERSIDADE FEDERAL DE MINAS GERAIS

CIT
Centro de Inteligência Territorial

OBSERVATÓRIO DO CÓDIGO FLORESTAL

NICFI
Norway's International Climate and Forest Initiative

10 YEARS OF THE NEW FOREST CODE

The Forest Code (FC) is the main legislation regulating conservation on rural private lands in Brazil[1]. In short, it defines where native vegetation must be conserved or can be suppressed and also establishes ways for managing the use of natural resources in areas of native vegetation. The law basically defines two types of conservation areas on private land: Permanent Preservation Areas (APP), land strips along river, water bodies and springs as well as steep slopes and hilltops, and the Legal Reserve (LR)–a percentage (from 80% in the Amazon to 20% in the other biomes) of the property's area where native vegetation must be conserved. For non-compliant properties, the FC also determines the areas needed to be restored to native vegetation at the owner's expense, i.e., LR and APP illegally deforested before 2008.

On May 25th, 2022, the revisions to the FC completed 10 years. A decade past these revisions that relaxed the country's environmental legislation by granting a large amnesty to past illegal deforesters and lowering the needs to recover native vegetation, this anniversary is marked above all by setbacks in public policies aimed at conserving the vast expanses of native vegetation of Brazil.

Apart from the self-registration on the country's Online Rural Environmental Registry (CAR), which has already surpassed 6.5 million rural properties, there was little progress towards the implementation of mechanisms introduced by the 2012 revision aimed at enabling the enforcement of the FC.

CAR (Environmental Rural Registry) is the first of those mechanism. SICAR is a national public database meant to support environmental regularization and to tackle illegal deforestation. Enrolment on the CAR, the first step towards regularization, is mandatory, although a self-report process. The veracity of CAR data must be checked by the state environmental agencies through the so-called "CAR validation", which has experienced continued delays. So far, validation is still carried out as a manual process that has analyzed no more than 0.49% of properties on SICAR. In the absence of validation, fraudulent CAR registries are often used as a tool for land grabbing, thus threatening protected and public areas and collective lands.

The lack of progress hinders also the implementation of other key mechanisms introduced to help landowners attain compliance, such as the Environmental Regularization Program (PRA), and the Market for Trading Environmental Quotas, also known as Forest Certificates (CRA). In addition to helping solving the country's FC environmental deficit, these mechanisms are essential to further national policies, such as Brazil's Nationally Determined Contribution (NDC), as they can boost large native vegetation restoration programs, providing at the same time monetary return to those who keep or restore native vegetation.

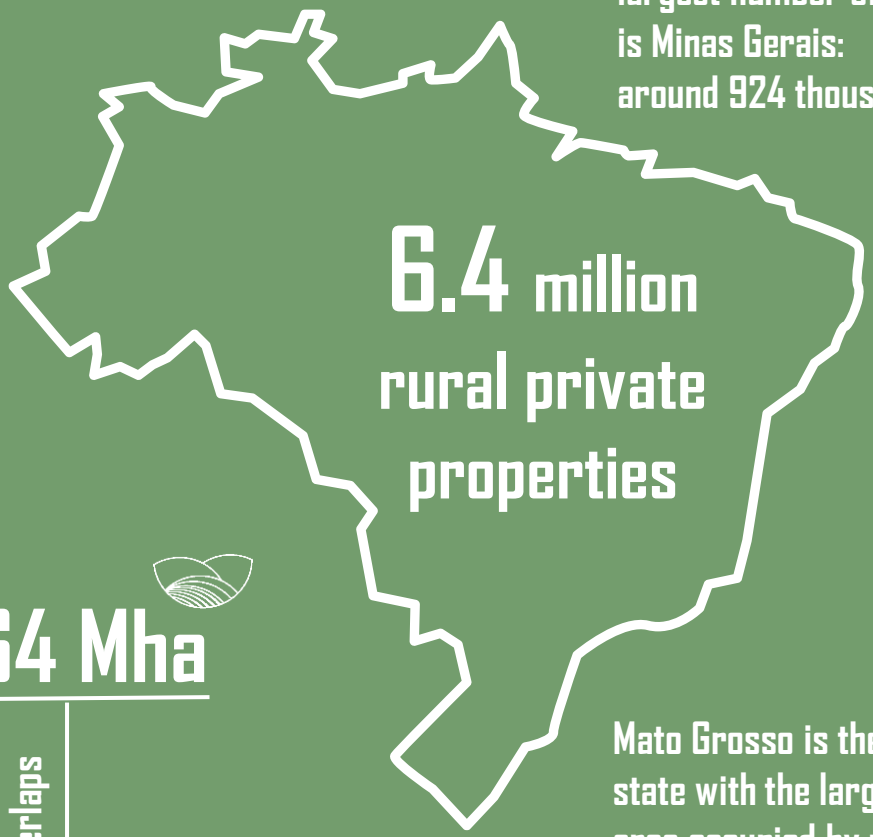
With this in mind, the civil society together with the country's scientific community has made important strides to help the Brazilian states to overcome the CAR validation bottleneck. Advances in computer modeling, the prompt availability of properties' boundaries from the Rural Environmental Registry (CAR), in addition to land use maps for the entire country, have already enabled high spatial resolution analyses[2,3] of the FC balance for numerous properties distributed over large regions of Brazil.

Here we present the results along with the methods of the latest run of our FC model for the country as a whole. The computer model we developed calculates the FC requirements and hence the level of compliance for each one of more than 6.5 million rural private properties (PP) registered on the CAR. For each individual property, the system informs the area requirements for conserving or restoring native vegetation as LR and APP. As a result, the system calculates the deficits (vegetation needed to be restored) or surpluses (vegetation above compliance) of each property. The system also informs on deforestation after 2008 (currently, only available for properties in the Amazon and Cerrado biomes).

Based on these scientific-technological advances, state governments and civil society are now provided with updated estimates of the FC balance as a means to help foster comprehensive public policies aimed at conserving or restoring native vegetation on private lands. The state of Pará has pioneered the application of this technology in order to advance the CAR validation process (the so-called CAR 2.0) as well as to develop SeloVerde–a public and transparent platform that allows tracing cattle and soy from all of the state's rural properties. CAR 2.0 is a science-based system that streamlines the validation process by applying state of art spatially-explicit modelling algorithms, including deep learning, together with high resolution remote sensed data. In turn, SeloVerde platform is a revolutionary technology that supports the due diligence to achieve deforestation-free agricultural supply chains. Both systems are now being expanded to Minas Gerais and other states of Brazil as well.

BRAZIL

The state with the largest number of PP is Minas Gerais: around 924 thousand



464 Mha

Without overlaps

Mato Grosso is the state with the largest area occupied by rural properties: 61 Mha

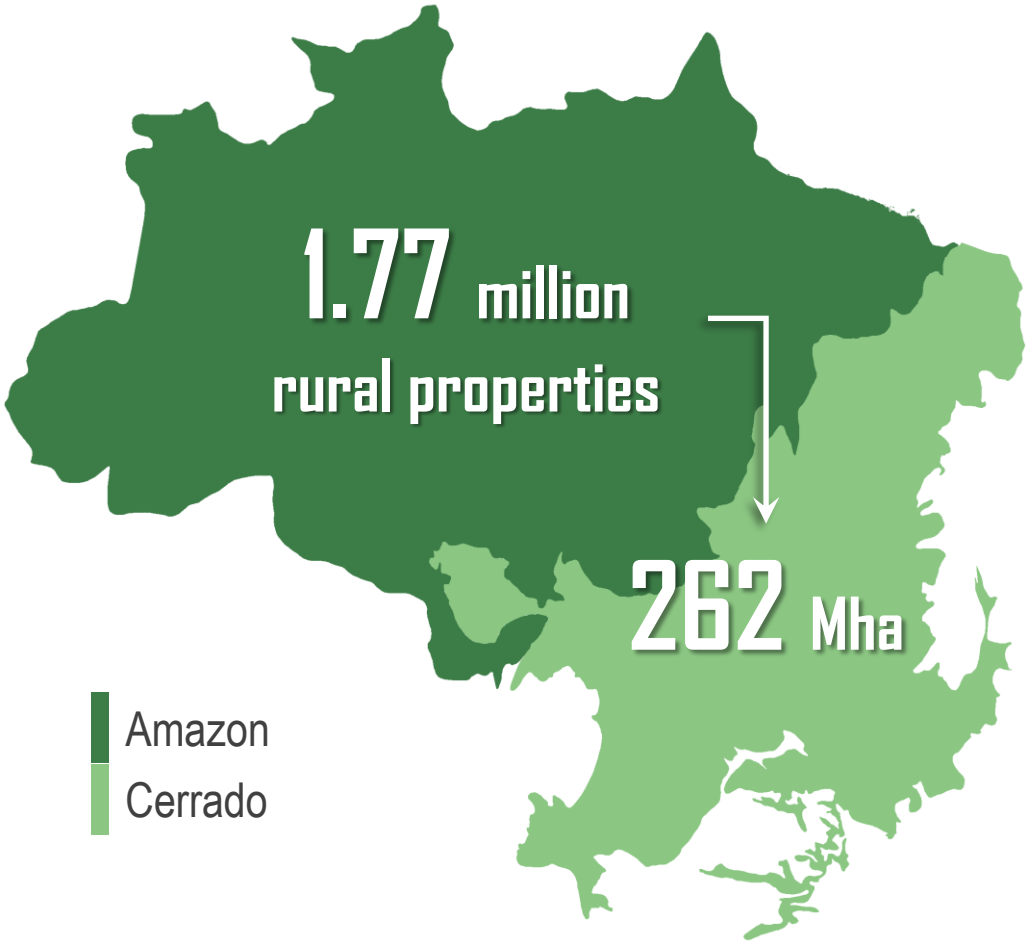
412 Mha | 49% Brazil's territory

77-91 Mha Legal reserve surplus | 16-19 Mha Legal reserve deficit | 3-4 Mha APP deficit

*Data from January 2022.

Biomes

The Amazon and the Cerrado are the two largest Brazilian biomes and the ones where the expansion of the agricultural frontier and deforestation are most critical despite their relevance for sociobiodiversity conservation, climate change mitigation and rainfall regulation. Therefore, the conservation of their native vegetation remnants is key to maintain the country's hydroelectric power generation, water supply to main urban centers, and the productivity of agribusiness in addition to many other ecosystem services.



Amazon

Legal reserve

8 ±1.3 Mha surplus | 9 ±1.3 Mha deficit

Rural properties

0.71 Million | 116 Mha

APP

1.01-1.35 Mha deficit

Deforestation after 2008

4.3 ±0.9 Mha

Cerrado

Rural properties

1.06 Million | 146 Mha

Legal reserve

30 ±2.4 Mha surplus | 4 ±0.3 Mha deficit

APP

0.72-0.95 Mha deficit

Deforestation after 2008

8.2 ±0.8 Mha

Atlantic Forest

Legal reserve

11 ±0.9 Mha surplus | 2.3 ±0.1 Mha deficit

Rural properties

2.60 Million | 79.1 Mha

APP

1.0-1.3 Mha deficit

The Atlantic Forest houses the largest cities of Brazil. Only about 15-20% of its forests remain.

Caatinga

Rural properties

1.80 Million | 44.7 Mha

Legal reserve

18 ±1.2 Mha surplus | 0.1 ±0.01 Mha deficit

APP

0.21-0.28 Mha deficit

Caatinga is the only biome that occurs exclusively in Brazil, it is home to a great diversity of endemic species.

Pantanal

Legal reserve

6.1 ±0.6 Mha surplus | 0.04 ±0.003 Mha deficit

Rural properties

0.01 Million | 12.5 Mha

APP

0.02-0.03 Mha deficit

Pantanal forms unique ecosystems that are prone to annual floods and wildfires as well.

Pampa

Rural properties

0.02 Million | 14.9 Mha

Legal reserve

5.6 ±0.2 Mha surplus | 0.16 ±0.005 Mha deficit

APP

0.09-0.13 Mha deficit

The Pampa biome is mostly converted to agriculture with very little of its natural ecosystem under protection.

Acre

40,614 private properties

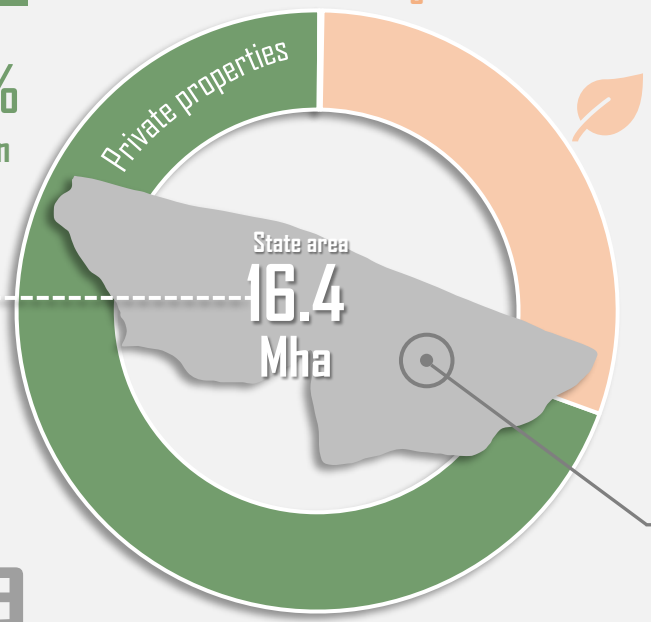
5.1 Mha

31%

70% Native vegetation

0.2% Water body

30% Agricultural land



0.6%

29.8-39.6 thousand ha

APP deficit

Deforestation after 2008

257±63 thousand ha

69%

Deforestation on APPs or with a LR below the minimum

Legal reserve

7% 0.34±0.07 Mha Surplus

4.8% 0.25±0.04 Mha Deficit

Alagoas

105,412 private properties

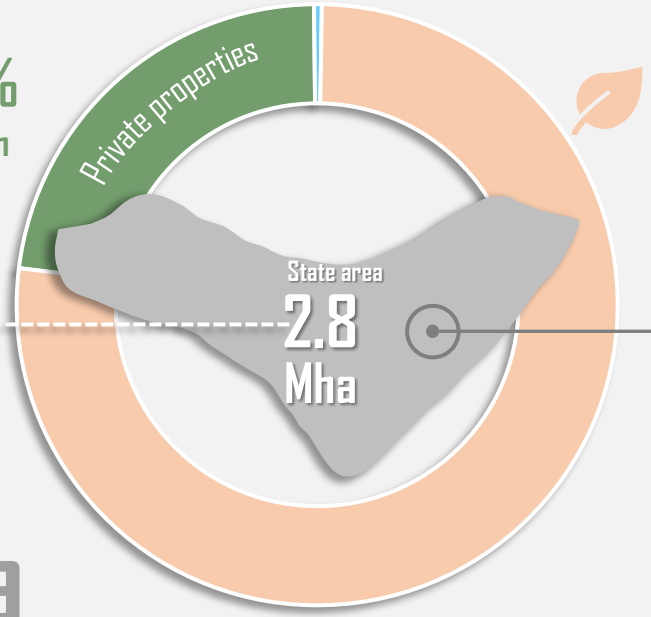
1.7 Mha

62%

23% Native vegetation

0.4% Water body

77% Agricultural land



0.8%

14.3-19.0 thousand ha

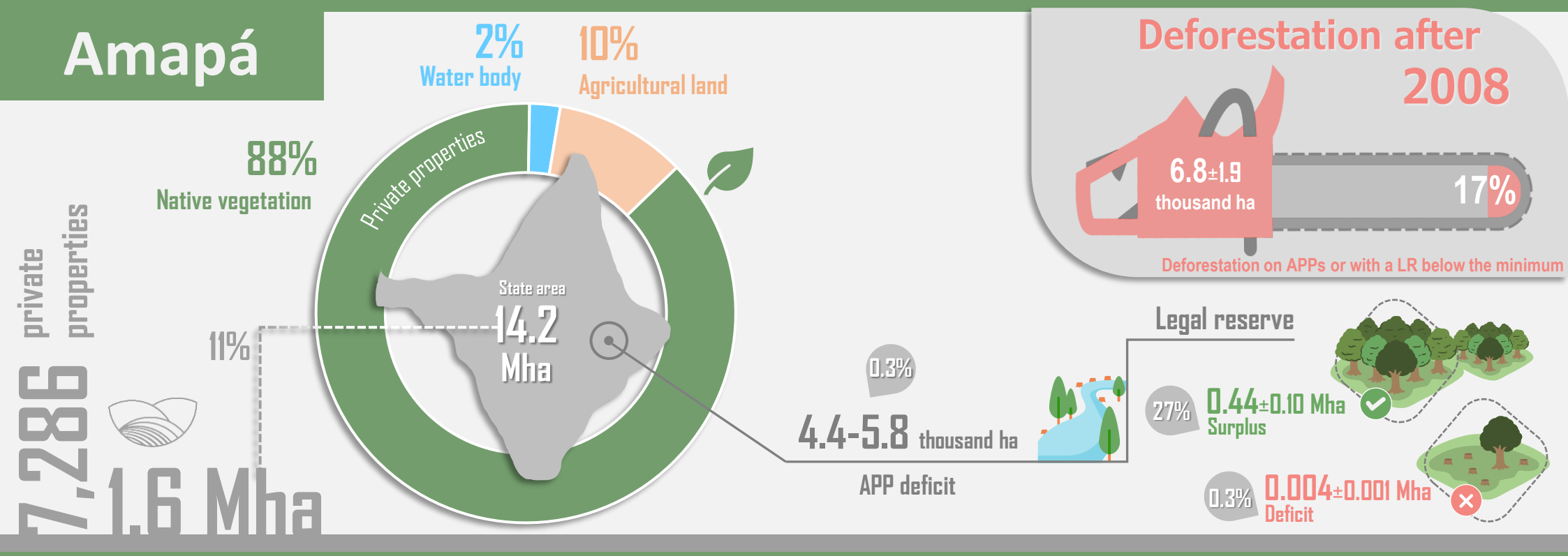
APP deficit

Legal reserve

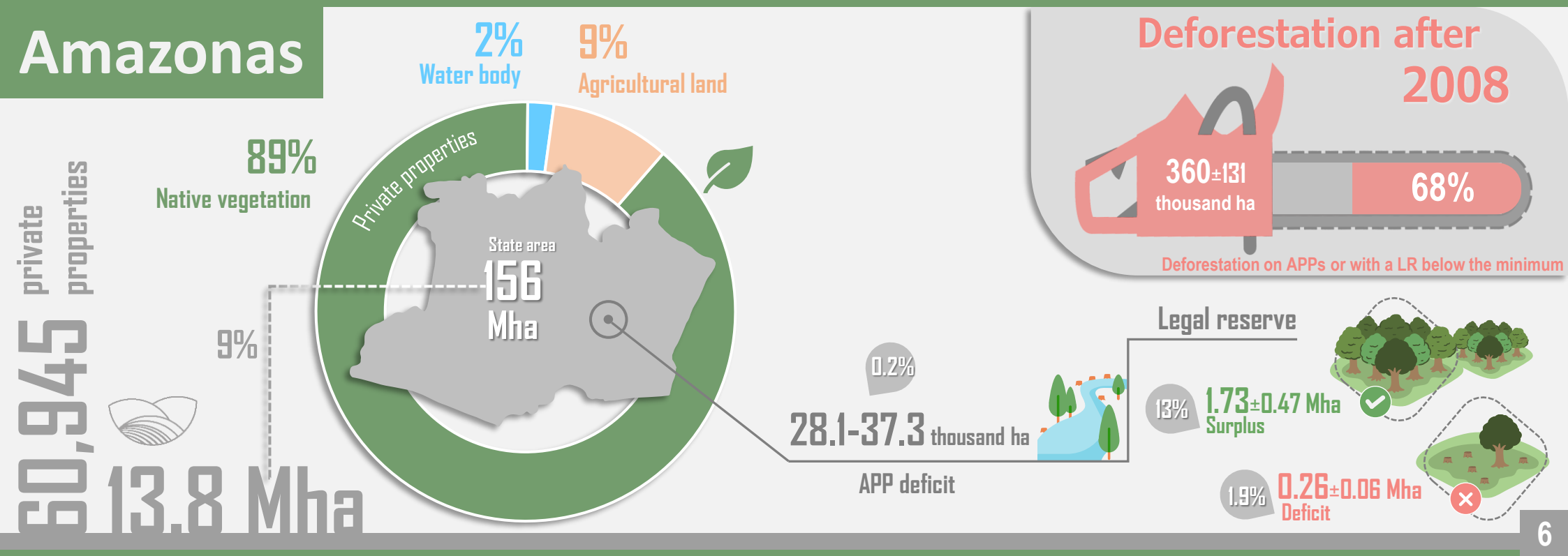
10% 0.18±0.02 Mha Surplus

3.7% 0.06±0.01 Mha Deficit

Amapá



Amazonas



Bahia

923,571 private properties

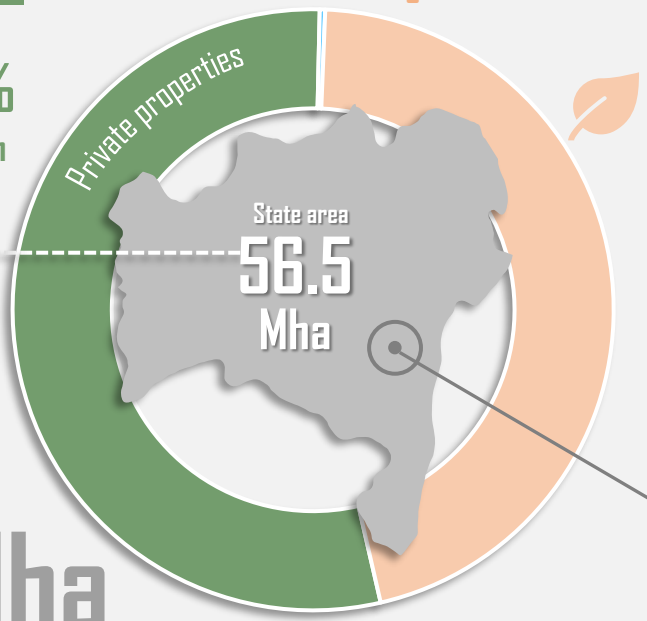
29.5 Mha

52%

54% Native vegetation

0.3% Water body

46% Agricultural land



0.5%

150-200 thousand ha

APP deficit

Deforestation after 2008

1.0±0.01 Mha

3%

Deforestation on APPs or with a LR below the minimum

Legal reserve

36% 10.7±0.12 Mha Surplus

1.1% 0.34±0.003 Mha Deficit

Ceará

287,684 private properties

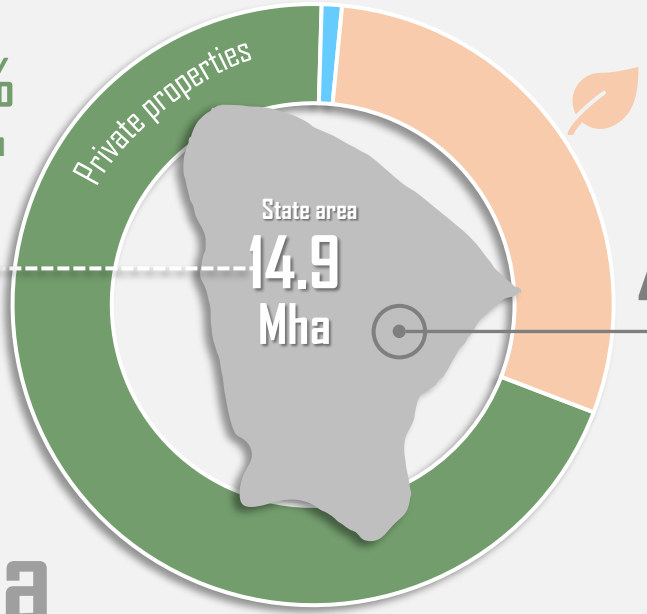
8.2 Mha

55%

70% Native vegetation

1% Water body

29% Agricultural land



0.5%

42.8-57.0 thousand ha

APP deficit

Legal reserve

45% 3.72±0.34 Mha Surplus

0.1% 0.01±0.001 Mha Deficit

Distrito Federal

15,442 private properties

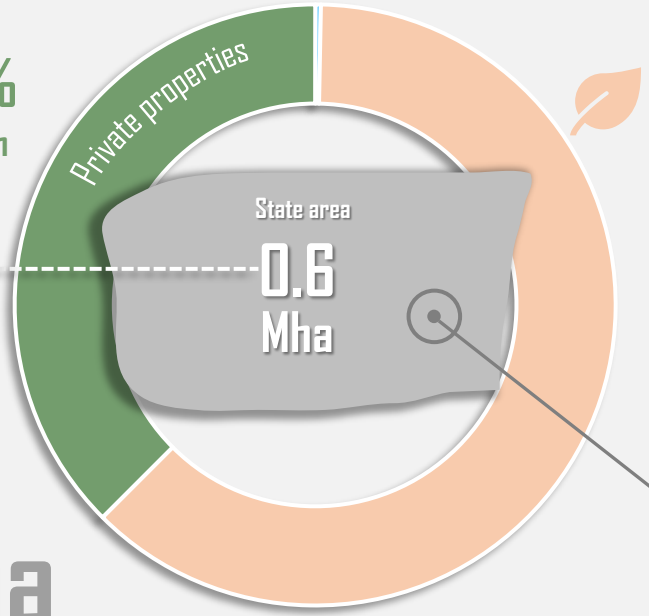
0.4 Mha

63%

38% Native vegetation

0.3% Water body

62% Agricultural land



0.5%

1.7-2.3 thousand ha

APP deficit

Deforestation after 2008

3.1±2.2 thousand ha

8%

Deforestation on APPs or with a LR below the minimum

Legal reserve

12% 0.04±0.03 Mha Surplus

1.8% 0.01±0.003 Mha Deficit

Espírito Santo

103,081 private properties

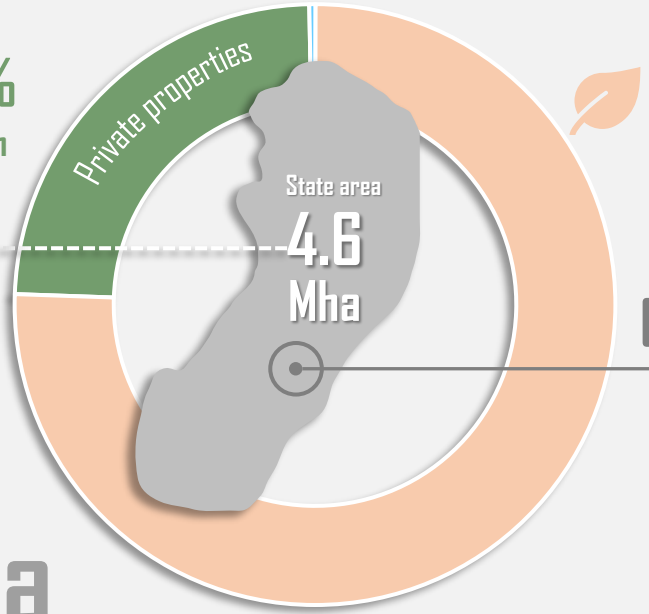
3.2 Mha

70%

24% Native vegetation

0.3% Water body

76% Agricultural land



2.0%

65.8-87.5 thousand ha

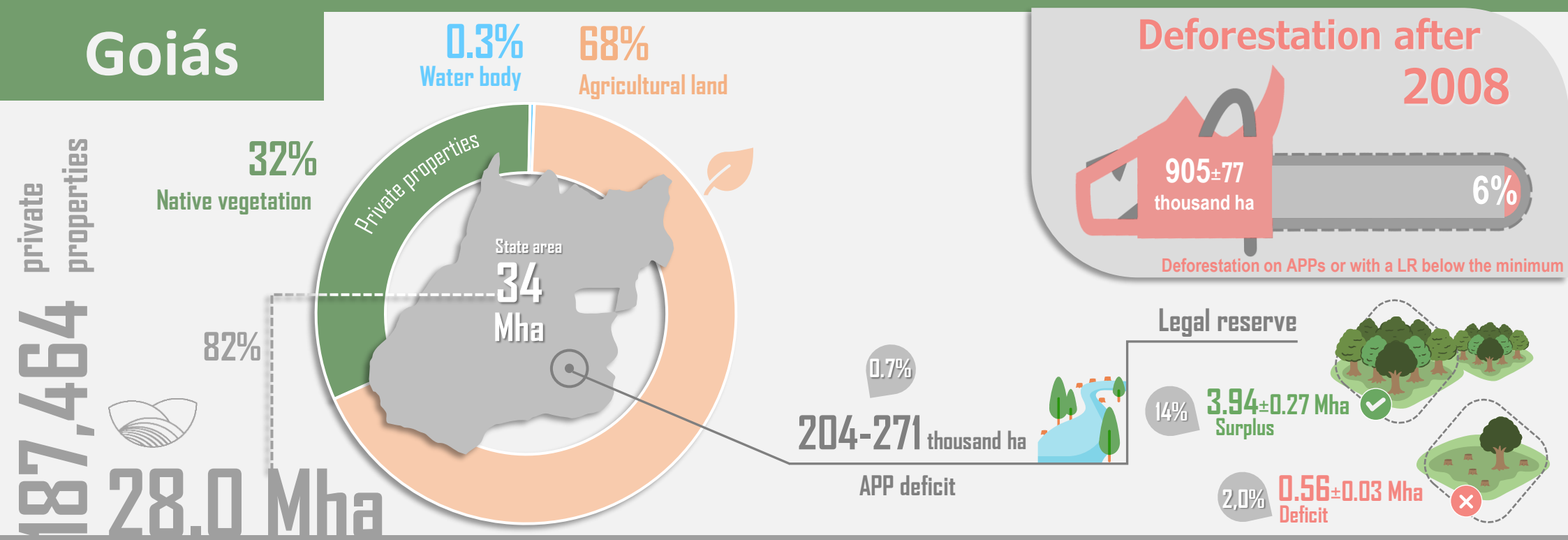
APP deficit

Legal reserve

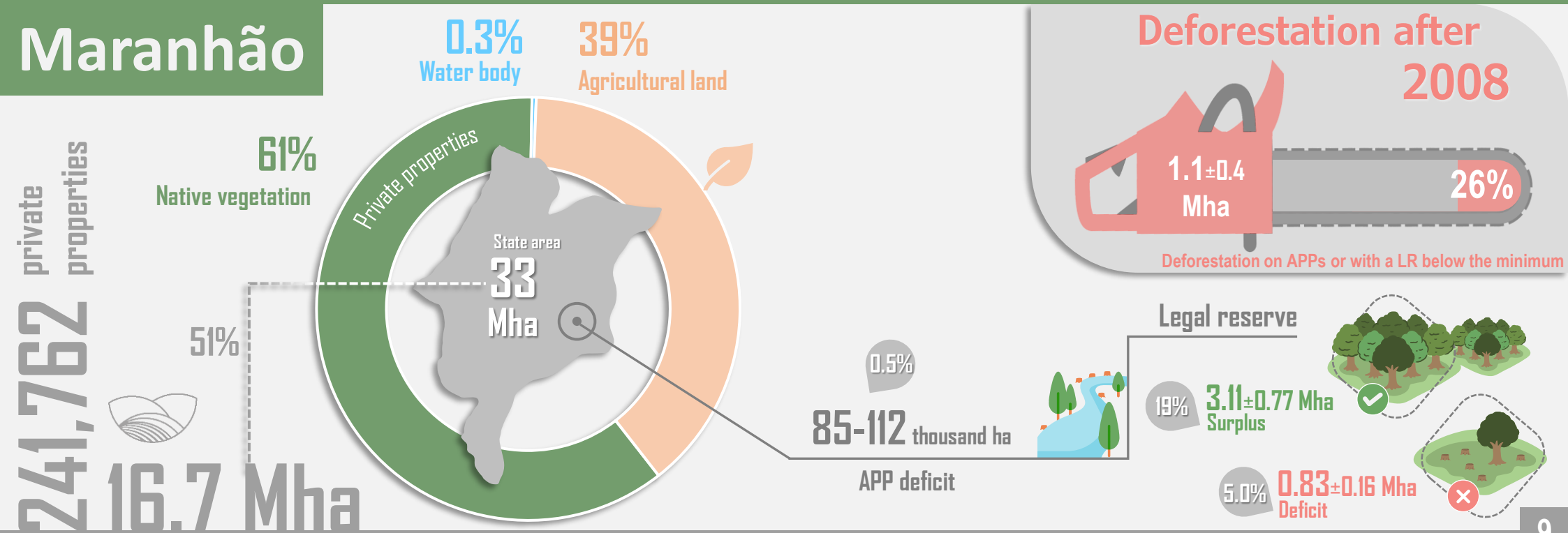
10% 0.35±0.02 Mha Surplus

3.4% 0.11±0.01 Mha Deficit

Goiás



Maranhão



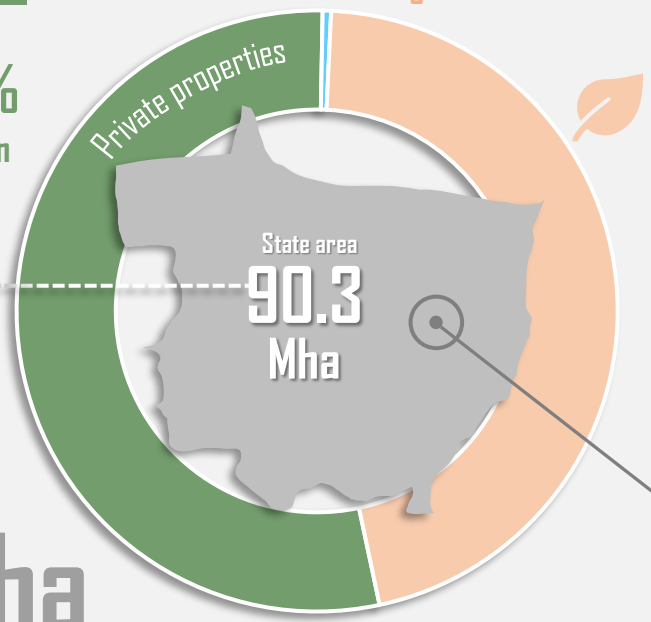
Mato Grosso

158,790 private properties

54% Native vegetation

68%

61.0 Mha



0.5%

285-379 thousand ha

APP deficit

Deforestation after 2008

1.8±0.4 Mha

42%

Deforestation on APPs or with a LR below the minimum

Legal reserve

10% 6.39±1.10 Mha Surplus

7.2% 4.42±0.62 Mha Deficit

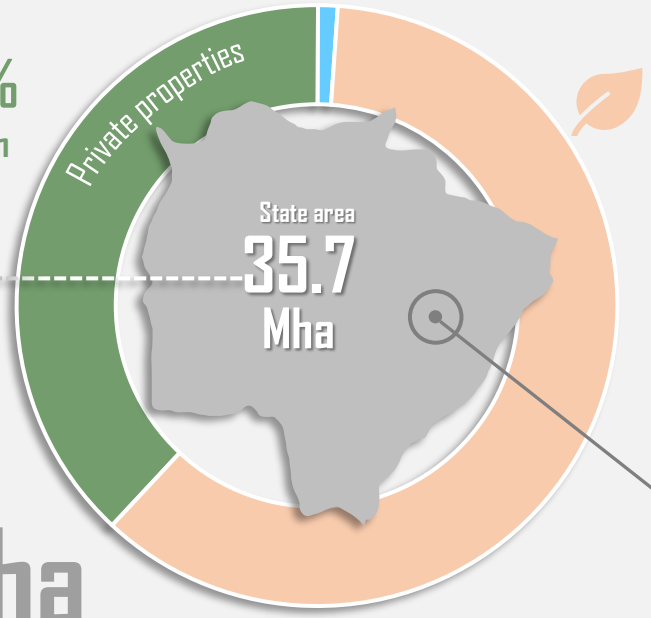
Mato Grosso do Sul

74,885 private properties

38% Native vegetation

88%

31.5 Mha



0.5%

158-210 thousand ha

APP deficit

Deforestation after 2008

375±14 thousand ha

7%

Deforestation on APPs or with a LR below the minimum

Legal reserve

20% 6.29±0.19 Mha Surplus

2.6% 0.83±0.02 Mha Deficit

Minas Gerais

924,042 private properties

1% Water body

63% Agricultural land

36% Native vegetation

Private properties

State area 58.7 Mha

76%

44.6 Mha

1.0%

442-588 thousand ha

APP deficit

Deforestation after 2008

850±89 thousand ha

6%

Deforestation on APPs or with a LR below the minimum

Legal reserve

19% 8.25±0.70 Mha Surplus

1.6% 0.70±0.05 Mha Deficit

Pará

249,290 private properties

1% Water body

43% Agricultural land

56% Native vegetation

Private properties

State area 124.6 Mha

32%

40.4 Mha

1.2%

481-640 thousand ha

APP deficit

Deforestation after 2008

2.1±0.3 Mha

77%

Deforestation on APPs or with a LR below the minimum

Legal reserve

7.1% 2.48±0.33 Mha Surplus

9.3% 3.74±0.41 Mha Deficit

Paraíba

160,882 private properties

3.5 Mha

62% Native vegetation

55% Native vegetation

1% Water body

44% Agricultural land

Private properties

State area 5.6 Mha

0.7%

25.4-33.8 thousand ha

APP deficit

Legal reserve

34% 1.21±0.06 Mha Surplus

0.6% 0.02±0.001 Mha Deficit

Paraná

479,232 private properties

15.8 Mha

80% Native vegetation

26% Native vegetation

1% Water body

73% Agricultural land

Private properties

State area 19.9 Mha

1.0%

165-219 thousand ha

APP deficit

Legal reserve

12% 1.85±0.14 Mha Surplus

2.6% 0.41±0.03 Mha Deficit

Deforestation after 2008

5.1±0.5 thousand ha

4%

Deforestation on APPs or with a LR below the minimum

Pernambuco

312,261 private properties

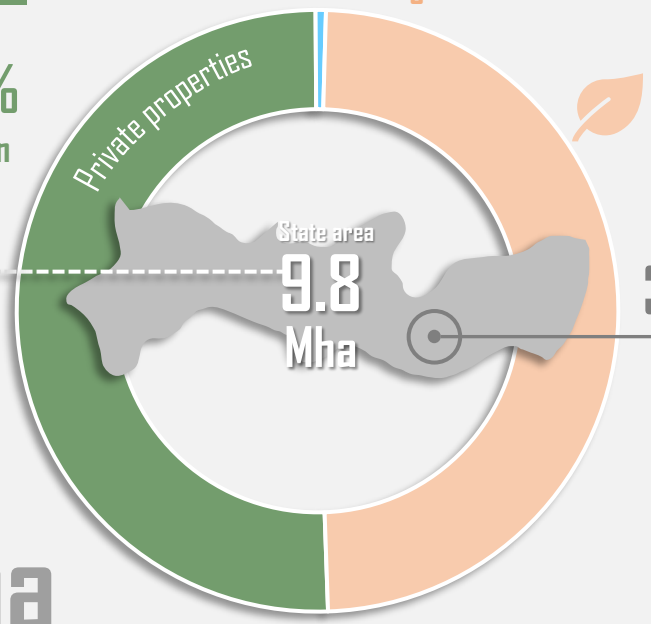
5.4 Mha

56%

50% Native vegetation

1% Water body

49% Agricultural land



0.7%

39.5-52.6 thousand ha

APP deficit

Legal reserve

32% 1.73±0.12 Mha Surplus

1.2% 0.06±0.004 Mha Deficit

Piauí

238,195 private properties

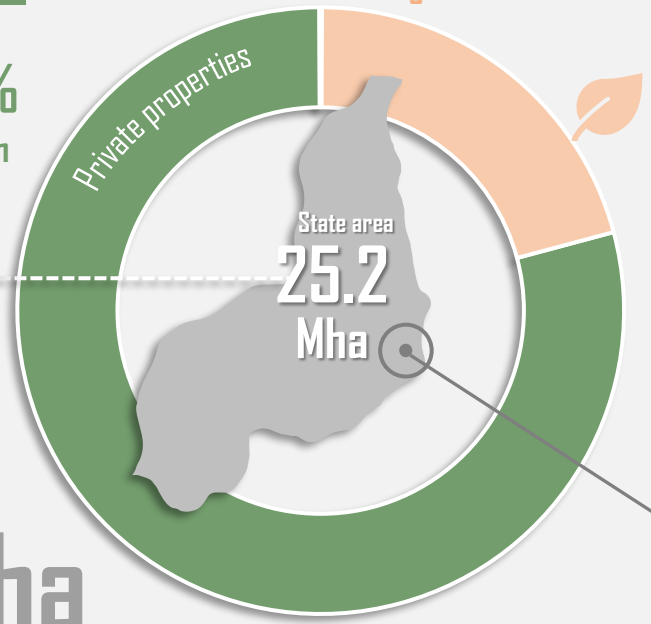
13.6 Mha

54%

79% Native vegetation

0.1% Water body

21% Agricultural land



0.2%

27.4-36.4 thousand ha

APP deficit

Legal reserve

53% 7.26±0.94 Mha Surplus

0.2% 0.02±0.003 Mha Deficit

Deforestation after 2008

853±139 thousand ha

2%

Deforestation on APPs or with a LR below the minimum

Rio de Janeiro

54,843 private properties

2.2 Mha

50%

26% Native vegetation

0.5% Water body

74% Agricultural land

Private properties

State area 4.4 Mha

2.1%

47.2-62.8 thousand ha

APP deficit

Legal reserve

12% 0.28±0.02 Mha Surplus

3.5% 0.08±0.004 Mha Deficit

Rio Grande do Norte

82,917 private properties

3.0 Mha

56%

57% Native vegetation

2% Water body

41% Agricultural land

Private properties

State area 5.3 Mha

0.8%

22.6-30.1 thousand ha

APP deficit

Legal reserve

35% 1.04±0.07 Mha Surplus

0.3% 0.01±0.001 Mha Deficit

Rio Grande do Sul

591,965 private properties

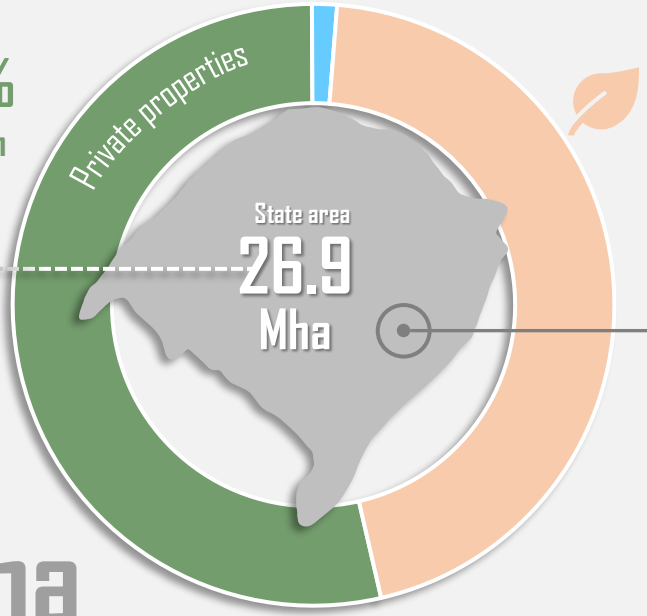
21.6 Mha

81%

54% Native vegetation

1% Water body

45% Agricultural land



0.6%

136-181 thousand ha

APP deficit

Legal reserve

33% 7.10±0.29 Mha Surplus

0.9% 0.19±0.01 Mha Deficit

Rondônia

137,416 private properties

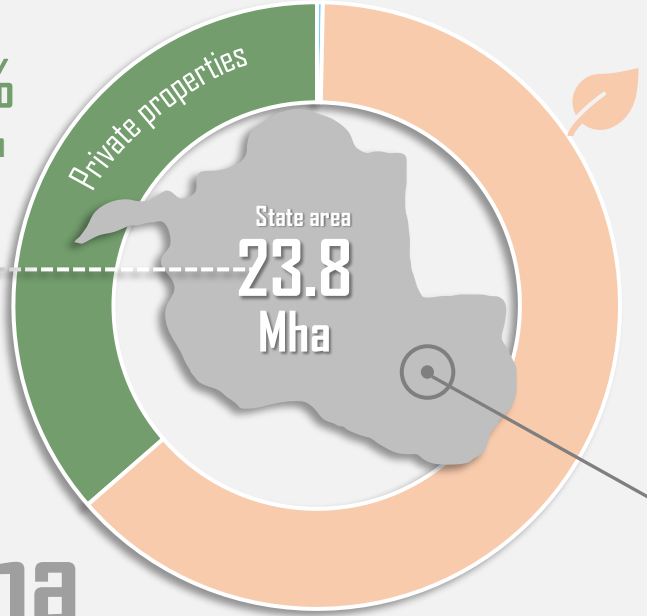
10.7 Mha

45%

36% Native vegetation

0.3% Water body

63% Agricultural land



0.8%

83-111 thousand ha

APP deficit

Deforestation after 2008

709±81 thousand ha

88%

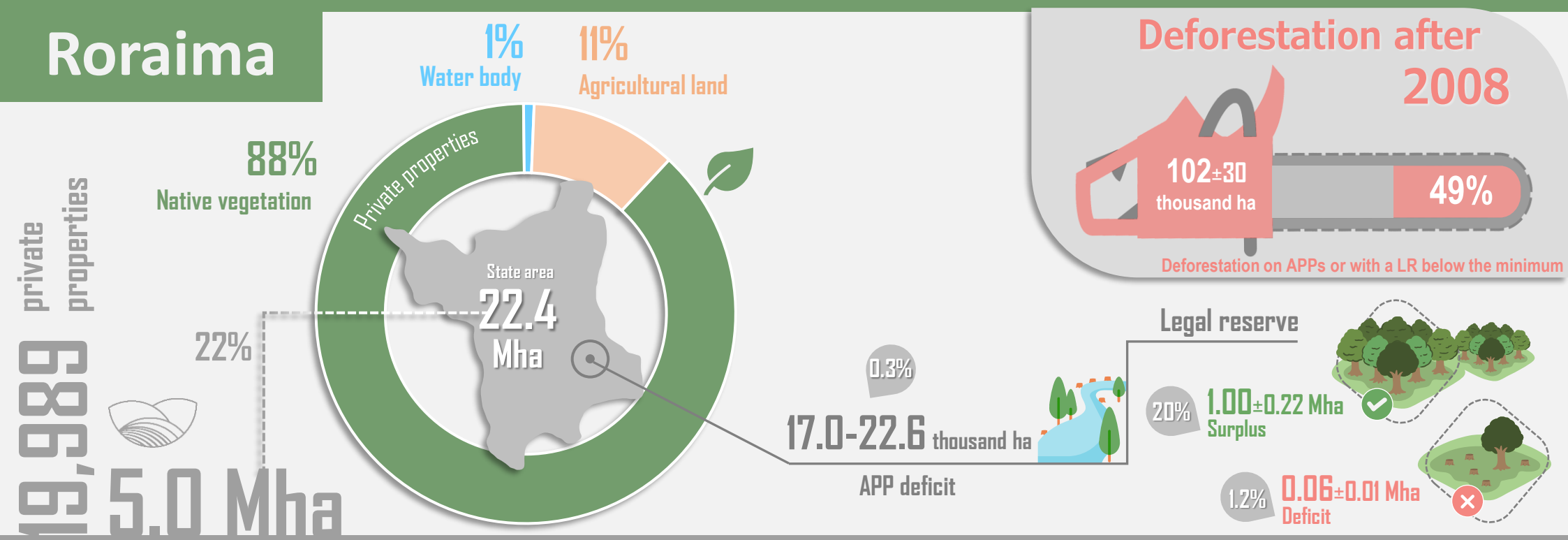
Deforestation on APPs or with a LR below the minimum

Legal reserve

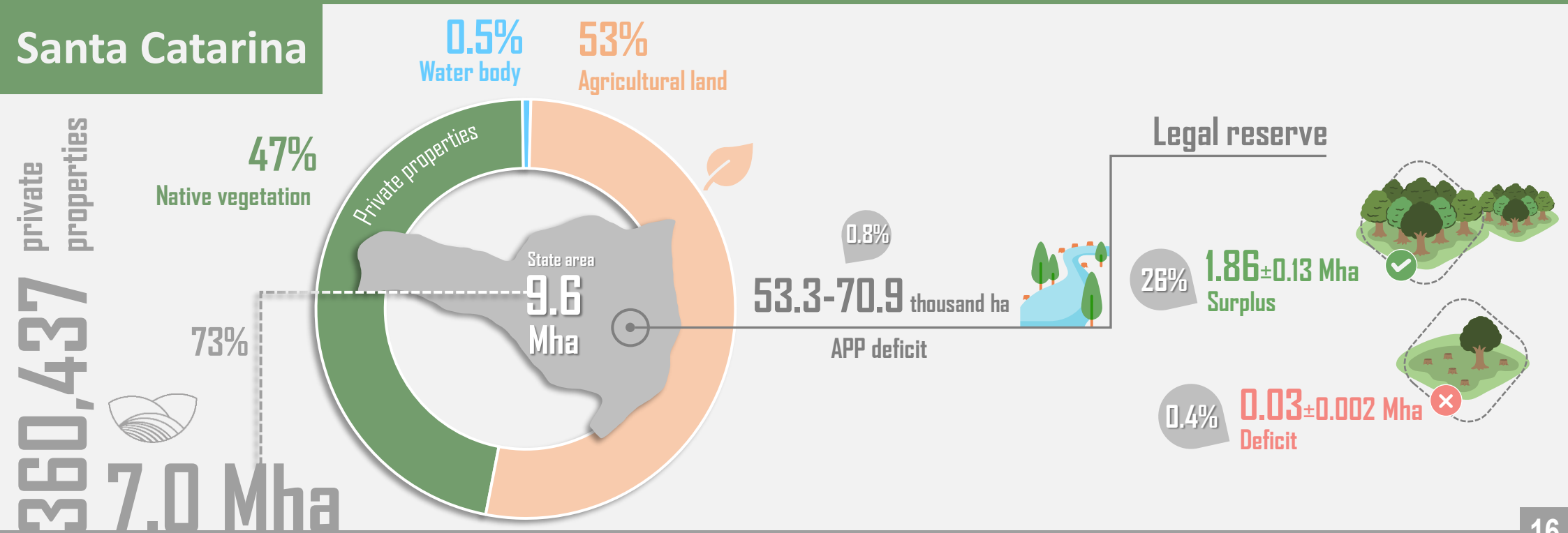
2.8% 0.30±0.03 Mha Surplus

10.6% 1.13±0.09 Mha Deficit

Roraima



Santa Catarina



São Paulo

390,295 private properties

19.0 Mha

77%

17% Native vegetation

2% Water body

81% Agricultural land

Private properties

State area 24.8 Mha

1.2%

219-291 thousand ha

APP deficit

Deforestation after 2008

6.8±0.7 thousand ha

25%

Deforestation on APPs or with a LR below the minimum

Legal reserve

5.9% 1.11±0.09 Mha Surplus

5.4% 1.02±0.07 Mha Deficit

Sergipe

87,018 private properties

1.4 Mha

63%

22% Native vegetation

0.4% Water body

78% Agricultural land

Private properties

State area 2.2 Mha

0.9%

12-16 thousand ha

APP deficit

Legal reserve

9.5% 0.13±0.02 Mha Surplus

2.2% 0.03±0.003 Mha Deficit

Tocantins

80,194 private properties

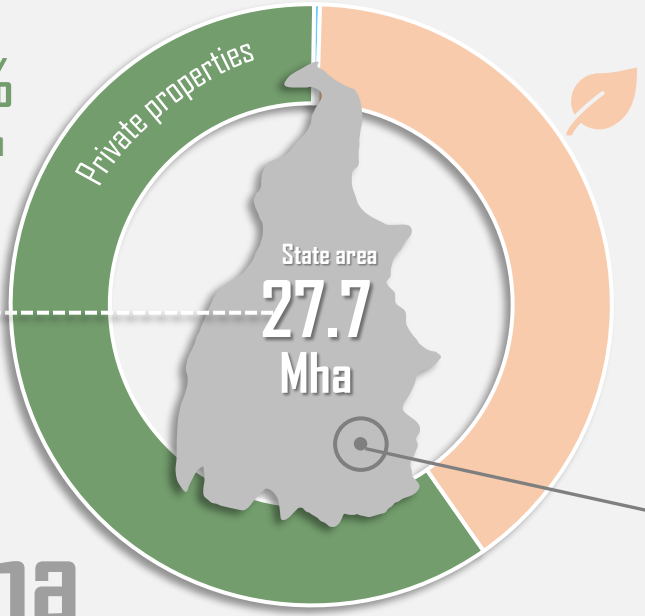
18.2 Mha

66%

60% Native vegetation

0.3% Water body

40% Agricultural land



0.6%

118-157 thousand ha

APP deficit

Deforestation after 2008

2.0±0.1 Mha

8%

Deforestation on APPs or with a LR below the minimum

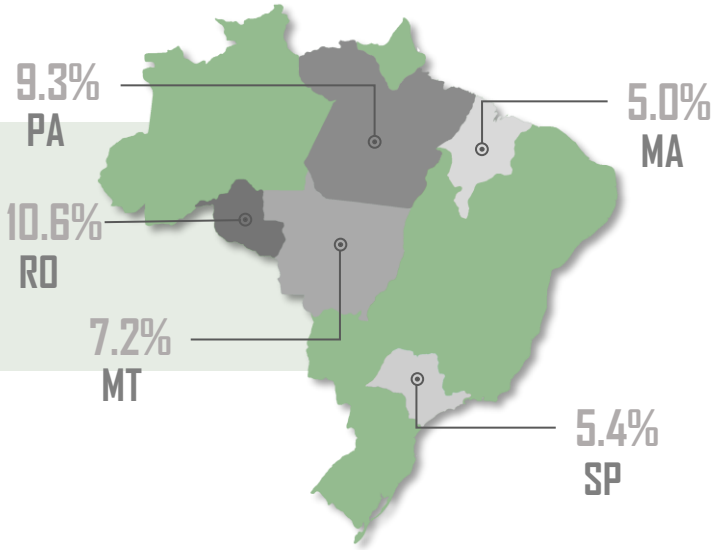
Legal reserve

24% 4.38±0.10 Mha Surplus

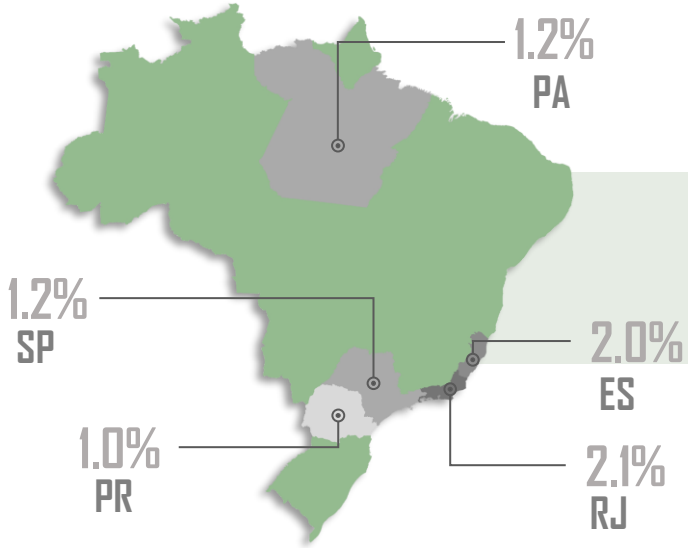
4.3% 0.78±0.02 Mha Deficit

Ranking top 5

Legal reserve deficit*



APP deficit*



Deforestation after 2008

2.11 Mha	PA
1.96 Mha	TO
1.83 Mha	MT
1.09 Mha	MA
1.00 Mha	BA

Estimated deforestation at property level, considering a minimum threshold of 6.25 ha.

Deforestation after 2008 in APP or with RL below the minimum*

5.9%	RO	624 kha
4.0%	PA	
3.5%	AC	
1.8%	AM	
1.7%	MA	

Deforestation after 2008 on APPs or within PP with a legal reserve below the minimum required for suppressing vegetation.

** With respect to the total area of rural properties.*

Methods

Datasets

To calculate the FC balance, we employed the CAR database from January 2022. We only analyzed private properties, excluding thus settlement projects and collective lands, such as quilombola (maroon) territories. We disregard CARs that overlap with conservation units, except Permanent Preservation Areas – APAs, and indigenous lands, according to the MPF[4] protocol criteria, and those canceled by the SFB. In addition, the model employs as input maps of state and municipal limits, municipal fiscal modules, the limit of Legal Amazon, vegetation distribution, drainage, land use, deforestation, and protected areas.

We used the map of municipalities from IBGE (Brazilian Institute for Geography and Statistics), so as to assign the municipality geocode to each CAR record. Each Brazilian municipality has a size for the fiscal module[5]. Through the municipality geocode, the size of fiscal module is attributed to the CAR. The FC considers as a small property those from one up to four fiscal modules, a medium property those between 4 and 15 fiscal modules, and as large properties the ones larger than 15 fiscal modules.

Public domain nature conservation units (except APAs) and demarcated indigenous lands[6] are used to calculate the percentage of a municipality and a state occupied by these land use categories, and the resulting numbers are assigned to the CAR via the IBGE geocode.

The boundary of the Legal Amazon has been extended several times as a result of changes in the political division of the country. For our modeling exercise, the limit of the Legal Amazon[7] was used to set the requirements of Legal Reserve (LR).

Vegetation formations from the Radam-Brasil are used to determine the percentage of LR in the Legal Amazon, i.e., 80% for forest formations, and 35% for other vegetation types. Outside of Legal Amazon, the FC establishes the percentage of 20% of the property for LR. When a property overlaps different biomes (i.e., Cerrado and Amazon), a weighted average is applied.

For calculating APP conservation and restoration requirements, we used the drainage maps, including springs and water bodies, from the National Water and Sanitation Agency (ANA).

Our Land-use map is a mosaic composed of water bodies from ANA, land-use categories identifying native vegetation remnants and agricultural areas (so-called “consolidated areas) from Mapbiomas, (collection 6), and maps of annual deforestation from PRODES-Amazon and PRODES-Cerrado[8-12].

O modelo

We have applied the rules and definitions of the Forest Code (FC)[1] for each rural private property from the CAR dataset obtained from SICAR—the Online National Rural Environmental Registry System. In doing so, we provide estimates of the FC level of compliance, i.e., landowners’ deficits—areas that must be reforested at the owners’ expenses, or and surpluses, areas of native vegetation that exceed the FC conservation requirements (Fig. 1).

To this end, we have developed an innovative geoprocessing set of tools that handle big data by employing PostgreSQL and PostGIS extension, and Dinamica EGO 7 freeware[13]. This system takes advantage of full parallel processing[14]. Dinamica EGO parallel execution system uses a variable number of execution threads (called workers) boosted by task-stealing algorithms to provide load balancing and increase the flexibility for running parallel tasks. In theory, all model components can run in parallel, including independent operators, loops, and map tiles[15,16].

Substantive improvements in our computing capacity and modeling tools enabled fine-scale reanalysis of the FC[3,17], making it feasible to estimate the FC balance; i.e., level of compliance, throughout the Brazilian territory at the property-level. These advances allowed us to frog-leap from a 60-meter spatial resolution[3] to a 5-meter (the narrowest APP width for restoration) by using parallel processing and memory allocation optimization. All processing relied on the computing resources of the Center for Remote Sensing[18] of the Federal University of Minas Gerais (Belo Horizonte, Brazil). All calculations can be replicated by downloading the software and opening the FC models (csr.ufmg.br/radiografia_do_car) using Dinamica EGO’s user-friendly graphical interface.

To calculate the forest balance (deficit and surpluses), the model first calculates the total area of each property where the law is applicable. Next, the model generates buffer sizes along river, spring and water bodies according to the rules of the FC (Fig. 1). To define the buffer width either for APP conservation or restoration requirements, the model uses the property size (defined in the number of fiscal modules as specified for each municipality) and river width. To calculate riparian APP buffer width to be restored, the model applies a set of rules so-called “escadinha” (little ladder), which specifies the buffer size to be restored according to the property size (defined in the number of fiscal modules as specified for each municipality) and river width.

Thereafter, the model applies the FC rules according to the property sizes to define LR requirements. In the Amazon biome, LR can be reduced by up to 50% in municipalities that have more than 50% of their territory occupied by conservation units and indigenous reserves (Art. 12, II - § 4). The FC exempts small landowners (up to 4 fiscal modules) to restore LR deficit (Art. 67). In addition, the law establishes a maximum percentage of the property for LR restoration (Art. 61-B), depending on the total extent of its riparian APPs (Art. 15). Here we consider the increase in the size of the Legal Reserve (LR) from 50% to 80% established by Provisional Measures 1,511 of 1996 and 2,166-67 of 2001. The FC also establishes that the percentage of LR for forest restoration can be reduced to 50% in the Amazon states that have the ecological-economic zoning approved.

In addition, article 68 of the of FC reviewed in 2012 states that landowners that suppressed native vegetation respecting the legislation in force at the time need not to recover LR to the percentage mandated by the current law, i.e., 80%. Therefore, it corrected conflicting past legislation to bring to legality "properties pushed into illegal status".

The difference in LR definition is the reason that we separated deforestation before 2002 and this year onwards. Deforestation before and after the decree must be analyzed with respect to different specification of LR size. Note that the time of deforestation occurring is also evidence for article 68 of the 2012's FC as specified in Paragraph 1, as follows:

"Owners of rural properties may prove their history of occupation by documents such as the description of historical facts of the region, commercialization records, data, agricultural activities, contracts and bank documents related to production, and by all other means of evidence permitted by law"[1].

The main sequence to obtain the FC balance is depicted in Fig.1. For each property, the model subtracts the total area required for LRs from the areas of native vegetation remnants within each private property and the areas of native vegetation within the customized APP buffer sizes to arrive at the level of compliance. We define a positive result as an environmental surplus and a negative result as an environmental deficit.

Uncertainties in the FC estimates arise from overlaps of properties and different drainage bases, as well as the accuracy of the mappings.

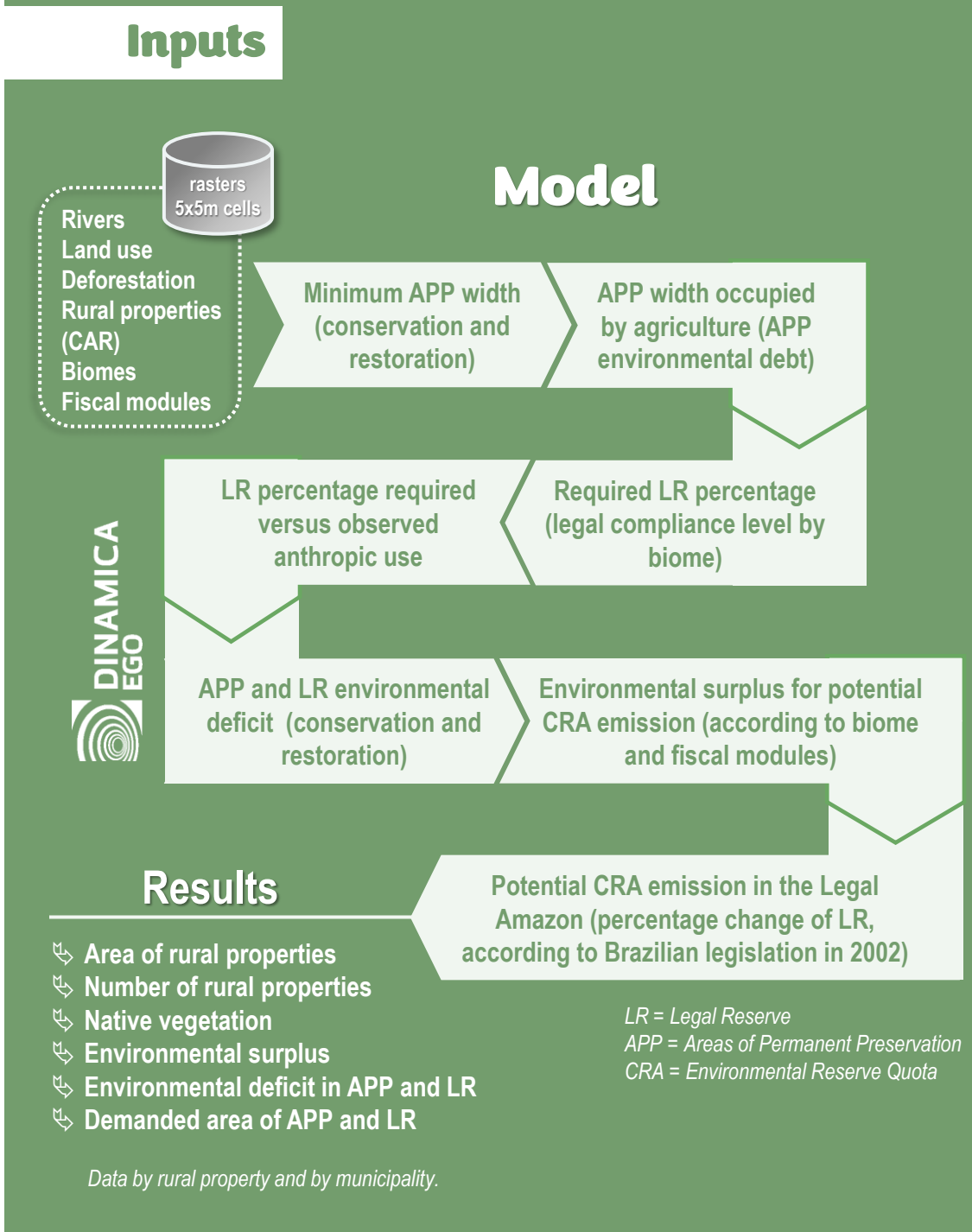


Fig. 1: Flowchart of the Forest Code compliance analysis model indicating main input data, calculations and results.

The SeloVerde platform

For traceability purpose the results per property are integrated with annual deforestation maps[10,11], soy cropping maps (Mapbiomas, collection 7), and GTA documents (permit to transport animals). The analyses of FC thus allow us to map potentially legal or illegal post-2008 deforestation (in APP or below a minimum of RL) — the amnesty deadline for past-deforesters[3] – so as to link deforestation to cattle and soy supply from each cattle ranch or soy farm on the SeloVerde Platform.

The CAR 2.0

In turn, the CAR 2.0 uses mapping and spatially explicit modeling based on high resolution images to automatically analyze the environmental compliance of each rural property through the methods described above. Properties without overlaps and without significative LR and APP deficits are, as a result, directed to the Canal Verde (Green light channel), a simplified procedure for joining the PRA based on the landowner's self-report, hence without the need to rectify the RL features, hydrography, land use and others features input by the landowner.

References

1. Brazil (2012) Federal Law Nº. 12.727 (17 October 2012). Available at: <www.planalto.gov.br/ccivil_03/_Ato2011- 2014/2012/Lei/L12727.htm>.

2. Rajão R, Soares-Filho B, Nunes F, Borner J, Machado L, Assis D, Oliveira A, Pinto L, Ribeiro V, Rausch L, Gibbs H, Figueira D (2020) The rotten apples of Brasil's agribusiness. Science, 369(6501), 246-248.

3. Soares-Filho BS, Rajão R, Macedo M, Carneiro A, Costa WLS, Coe M, Rodrigues HO, Alencar A (2014) Cracking Brasil's Forest Code. Science 344, 363-364.

4. Ministério Público Federal - MPF (2020) Protocolo de monitoramento de fornecedores de gado da Amazônia. Available at: <https://www.mpf.mp.br/atuacao-tematica/ccr4/dados-da-atuacao/grupos-de-trabalho/amazonia-legal/Protocolodemonitoramentodegadov.12.05.2020.pdf/view>.

5. Instituto Nacional de Colonização e Reforma Agrária - INCRA (2013) Fiscal Modules by municipality of Brazil. Brazil: INCRA. Available at: <https://www.gov.br/incra/pt-br/assuntos/governanca-fundiaria/modulo-fiscal>.

6. Centro de Sensoriamento Remoto da Universidade Federal de Minas Gerais - CSR/UFMG (2021) Protected areas. Belo Horizonte, Brazil: CSR/UFMG. Available at: <www.csr.ufmg.br/maps >.

7. Instituto Brasileiro de Geografia e Estatística - IBGE (2020) Limit of the Legal Amazon. Brazil: IBGE. Available at: <https://www.ibge.gov.br/geociencias/organizacao-do-territorio/estrutura-territorial/15819-amazonia-legal.html?edicao=30963&t=acesso-ao-produto >.

8. Agência Nacional de Águas - ANA (2017) Ottocoded Hydrographic Base 1:250.000 (BHO250). Brasília: ANA. Available at: <https://metadados.snirh.gov.br/geonetwork/srv/por/catalog.search#/metadata/0f57c8a0-6a0f-4283-8ce3-114ba904b9fe >.

9. Agência Nacional de Águas - ANA (2019) Water bodies - version 2019. Brasília: ANA. Available at: <https://metadados.snirh.gov.br/geonetwork/srv/por/catalog.search;jsessionid=2D7CA1AA9B2C516E7BA71AE6BF8A65B0#/metadata/7d054e5a-8cc9-403c-9f1a-085fd933610c >.

10. Projeto de Mapeamento Anual da Cobertura e Uso do Solo no Brasil - MapBiomas (2021) Land use maps - collection 6 (base digital georreferenciada). Available at: <https://mapbiomas.org/colecoes-mapbiomas-1?cama_set_language=pt-BR >

11. Instituto Nacional de Pesquisas Espaciais - INPE (2022) PRODES Project - Deforestation monitoring of the Brazilian Amazon rainforest by satellite. Available at: <http://terrabrasilis.dpi.inpe.br/downloads />.

12. Instituto Nacional de Pesquisas Espaciais – INPE (2022) PRODES Project - Satellite monitoring of the Cerrado biome. Available at: <http://terrabrasilis.dpi.inpe.br/downloads/>.

13. Soares-Filho BS, Rodrigues HO, Follador M (2013) A hybrid analytical-heuristic method for calibrating land-use change models. Environmental Modelling & Software 43, 80-87.

14. Argemiro T. Leite-Filho, Britaldo S. Soares-Filho, Juliana L. Davis, Hermann O. Rodrigues (2020). Guidebook 2.0 Dinamica EGO. Disponível em: <https://www.csr.ufmg.br/dinamica/dokuwiki/doku.php?id=guidebook_start>.

15. Rana S. (1993) A distributed solution of the distributed termination problem. Information Processing Letter 17, 43-46.

16. Blumofe R., Leiserson C. (1999) Scheduling multithreaded computations by work stealing. Journal of Association for computing Machinery 46, 720-748.

17. Soares-Filho BS, Rajão R, Merry F, Rodrigues H, Davis J, Lima L, Macedo M, Coe M, Carneiro A, S7ntiago L (2016) Brasil's Market for trading forest certificates. Plos One 11(4), e0152311.

18. Center for Remote Sensing of the Federal University of Minas Gerais (CSR/UFMG). Available at: <www.csr.ufmg.br>.

Panorama of Brazil's Forest Code

Policy brief
July 2023