# Effects of IBGE's 2019 Definition for Brazilian Biomes in Different Political-Administrative Scales

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***Abstract.*** *In 2019, the official delimitation of the Brazilian biomes was updated to a considerably more detailed description compared to the previous definition that lasted 15 years. This work investigates the possible effects of such changes in different political-administrative scales, ranging from biomes to the municipality level. We define effect levels according to the changes between the biomes in each scale, indicating the areas more subject to the changes in the newest version of the Brazilian biomes. Depending on the scale of the study, the changes in the Brazilian biomes might have significant effects, mainly in the Pampa biome, in Piauí, São Paulo, Sergipe, and Bahia states, and at the municipality level.*

## 1. Introduction

A biome is an area of geographic space with dimensions up to exceeding one million square kilometers, represented by a uniform type of environment, identified and classified according to the macroclimate, phytophysiognomy, soil, and altitude, the main elements that characterize the diverse continental environments [Walter 1986, Coutinho 2006]. Examples of biomes include tropical rainforests, savannas, tundras, deserts, and oceans. Despite the difficulties in defining biomes, they help describe ecosystems' function and role in the Earth system [Moncrieff et al. 2016].

In Brazil, biomes are officially defined by the Brazilian Institute of Geography and Statistics (IBGE). The six biomes[1] are (ordered by size) Amazônia, Cerrado, Mata Atlântica, Caatinga, Pampa, and Pantanal. In 2004, IBGE and the Ministry of Environment (MMA) produced an official biome map with a resolution of 1:5,000,000 [IBGE 2004]. It was the first official definition of Brazilian biomes, also called the *first approximation*. At the time of this publication, several points still needed to be better studied in the light of knowledge about more accurate information on the country's natural resources [IBGE 2019].

In 2019, the official delimitation of the Brazilian biomes was updated to a considerably more detailed description compared to the previous definition that lasted 15 years

[1]In this work, we focus only on the terrestrial biomes.

[IBGE 2019]. It incorporates several conceptual and technological advances to the previous version of the biomes. The new version has a scale of 1:250,000, based on the latest vegetation map for Brazil, produced in the same scale.

A Google Scholar search for the words "Brazilian biome IBGE" (without quotes) returned more than 16,000 papers published from 2004 until 2023. Some of these studies use the 2004 version of the Brazilian biomes, for example [De Araújo et al. 2012, Menezes et al. 2012, Rada 2013, Soterroni et al. 2019, Rajão et al. 2020, Guerra et al. 2020, Bezerra et al. 2022, Arcoverde et al. 2023]. The results of articles that use the previous definition of the Brazilian biomes might be potentially affected by the changes that took place in 2019.

In this work, we investigate the possible effects of the changes in the definition of biomes in different political-administrative scales, ranging from biomes themselves to the municipality level. We define effect levels to indicate the areas more subject to the changes in the newest version of the Brazilian biomes.

## 2. Methodology

We use the biomes defined by IBGE for 2004 and 2019[2], shown in Figure 1[3]. Note how the data in 2004 has several holes related to hydrography. Additionally, in some locations, there are significant differences between the two versions of the biomes. Figure 2 shows details of a region between Amazônia and Cerrado. It is possible to see how the newest version is more detailed.

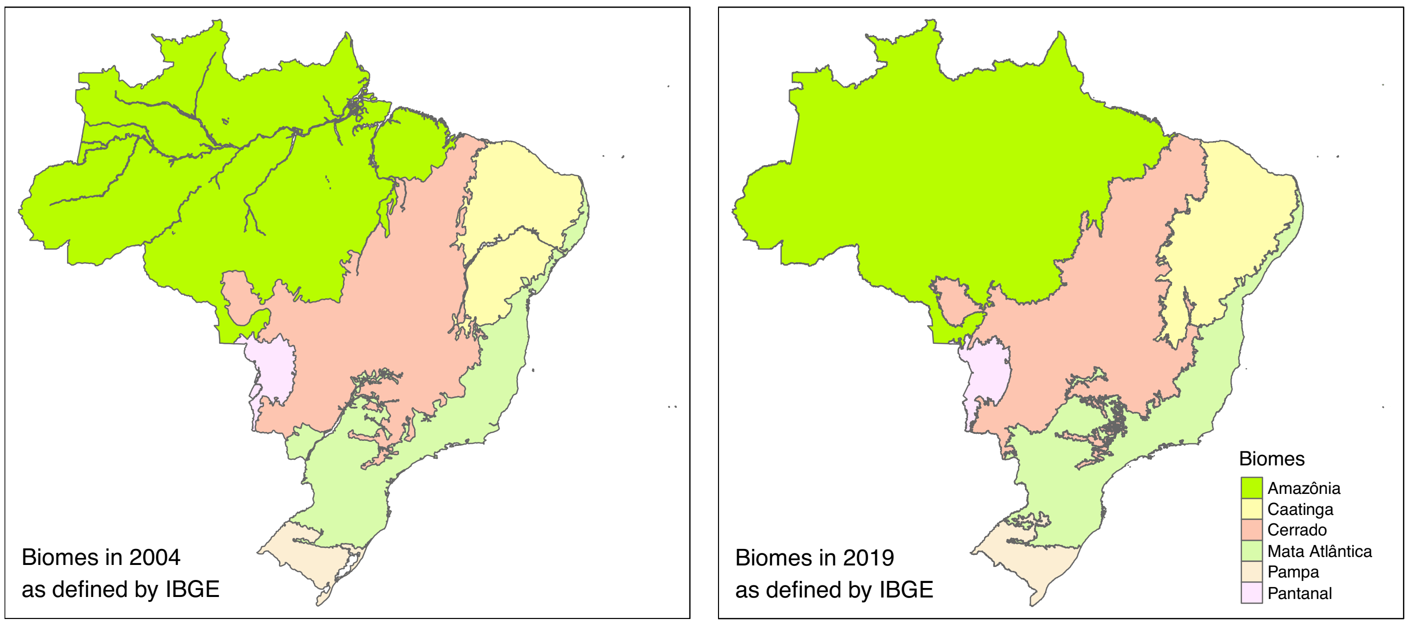


**Figure 1. Brazilian biomes in 2004 (left) and 2019 (right), as defined by IBGE.**

The biomes maps are not directly comparable, mainly because the 2004 version does not consider some rivers as part of the biomes. Additionally, they do not share pre-

[2]The data was obtained using R package geobr [Pereira et al. 2019], which is a copy of the original data available in IBGE's FTP at `https://geoftp.ibge.gov.br/informacoes_ambientais/estudos_ambientais/biomas/vetores/`.

[3]All the Figures in this article are vectorial; therefore, it is possible to zoom in to see minor details in the polygons.

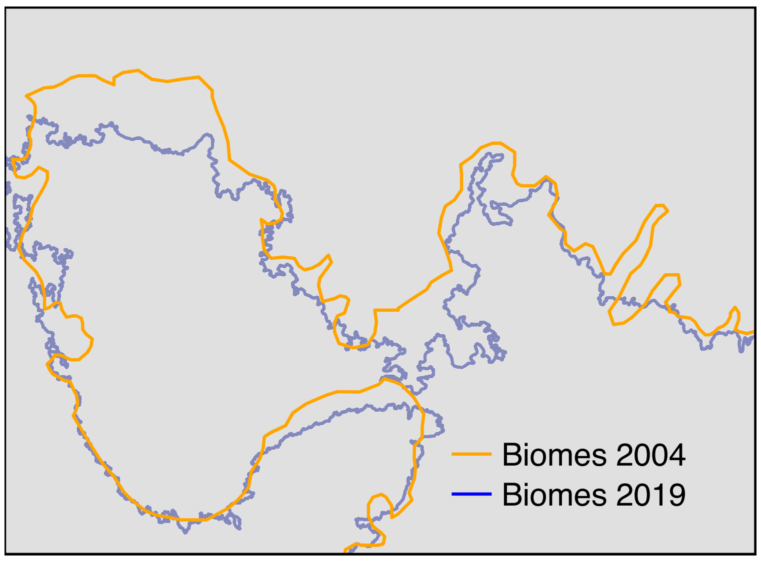


**Figure 2. Detailing a region between Amazônia and Cerrado biomes.**

cisely the same Brazilian limits. We use the official delimitation of Brazil from IBGE as our basis for producing maps of biomes with the same limits. This dataset has a scale of 1:250,000, the same used by the 2019 version of the biomes. Using this data allows a fair comparison of the areas of the biomes and assessing the changes in the state and municipality scales. The procedure to create comparable biome maps uses the following steps:

1. Remove the areas of the biomes outside the IBGE's delimitation for Brazil.
2. Compute the spatial difference between Brazil and the biomes, representing the areas within Brazil that are not mapped by the biomes data. The resulting polygons include the missing hydrography areas of 2004, for example. For 2004, there were 5,200 polygons covering 15.23 million hectares (Mha), or 1.79% of Brazil. For 2019, there are 13,285 polygons covering 0.54 Mha, 0.06% of Brazil. As the 2019 data is more detailed, it has considerably more missing polygons but an almost insignificant missing area. These polygons will be added to the biomes maps to guarantee that total area covered by the biomes is the area of Brazil, detailed in the next steps.
3. Apply a buffer of approximately 1 meter to such polygons and then compute the overlap with the biomes. The polygons that overlap only one biome are added to the respective biome.
4. The remaining polygons overlap more than one biome. Compute the intersection between these polygons and the biomes. The biome with a greater intersection will contain the respective polygon.
5. Two polygons in 2004 cross biomes, as they represent the São Francisco and Tocantins rivers. They were split into three polygons each and allocated to the respective biome.

The procedure above generates updated and comparable maps for the biomes. We then investigate the following questions using these data:

1. How much area did each biome gain and lose from 2004 to 2019?
2. How much area of each state was affected by the changes in the biomes?
3. How many municipalities did each biome gain and lose from 2004 to 2019?
4. How much area of each municipality was affected by the changes in the biomes?

Based on the results of these questions, we analyze the changes in the different scales. We consider that changes below 5% are not relevant, between 5% and 50% have considerable relevance, between 50% and 90% have high relevance, and above 90% have huge relevance.

## 3. Results

Figure 3 shows the resulting maps of biomes for 2004 and 2019. We can see that the 2004 map fixes the hydrology issues. The 2019 map is very similar to the original one, but there are some differences, such as the area of Lagoa dos Patos in the southernmost part of the country (compare the right map with the respective map in Figure 1).

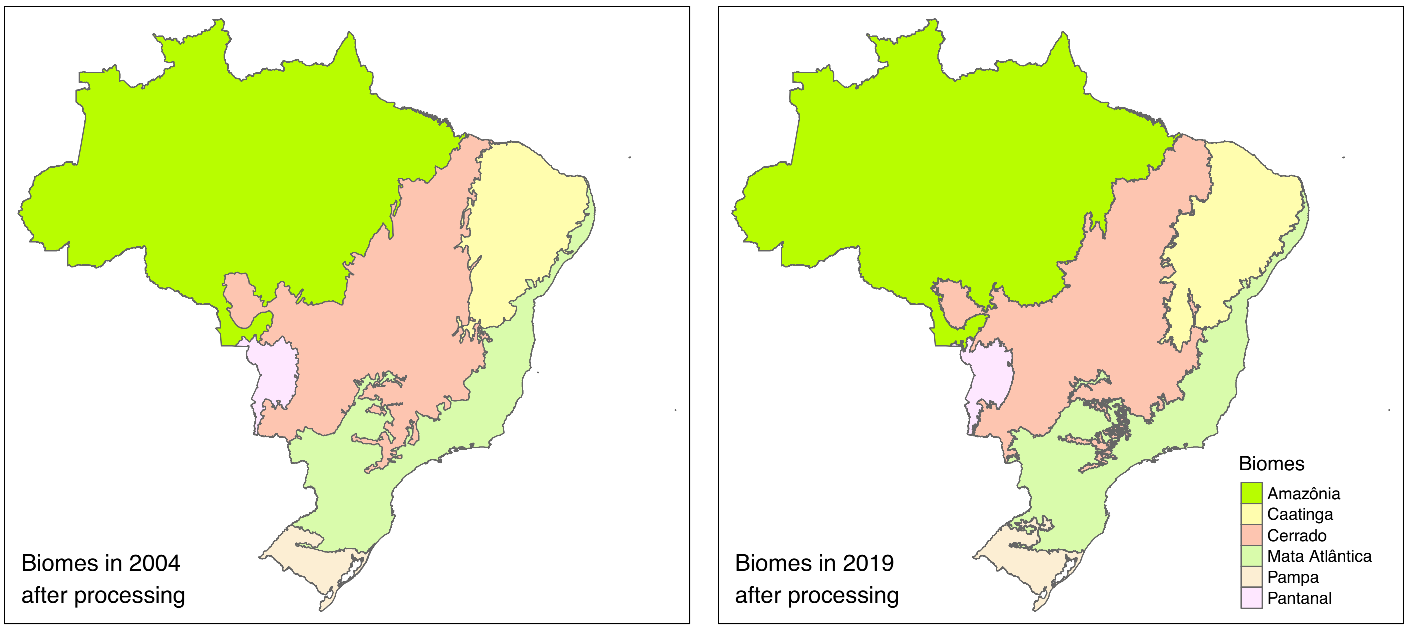


**Figure 3. Brazilian biomes in 2004 (left) and 2019 (right) after processing.**

Table 1 shows the extent of each Brazilian biome in 2004 and 2019. In the final balance between gained and lost areas, most of the biomes experience minor relative changes in size, except for Pampa, which had an increase of nearly 10%. The Mata Atlântica and Cerrado biomes reduced their areas while the other biomes gained. Pantanal was the only one that kept its total area. In general terms, most of the area lost by Mata

**Table 1. Area of the Brazilian biomes (in Mha). The Difference and Delta columns are for 2019 compared to 2004.**

| Biome | Area 2004 | Area 2019 | Difference | Delta (%) |
|---|---|---|---|---|
| Amazônia | 421.73 | 423.42 | 1.69 | 0.40 |
| Caatinga | 83.07 | 86.62 | 3.55 | 4.27 |
| Cerrado | 204.73 | 199.18 | –5.55 | –2.71 |
| Mata Atlântica | 112.31 | 111.02 | –1.29 | –1.15 |
| Pampa | 16.51 | 18.13 | 1.62 | 9.81 |
| Pantanal | 15.15 | 15.15 | 0.00 | 0.00 |

**Table 2. Changes in area of the Brazilian biomes (in Mha).**

| Biome | Amaz. | Caatinga | Cerrado | M. Atl. | Pampa | Pant. | Tot 2019 |
|---|---|---|---|---|---|---|---|
| Amazônia | 418.87 | 0.00 | 4.07 | 0.00 | 0.00 | 0.47 | 423.41 |
| Caatinga | 0.00 | 75.77 | 9.45 | 1.40 | 0.00 | 0.00 | 86.62 |
| Cerrado | 2.80 | 6.76 | 184.57 | 4.42 | 0.00 | 0.63 | 199.18 |
| Mata Atlântica | 0.00 | 0.55 | 5.60 | 104.58 | 0.30 | 0.00 | 111.03 |
| Pampa | 0.00 | 0.00 | 0.00 | 1.91 | 16.21 | 0.00 | 18.12 |
| Pantanal | 0.06 | 0.00 | 1.05 | 0.00 | 0.00 | 14.05 | 15.16 |
| Total 2004 | 421.73 | 83.08 | 204.74 | 112.31 | 16.51 | 15.15 | 853.52 |

Atlântica moved to Pantanal, and most of the area lost by Cerrado moved to Amazônia and Caatinga.

Although most biomes did not significantly change their areas in the final balance, there were notable changes in their borders as they exchanged limits with their neighbors. Table 2 shows the gains and losses of each biome's related areas. For example, Amazônia gained 4.07 Mha from Cerrado and 0.47 Mha from Pantanal but lost 2.80 Mha to Cerrado and 0.06 Mha to Pantanal. All the zero values in the table indicate that the respective biomes do not share borders. The main diagonal represents areas that did not change between versions.

Figure 4 shows the areas that changed between biomes on top of the Brazilian state limits highlighting the gained areas in each biome. For example, along the border

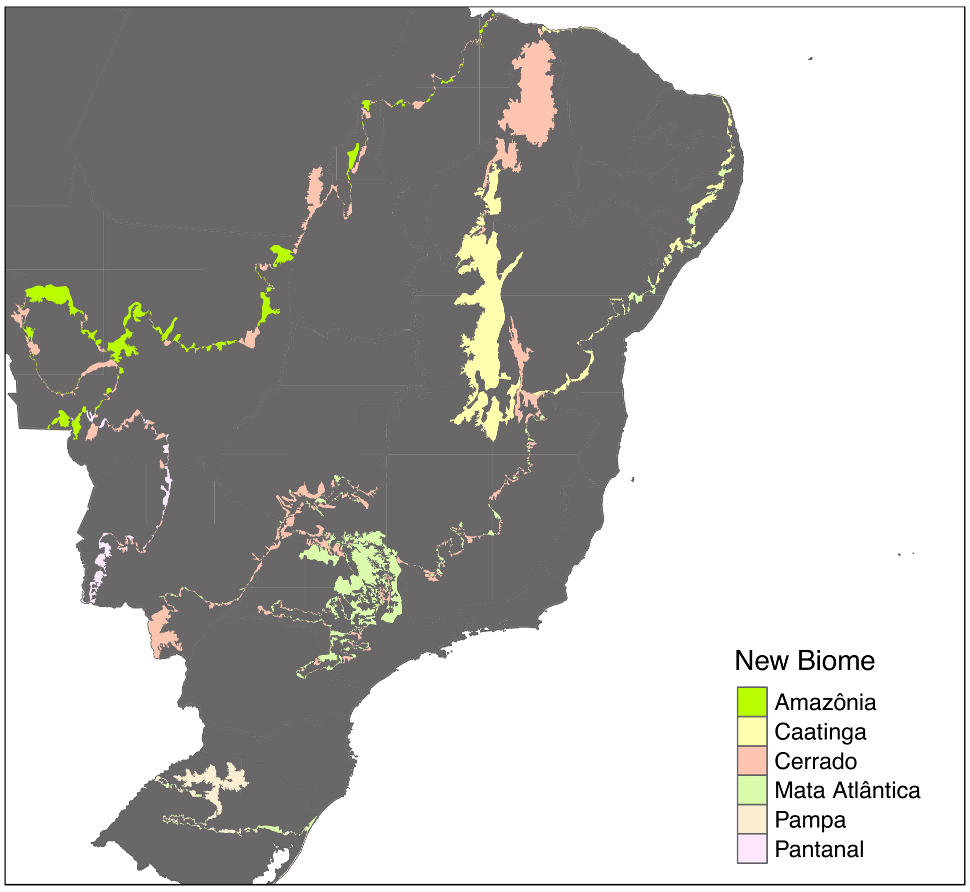


**Figure 4. Areas that changed between biomes on top of Brazilian states.**

**Table 3. Overlaps of changing biomes within states (in Mha).**

| State | Total area | Area that changed between biomes | Percentage (%) |
|---|---|---|---|
| Piauí | 25.26 | 7.61 | 30.13 |
| São Paulo | 24.89 | 4.88 | 19.61 |
| Sergipe | 2.20 | 0.27 | 12.27 |
| Bahia | 56.69 | 6.73 | 11.87 |
| Minas Gerais | 58.84 | 5.03 | 8.55 |
| Rio Grande Do Sul | 26.91 | 2.21 | 8.21 |
| Mato Grosso Do Sul | 35.82 | 2.48 | 6.92 |
| Mato Grosso | 90.68 | 5.88 | 6.48 |
| Alagoas | 2.79 | 0.18 | 6.45 |
| Pernambuco | 9.86 | 0.52 | 5.27 |

between the Caatinga and Cerrado biomes, the gained areas in Caatinga are highlighted in yellow and the gained areas in Cerrado are in salmon.

Table 3 quantifies the states that had more than 5% of change. Rio Grande do Sul is on the list as it contains the whole Pampa biome. However, on this scale, other states also had some effects, some even more than Rio Grande do Sul. It is worth mentioning that more than 30% of the Piauí state changed biome, primarily moving from Caatinga to Cerrado. São Paulo had almost 20% of change, transitioning from Cerrado to Mata Atlântica. Sergipe and Bahia had more than 10%, primarily moving from Cerrado to Caatinga and from Mata Atlântica to Caatinga, respectively. Studies that rely on the previous definition of biomes in these states could have a considerable effect.

Considering the Brazilian municipalities, although the number of municipalities in each biome does not change considerably (except for Pampa), there are significative changes in Caatinga, Cerrado, and Mata Atlântica, as shown in Table 4 (note that the sum of the municipalities in each biome is greater than the number in Brazil as municipalities can belong to more than one biome). Cerrado is the biome that gained and lost most municipalities, as it shares its border with all other biomes but Pampa. Therefore,

**Table 4. Number of municipalities in each biome that changed from 2004 to 2019.**

| Biome | Total 2004 | Added | Removed | Total 2019 |
|---|---|---|---|---|
| Amazônia | 553 | +8 | –3 | 558 |
| Caatinga | 1223 | +91 | –102 | 1212 |
| Cerrado | 1398 | +158 | –121 | 1435 |
| Mata Atlântica | 3055 | +118 | –93 | 3080 |
| Pampa | 173 | +87 | –24 | 236 |
| Pantanal | 26 | +1 | –5 | 22 |

studies at the municipal level using biomes might have significant changes if changing the biomes map.

Looking at the municipalities themselves, 163 have 100% of change in their biomes. Table 5 shows the results for municipalities grouped by states. Beyond the previous states, Tocantins, Sergipe, Paraiba, and Rio Grande do Norte states have municipalities with more than 90% of change in their biomes. São Paulo and Minas Gerais, the two states with more municipalities, were the ones with more municipalities with more than 5% of change in the biome. A total of 749 municipalities, or 13.4% of Brazil, have some effect related to the newest version of the biomes.

**Table 5. Number of municipalities per state with more than 5%, 50%, and 90% of change in their biomes.**

| State | $n \geq 5\%$ | $n \geq 50\%$ | $n \geq 90\%$ |
|---|---|---|---|
| São Paulo | 199 | 114 | 45 |
| Minas Gerais | 129 | 50 | 14 |
| Piauí | 116 | 88 | 56 |
| Rio Grande do Sul | 100 | 59 | 19 |
| Bahia | 77 | 26 | 12 |
| Pernambuco | 31 | 24 | 12 |
| Mato Grosso do Sul | 26 | 5 | 2 |
| Tocantins | 22 | 4 | 3 |
| Sergipe | 17 | 11 | 3 |
| Alagoas | 13 | 6 | 1 |
| Paraíba | 11 | 9 | 5 |
| Rio Grande do Norte | 8 | 4 | 2 |
| Total | 749 | 400 | 174 |

## 4. Conclusions

Depending on the political-administrative scale, the changes in the official delimitation of the Brazilian biomes might have significant effects, especially in the following areas:

- Pampa biome;
- Caatinga, Mata Atlântica, and Cerrado biomes, particularly within the municipality level.
- Piauí, São Paulo, Sergipe, and Bahia states, but also in Minas Gerais, Rio Grande do Sul, Mato Grosso do Sul, Mato Grosso, Alagoas, and Pernambuco;
- Municipalities in the previous states and also from Tocantins, Paraíba, and Rio Grande do Norte.

Other spatial representations might not produce significant changes (less than 5%). Different resolutions require further investigation, but the results shown in this article can present an initial analysis.

Studies that examine more than one contiguous biome at the municipality level might have reduced effects, as the changes in one biome are directly related to its neighbors. The borders between Caatinga and Cerrado and between Cerrado and Mata Atlântica have more changes in municipalities. Studies that use these two combinations of biomes might have smaller effects on the changes in municipalities.

Changes in biome boundaries have a significant impact on studies and the planning of priority areas for conservation, ecological connectivity, zoning, the establishment of conservation units and enforcement of national legislations. Many of these decisions are made at the level of Federative Units. This research can contribute to a better understanding of these changes, facilitating the potential adaptation of ongoing projects and initiatives. It is worth noting that, as other biophysical cartographic bases are updated, the limits of biomes will also require adjustments. Brazilian institutions must be prepared to adapt to these changes.

Two types of analyses can be developed based on this study. Firstly, an investigation of the land use and cover changes that transitioned between biomes. Which biomes have seen gains or losses in native vegetation, and do these areas have experienced intensive land use? Secondly, an assessment of the implications of these changes in the implementation of national legislation. Two major examples of key laws that refer to the Brazilian biomes are the Native Vegetation Protection Law (No. 12,651/2012), also know as Brazil's Forest Code, and the Atlantic Forest Law (No. 11,428/2006). What are the possible effects of those changes in conservation policies? How much do these changes impact legal reserves within the Legal Amazon?

It is possible to use the methodology presented in this study to investigate new definitions of biomes for Brazil. The scripts that implement the method of this study were written in R using the sf package [Pebesma et al. 2018]. All scripts and data presented in this paper are available on GitHub[4].

## 5. Acknowledgements

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[4]https://github.com/pedro-andrade-inpe/brazilian-biomes-2004-2019

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