

TerraClass Digital Platform for analysis of the dynamics of land use and land cover in the Upper Paraguay Basin

Plataforma Digital TerraClass para análise da dinâmica do uso e cobertura da terra na Bacia do Alto Paraguai

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Abstract

The Upper Paraguay Basin (BAP, Portuguese acronym) is an ecosystem of strategic importance to Brazil because it includes the Pantanal, one of the world's largest floodplains. The wet plain is well preserved, but the plateau suffered the impact of anthropic activities on the natural resources, due to the rapid conversion of vegetation cover in recent decades. Therefore, it is essential to investigate land use and cover changes to define strategies that stimulate environmental conservation and regional development. The BAP plateau region is covered by the mappings of the TerraClass Project, which provides official data for monitoring land use and cover in the Amazon and Cerrado biomes. In this context, the objective of the work was to analyze changes in land use and land cover in municipalities of the BAP, using the modern GeoPortal TerraClass and the recent data collection from 2018, 2020, and 2022. The spatial analysis showed that the native forest loss occurred due to increased deforestation. Most of the forest regeneration areas persisted during this period, and the lost area was converted into pastures, where agriculture expanded, initially with one cycle production, followed by the intensification of crop and off-season production. The results demonstrate the potential of the data and tools offered by the Digital Platform TerraClass to support territorial management.

Keywords:

BAP, Spatial database, Geographic mapping, Interactive map, Territorial management.

Resumo

A Bacia do Alto Paraguai (BAP) é um ecossistema de importância estratégica para o Brasil, uma vez que abriga o Pantanal, uma das maiores áreas inundáveis do mundo. A planície úmida é bem conservada, mas o planalto tem sofrido o impacto das atividades antrópicas sobre os recursos naturais, devido à rápida conversão da cobertura vegetal nas últimas décadas. Por isso é importante investigar a mudança de uso e cobertura da terra para definir estratégias que estimulem a

conservação ambiental e o desenvolvimento regional. A região do planalto da BAP é contemplada pelos mapeamentos do Projeto TerraClass, que oferecem dados oficiais para o monitoramento do uso e cobertura da terra nos biomas Amazônia e Cerrado. Nesse contexto, o objetivo do trabalho foi analisar as mudanças do uso e cobertura da terra em municípios da BAP, utilizando o modernizado GeoPortal TerraClass e a nova coleção dos dados de 2018, 2020 e 2022. A análise espacial mostrou que ocorreu perda da floresta nativa devido ao aumento do desmatamento, a maior parte das áreas de regeneração florestal persistiu nesse período e a área perdida foi convertida em pastagens, onde se expandiu a agricultura, inicialmente com um ciclo de produção, seguido posteriormente pela intensificação de ciclos de produção de safra e safrinha. Os resultados demonstram o potencial dos dados e das ferramentas oferecidas pela Plataforma Digital TerraClass no apoio à gestão territorial.

Palavras-chave:

BAP, Banco de dados geoespaciais, Mapeamento geográfico, Mapa interativo, Gestão territorial.

I. INTRODUCTION

The Upper Paraguay Basin (BAP, Portuguese acronym), whose Brazilian portion encompasses part of Mato Grosso and Mato Grosso do Sul States, is of great strategic importance for Brazil due to the ecological diversity of its landscape. The Pantanal, one of the largest floodplains in the world, with a rich biodiversity of fauna and flora, is well preserved. The plateau has undergone anthropogenic changes, where natural vegetation was replaced by livestock farming, agriculture, reforestation and urban constructions (Silva et al., 2011). However, the replacement of areas with native vegetation by cultivated areas and pastures on the plateau, also affected negatively the Pantanal foodplain (Bergier, 2013; Colman et al., 2019).

The suppression of native vegetation areas on the plateau can increase soil loss through erosion (Guerra et al., 2020), change the flow of watercourses and the flood regime (Marques; Rodriguez, 2022) and, finally, it can increase the incidence of fire in the Pantanal (Libonati et al., 2020). In this context, the BAP must be constantly monitored, to support public policies aiming to a sustainable development, regarding the environmental impacts of agricultural production in the plateau area.

In recent decades, the State of Mato Grosso has seen a rapid conversion of its natural vegetation cover, in which livestock, agricultural and timber extraction activities have promoted major economic, social and environmental dynamics, to the detriment of the conservation of natural resources (Becker, 2005). The occupation of Mato Grosso was fostered by federal policy to colonize the “empty spaces” of the Central-West and by the construction of major highways to transport production (Chioveto, 2014).

During this same period, the State of Mato Grosso do Sul underwent a similar process of important socio-economic transformations, from a productive structure of raw material supplier, essentially for the southeast

region, to an economy geared towards the foreign market (Corrêa et al., 2018). Agricultural expansion and modernization have accelerated this process, making the state a major producer of grains and meat for the national and international markets (Calixto; Gomes, 2014). For this reason, information on the qualification of land use and cover is necessary to define strategies that encourage environmental conservation and regional development (Lambin; Geist, 2006).

The TerraClass Project is the result of a partnership between the National Institute for Space Research (INPE) and the Brazilian Agricultural Research Corporation (Embrapa), started in 2008, whose objective is to map land use and land cover in deforested areas identified by the Satellite Deforestation Monitoring Program (PRODES, Portuguese acronym) (INPE, 2024), such as pasture, agriculture and forest regeneration (Coutinho et al., 2013; Almeida et al., 2016). These maps provide subsidies for the definition and monitoring of public policies and government actions, helping to promote and enhance agricultural production on a sustainable basis, the preservation of natural vegetation cover and the maintenance of ecosystem services. New official data for the years 2018, 2020 and 2022 were recently released for the Amazon and Cerrado biomes, which cover together cover over 70% of the Brazilian territory, and are available on the TerraClass GeoPortal. This digital platform is designed to facilitate the access and visualization of geospatial data from an interactive map. It allows simple and intuitive obtaining of spatial information from maps, as well as to perform the analysis of land use and land cover dynamics (INPE; EMBRAPA, 2024).

In this context, the objective of the present work was to identify, quantify and analyze the dynamics of land use and land cover in the BAP municipalities using tools available on the TerraClass Digital Platform, based on data from the Amazon and Cerrado biomes.

II. MATERIALS AND METHODS

Within the scope of the BAP, considering that the Pantanal floodplain has some restrictive specificities in terms of land use and cover, the plateau suffered an intense landscape transformation, mainly due to livestock farming, grain production, forestry and the sugar and alcohol industry (Silva; Carlini, 2015). Based on this, the study region comprises the 39 municipalities located on the BAP plateau that are fully covered by the TerraClass Amazônia and Cerrado data, 15 in Mato Grosso do Sul and 24 in the Mato Grosso, listed in Table 1.

Table 1 – Municipalities of the BAP plateau fully covered by TerraClass data.

| Number | Municipality | State | Area (km ²) | Number | Municipality | State | Area (km ²) |
|--------|-----------------------|-------|-------------------------|--------------|----------------------------|-------|-------------------------|
| 1 | Acorizal | MT | 852.7 | 21 | Jardim | MS | 2,201.5 |
| 2 | Alcinópolis | MS | 4,399.7 | 22 | Juscimeira | MT | 2,293.6 |
| 3 | Alto Paraguai | MT | 1,844.8 | 23 | Nioaque | MS | 3,923.8 |
| 4 | Anastácio | MS | 2,946.3 | 24 | Nova Olímpia | MT | 1,367.8 |
| 5 | Araputanga | MT | 1,610.1 | 25 | Pedra Preta | MT | 4,049.5 |
| 6 | Arenópolis | MT | 415.6 | 26 | Pedro Gomes | MS | 3,651.2 |
| 7 | Barra do Bugres | MT | 5,981.6 | 27 | Reserva do Cabaçal | MT | 1,342.1 |
| 8 | Bela Vista | MS | 4,892.6 | 28 | Rio Branco | MT | 561.6 |
| 9 | Bonito | MS | 4,934.4 | 29 | Rio Negro | MS | 1,807.7 |
| 10 | Caracol | MS | 2,940.3 | 30 | Rochedo | MS | 1,561.1 |
| 11 | Chapada dos Guimarães | MT | 6,611.7 | 31 | Rondonópolis | MT | 4,686.7 |
| 12 | Corguinho | MS | 2,638.2 | 32 | Salto do Céu | MT | 1,754.5 |
| 13 | Cuiabá | MT | 3,293.6 | 33 | Santo Afonso | MT | 1,174.2 |
| 14 | Denise | MT | 1,278.5 | 34 | São Gabriel do Oeste | MS | 3,864.7 |
| 15 | Dois Irmãos do Buriti | MS | 2,341.7 | 35 | São José do Povo | MT | 448.3 |
| 16 | Figueirópolis D'Oeste | MT | 888.1 | 36 | São José dos Quatro Marcos | MT | 1,287.9 |
| 17 | Guia Lopes da Laguna | MS | 1,210.6 | 37 | São Pedro da Cipa | MT | 344.1 |
| 18 | Indiavaí | MT | 592.6 | 38 | Terenos | MS | 2,841.7 |
| 19 | Jaciara | MT | 1,675.1 | 39 | Várzea Grande | MT | 1,048.4 |
| 20 | Jangada | MT | 1,015.3 | TOTAL | | | 92,574.0 |

Source: Source: Authors.

The dynamics of land use and land cover in the 39 municipalities of the BAP plateau was analyzed using the modern GeoPortal TerraClass (Figure 1), which provides the updated data collection from 2018, 2020 and 2022 for the Amazon and Cerrado biomes. It offers a new interactive map (Figure 2) composed of a broad and powerful set of tools for spatial analysis of the historical series maps.

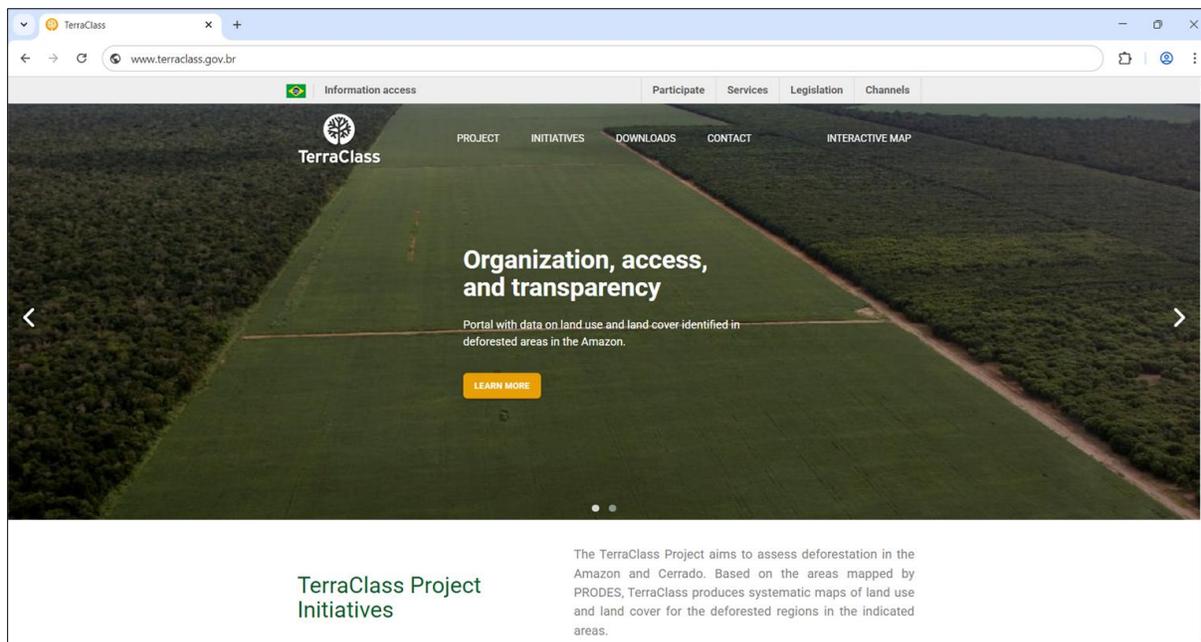


Figure 1 – TerraClass Digital Platform home screen. (Source: INPE; Embrapa, 2024).

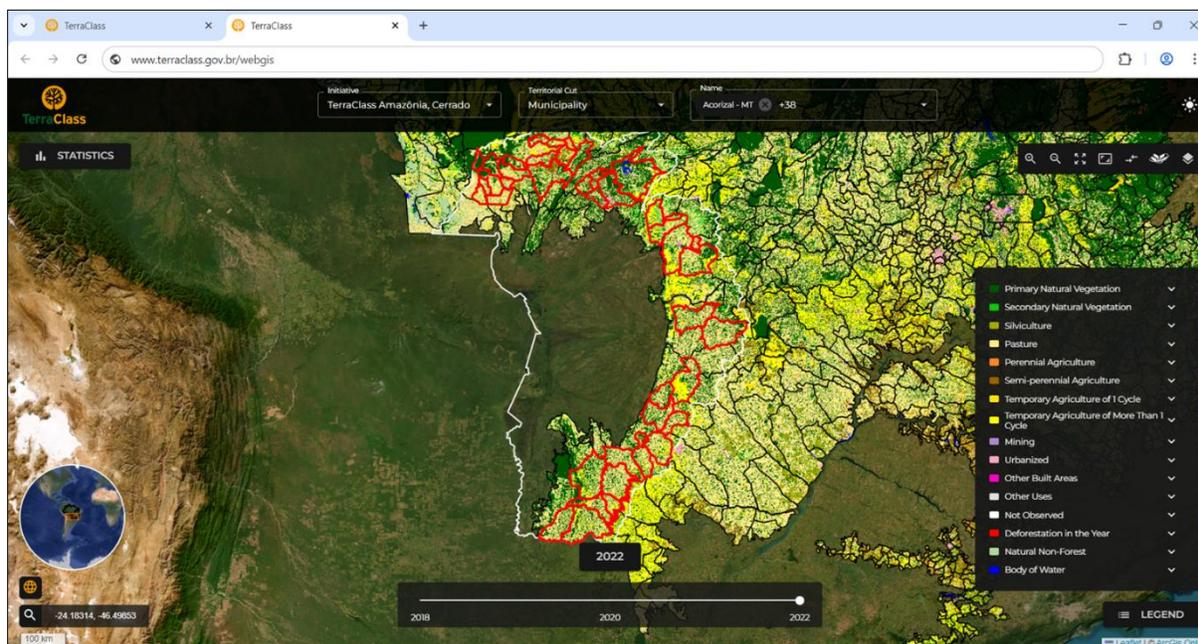


Figure 2 – TerraClass interactive map interface highlighting the 39 municipalities on the BAP plateau. (Source: INPE and Embrapa, 2024).

The new TerraClass maps were generated with an innovative methodology in Brazil using multidimensional data cubes from Sentinel-2 image time series, 10m spatial resolution and 16-day temporal resolution compositions. It is available at the Brazil Data Cube (BDC) project (Ferreira et al., 2020), through the SpatioTemporal Asset Catalog (STAC) technology. The open-source Satellite Image Time Series Analysis for Earth Observation Data Cubes (SITS) package is also used. It was developed in R language (R CORE TEAM, 2024), for analysis, visualization and classification of satellite image time series through machine learning algorithms, in the most recent version, especially for deep learning algorithms (Simões et al., 2021).

TerraClass mappings consider the following thematic classes: Primary Natural Vegetation, Secondary Natural Vegetation, Silviculture, Pasture, Perennial Agricultural, Semi-perennial Agricultural, Temporary Agricultural with 1 Cycle, Temporary Agriculture of More Than 1 Cycle, Mining, Urbanized, Other Built Areas, Other Uses, Not Observed, Deforestation in the Year, Natural Non-Forestry and Body of Water.

The TerraClass GeoPortal was developed from opensource tools, with data stored in a PostgreSQL database (POSTGRESQL, 2024), which uses the functionalities of the PostGIS extension (POSTGIS, 2024) to implement spatial queries in an optimized way. The interactive map provides access, visualization, overlay and manipulation of spatial data from the historical series for different territorial sections, quickly and intuitively. It offers tools to generate sector graphs, evolution graphs, transition matrices between pairs of maps and Sankey flow transition diagrams (Schmidt, 2008), combining multiple maps of thematic classes over the years. It enables

the quantification and visualization of the historical trajectories of the land use and land cover classes from selected land sections, as well as the delimitation of areas from a specific transition (Santos, 2022).

III. RESULTS AND DISCUSSION

The Brazilian portion of the BAP, with an area of 361.6 thousand km², includes 91 municipalities, and approximately 58% (210.7 thousand km²) are located outside the Pantanal biome, with 16% in the Amazon and 84% in the Cerrado biome. The analyses presented in this study refer to the 39 municipalities entirely located in the BAP plateau region, totaling 92.5 thousand km², covered by TerraClass data. Table 2 presents areas of thematic classes land use and land cover in the 39 municipalities of the BAP plateau, for the years 2018 and 2022. The difference that represents the dynamics between the years is also presented, whose values were exported through the TerraClass interactive map.

Table 2 – Area and dynamics of thematic classes land use and land cover for the years 2018 and 2022 in the 39 municipalities of the BAP plateau.

| Thematic Class / Year | 39 Municipalities of BAP | | | |
|--|--------------------------|------------------|-------------|--------------|
| | Area (km ²) | | Dynamics | Dynamics (%) |
| | 2018 | 2022 | | |
| Primary Natural Vegetation | 29,992.83 | 29,130.74 | -862.09 | -2.9 |
| Secondary Natural Vegetation | 7,536.36 | 5,894.95 | -1,641.41 | -21.8 |
| Silviculture | 692.18 | 481.25 | -210.93 | -30.5 |
| Pasture | 45,174.96 | 46,263.75 | 1,088.78 | 2.4 |
| Perennial Agriculture | 13.84 | 19.19 | 5.35 | 38.6 |
| Semi-perennial Agriculture | 1,130.15 | 1,074.06 | -56.09 | -5.0 |
| Temporary Agriculture of 1 Cycle | 536.86 | 1,048.03 | 511.17 | 95.2 |
| Temporary Agriculture of More Than 1 Cycle | 5,844.11 | 7,027.48 | 1,183.38 | 20.2 |
| Mining | 21.98 | 21.97 | -0.01 | -0.1 |
| Urbanized | 528.20 | 500.89 | -27.31 | -5.2 |
| Other Built Areas | 92.23 | 99.13 | 6.90 | 7.5 |
| Other Uses | 1.20 | 6.25 | 5.05 | 421.0 |
| Not Observed | 0.00 | 0.23 | 0.23 | 23.0 |
| Deforestation in the Year | 189.30 | 207.65 | 18.36 | 9.7 |
| Natural Non-Forest | 323.74 | 299.39 | -24.35 | -7.5 |
| Body of Water | 472.90 | 475.88 | 2.97 | 0.6 |
| TOTAL | 92,550.85 | 92,550.85 | 0.00 | 0.0 |

Source: Authors.

The figures generated through the TerraClass interactive map used the configuration TerraClass Amazon, Cerrado Initiative, Municipality Territorial Cut and the selection of 39 municipalities listed in Table 1.

Figure 3 displays the sector graphs generated from the STATISTICS → SECTORS menu of the TerraClass interactive map, showing the most relevant relative frequencies of the thematic classes land use and land cover in the 39 municipalities of the BAP plateau, for the years 2018 and 2022.

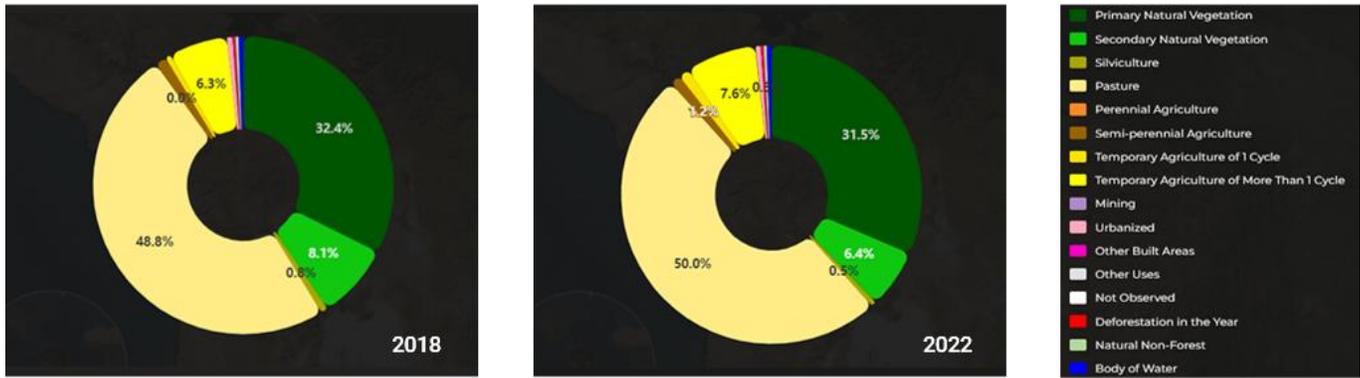


Figure 3 – Most relevant relative frequencies of land use and land cover classes in the 39 municipalities of the BAP plateau, for the years 2018 and 2022. (Source: INPE; Embrapa, 2024).

Unlike the wet plain, the plateau has historically been dominated by extensive pasture areas and, to a lesser extent, areas for commercial agricultural production, such as soybean and corn, resulting in losses of primary and secondary native vegetation in recent years (Broquet et al., 2024).

From the results presented in Table 2 and Figure 3, one verifies that in 2018, almost 30 thousand km² (32.4%) of the BAP plateau were covered by Primary Natural Vegetation and 7.5 thousand km² (8.1%) by Secondary Natural Vegetation. In 2022, there was a reduction of 862 km² (-2.9%) in Primary Natural Vegetation, related to the 9.7% increase in deforestation, as well as the loss of 1,641 km² (-21.8%) of Secondary Natural Forest Vegetation. In this 4-year period, one observes an increase of 511 km² (95.2%) in the Temporary Agriculture of 1 Cycle area, 1.2 thousand km² (20.2%) in the Temporary Agriculture of More Than 1 Cycle area and 1.1 thousand km² (2.4%) in the Pasture area, which continues to predominate over a large area in this section of the BAP plateau.

To improve understanding of the dynamics between the thematic classes, a transition matrix was generated from the STATISTICS → MATRIX menu of the TerraClass interactive map, which cross-references the results of the 2018 and 2022 mappings, as shown in Figure 4. The main diagonal of the transition matrix shows the areas that remained constant between the 2018 and 2022 mappings, which corresponds to 88.8%, while the values outside the main diagonal show the transitions between the thematic classes in the 4-year period, representing 11.2% of the total areas.

| SECTORS | EVOLUTION | MATRIX | TRANSITIONS | Unit | | | | | | | | | | | | | | | |
|---|-----------|----------|-------------|--------------------|------|--------|--------|----------|-------|--------|-------|------|------|--------|--------|------------|--------|--|--|
| | | | | km ² ha | | | | | | | | | | | | | | | |
| Initial Year | | | | | | | | | | | | | | | | Final Year | | | |
| 2018 | | | | | | | | | | | | | | | | 2022 | EXPORT | | |
| | VP | VS | SI | PA | CAP | CAS | CATI | CAT+ | MI | UB | OE | OU | NO | DA | NNF | CA | | | |
| Primary Natural Vegetation (VP) | 29,130.74 | 44.04 | 0.96 | 569.15 | 0.03 | 0.14 | 3.20 | 31.56 | 1.09 | 1.76 | 1.69 | 0.52 | 0.00 | 205.75 | - | 2.19 | | | |
| Secondary Natural Vegetation (VS) | - | 4,224.77 | 15.10 | 3,209.03 | 1.91 | 6.89 | 7.33 | 61.61 | 0.96 | 2.56 | 4.17 | 0.14 | 0.08 | 0.77 | - | 2.24 | | | |
| Silviculture (SI) | - | 23.69 | 432.49 | 214.85 | 0.59 | 1.40 | 10.66 | 8.00 | 0.00 | - | 0.12 | 0.37 | - | - | - | 0.00 | | | |
| Pasture (PA) | - | 1,484.89 | 25.94 | 41,376.78 | 9.67 | 96.25 | 450.64 | 1,683.39 | 4.95 | 14.15 | 24.08 | 3.84 | 0.14 | 0.01 | - | 0.22 | | | |
| Perennial Agriculture (CAP) | - | 0.43 | 0.13 | 6.20 | 6.41 | - | 0.00 | 0.67 | - | - | - | - | - | - | - | - | | | |
| Semi-perennial Agriculture (CAS) | - | 3.63 | 2.84 | 62.15 | - | 855.80 | 113.00 | 92.66 | - | 0.03 | 0.05 | - | 0.01 | - | - | 0.00 | | | |
| Temporary Agriculture of 1 Cycle (CATI) | - | 5.90 | 0.11 | 61.50 | 0.00 | 108.58 | 58.38 | 302.20 | - | 0.01 | 0.16 | - | 0.00 | - | - | 0.02 | | | |
| Temporary Agriculture of More Than 1 Cycle (CAT+) | - | 80.09 | 3.34 | 507.50 | 0.51 | 4.94 | 402.35 | 4,840.55 | 0.00 | 0.22 | 4.60 | - | - | - | - | 0.00 | | | |
| Mining (MI) | - | 1.55 | - | 5.81 | - | - | - | 0.00 | 14.46 | - | - | 0.14 | - | - | - | 0.03 | | | |
| Urbanized (UB) | - | 5.09 | 0.14 | 28.22 | 0.05 | - | 0.13 | 2.32 | - | 473.53 | 17.82 | 0.88 | - | - | - | 0.01 | | | |
| Other Built Areas (OE) | - | 1.90 | 0.18 | 35.27 | - | - | 0.04 | 0.46 | 0.09 | 8.19 | 45.95 | 0.16 | - | - | - | - | | | |
| Other Uses (OU) | - | 0.07 | - | 0.97 | - | - | - | - | - | - | - | 0.15 | - | - | - | 0.00 | | | |
| Not Observed (NO) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | |
| Deforestation in the Year (DA) | - | 17.60 | 0.00 | 164.16 | - | 0.07 | 2.00 | 3.99 | 0.40 | 0.42 | 0.51 | 0.05 | 0.00 | 0.03 | - | 0.07 | | | |
| Natural Non-Forest (NNF) | - | 0.34 | - | 21.93 | - | - | 0.31 | 0.07 | - | - | - | - | 0.00 | 1.70 | 239.39 | - | | | |
| Body of Water (CA) | - | 1.56 | 0.00 | 0.23 | - | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | - | - | - | - | - | 471.10 | | | |

Figure 4 – Matrix of transitions among land use and land cover classes between 2018 and 2022 in the 39 municipalities of the BAP plateau. (Source: INPE and Embrapa, 2024).

Based on Figure 4, one verifies that the growth of agricultural production areas in the study region during this period is predominantly associated with the incorporation of areas previously used for livestock farming. After the conversion of pasture areas, the intensification of agriculture follows with crop and off-season production cycles. The transition from Pasture to Temporary Agriculture of 1 Cycle or Temporary Agricultural of More than 1 Cycle were the most significant dynamics found in this region, with 4.4% and 16.3% of the total transitions, respectively. During this period, 450.6 km² (43%) of area the Temporary Agricultural of with 1 Cycle and 1,683.4 km² (24%) of the area the Temporary Agricultural of More than 1 Cycle in 2022 were Pasture in 2018. The conversion of 302.2 km² of area the Temporary Agricultural of with 1 Cycle into Temporary Agricultural of More than 1 Cycle was also observed.

The expansion of crops over pastures is a common process in regions of consolidated agriculture in the South and Southeast of Brazil, where pastures are displaced to other regions, mainly the Center-West and North of the country, where they cause deforestation (Barretto et al., 2013). In contrast, in the study region, the replacement of Pasture by Temporary Agriculture occurred in parallel with the expansion of Pasture over Primary and Secondary Natural Vegetation, indicating that the expansion of temporary crops observed in 2022 is indirectly related to losses of native vegetation in the BAP.

The transition diagram (Figure 5), obtained from the STATISTICS → TRANSITION menu of the TerraClass interactive map, allows a detailed analysis of land use and land cover changes across several years. In this case, the years 2018, 2020 and 2022 from the 39 municipalities of the BAP plateau, were selected and the thematic class Temporary Agriculture of More Than 1 Cycle was activated in 2022. The thickness of the lines highlighted

in cyan, show the historical transitions and the areas of the thematic classes converted to Temporary Agriculture of More Than 1 Cycle in 2022. The largest flows towards this class in 2022 originate from the class itself in 2018 and 2020, which indicates its maintenance during this period.

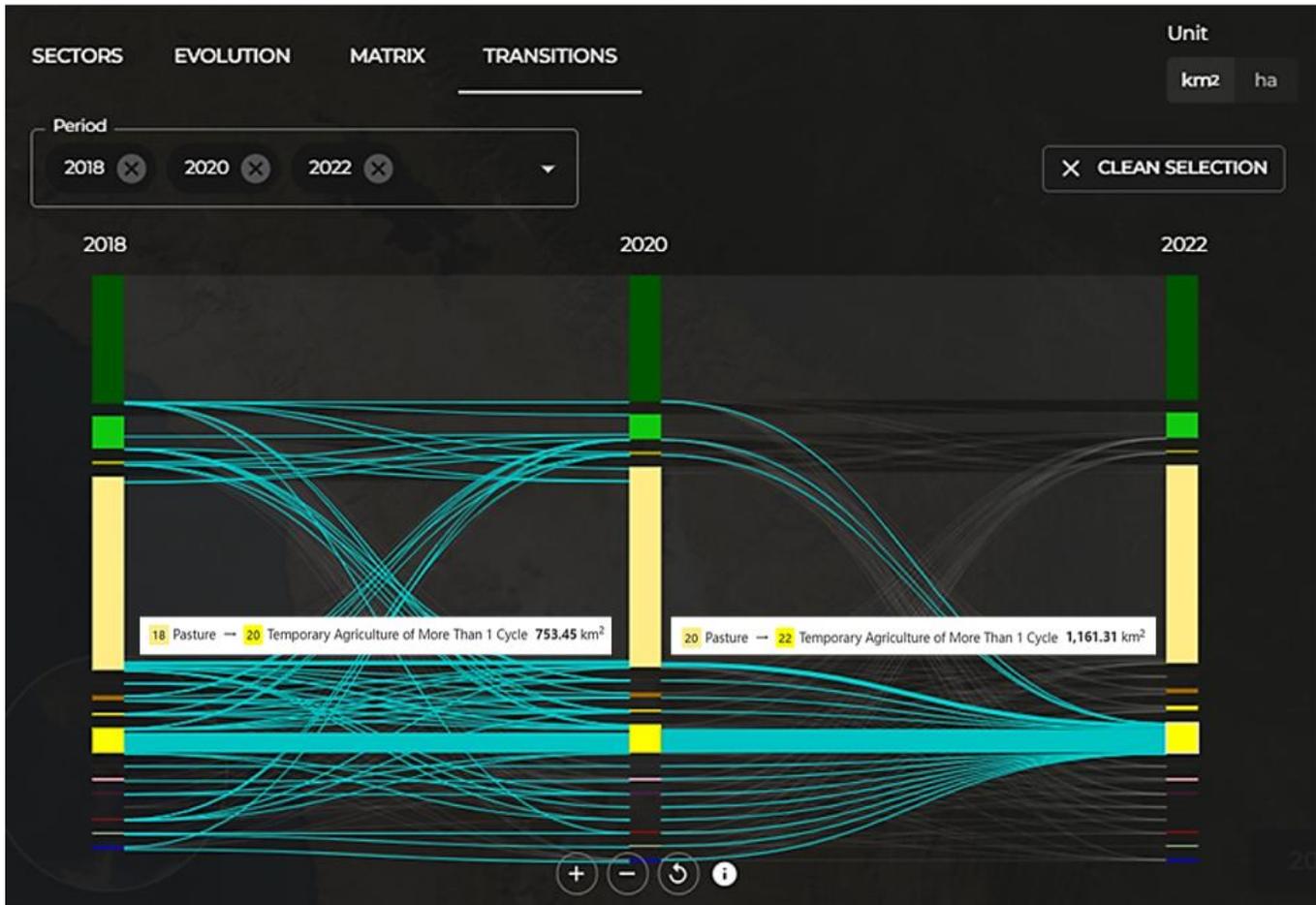


Figure 5 – Transition diagram for the years 2018, 2020 and 2022 in the 39 municipalities of the BAP, activated the thematic class Temporary Agriculture of More Than 1 Cycle in 2022. (Source: INPE; Embrapa, 2024).

Disregarding the flows originated in the class itself, one observes (Figure 5) that Pasture was the class whose transitions were represented by thicker lines, that is, it contributed the most to increase Temporary Crop with more than 1 Cycle between 2018 and 2022. Positioning the cursor over the cyan lines, one identifies the transition area from Pasture to Temporary Agriculture of More Than 1 Cycle between 2018 and 2020 (753.45 km²). Already, between 2020 and 2022, the transition was 1,163.96 km².

The results presented in Table 2, show that from the 5.9 thousand km² (6.4%) Secondary Natural Vegetation area in 2022, approximately 72% already existed in 2018 and 21.8% were converted to other agricultural uses. The expansion of Pasture was the main cause for the decrease of Secondary Natural Vegetation (3,209 km²) and, to a lesser extent, of Primary Natural Vegetation (569.1 km²) between 2018 and

2022 (Figure 4). As previously discussed, agricultural crops had little impact on the decrease from the total area of native vegetation in this period, since the expansion of Temporary Agriculture areas occurred predominantly over Pasture areas. Nevertheless, this is a recurring conversion pattern of native vegetation areas in Brazil, when recently opened areas are transformed into pastures and later converted to agriculture. As a consequence, pastures are moved to other areas in the same region, causing new losses of native vegetation, restarting the process (Ribeiro et al., 2025).

Soybean expansion in the Amazon and Cerrado has suppressed large areas of native vegetation. It has occurred faster than improvements in productivity (Marin et al., 2022). This means that increases in soybean productivity in these biomes has little or no potential to reduce agricultural pressure on native vegetation areas, and may even encourage it (Goulard et al., 2023). In the BAP, the effects of increased pressure from productive areas on native areas on the plateau affect directly the hydrological dynamics of the wet plain (Marques; Rodriguez, 2022). The soil degradation, erosion and deforestation of native areas on the plateau increase the sediment transport, organic matter and nutrients to the wet plain (Guerra et al., 2020).

On the other hand, Figure 4 shows that Pasture also lost 1,484.9 km² from 2018 to Secondary Natural Vegetation in 2020, which corresponds to 14.4% of the dynamics, indicating a relevant forest regeneration in this period. To enable the analysis of the time from establishment of forest regeneration in the study region, Figure 6 shows the transition diagram, generated from the STATISTICS → TRANSITION menu of the TerraClass interactive map, in which the years 2018, 2020 and 2022 were selected for analysis of the 39 municipalities of the BAP plateau and the thematic class Secondary Natural Vegetation was activated in the three years.

From the transition diagram shown in Figure 6, one observes that 3,751.7 thousand km² (64%) of the 2022 area remain in the process of forest regeneration for at least 4 years. Since this is a region of pasture expansion, mainly over areas of Secondary Natural Vegetation for later entry of agricultural crops, it is likely that the areas that persist in regeneration are less suitable for mechanization. Due to that, they remain as Secondary Natural Vegetation. Likewise, it is also possible that older areas of pasture converted to temporary crops may be less suitable for mechanization or unsuitable for agriculture and, therefore, are abandoned and start the regeneration process (Silva et al., 2007; CRK et al., 2009).

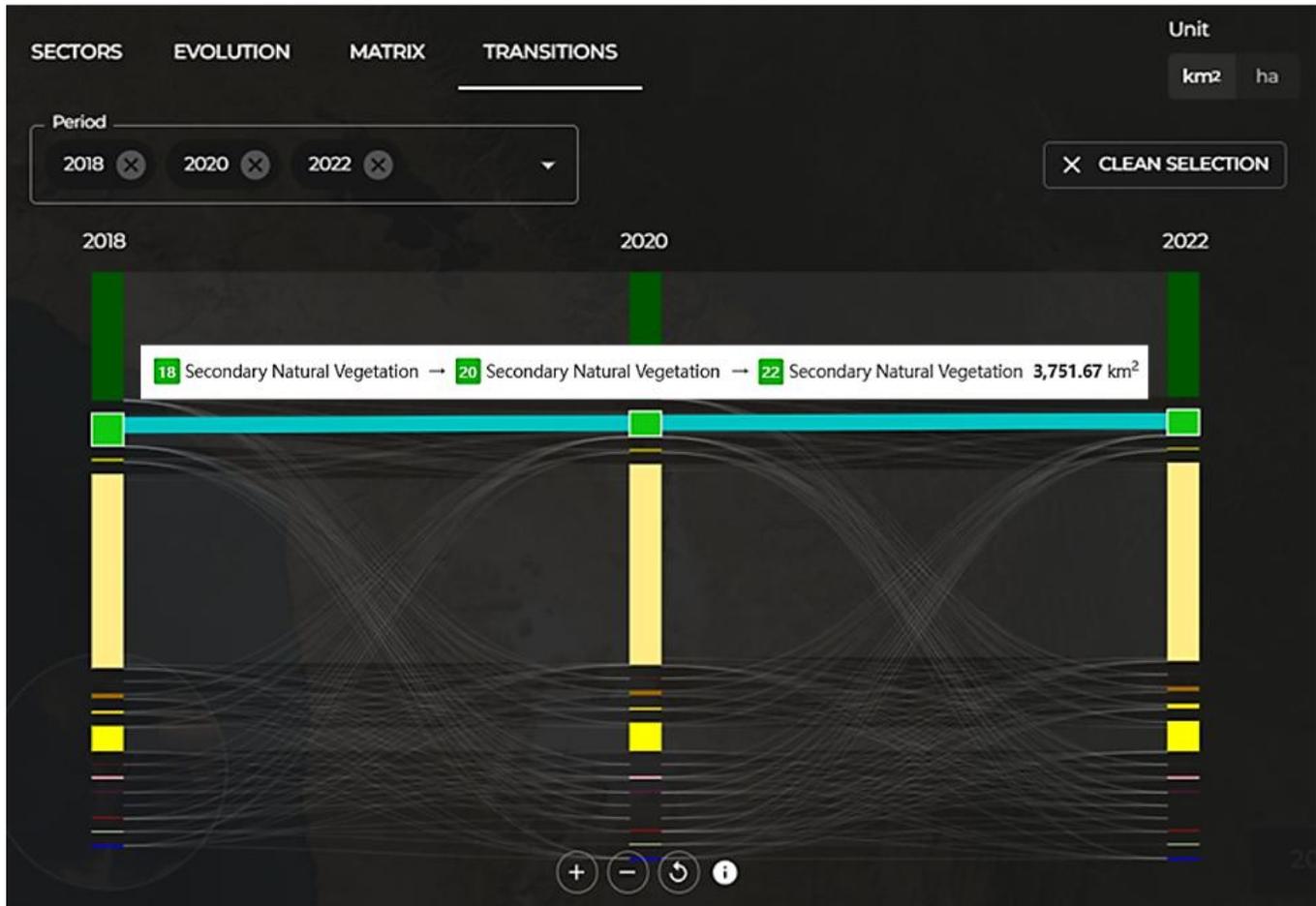


Figure 6 – Transition diagram for the years 2018, 2020 and 2022 in the 39 municipalities of the BAP and activated thematic class the Secondary Natural Vegetation in all three years. (Source: INPE; Embrapa, 2024).

Using the available tools on the TerraClass Digital Platform, it was possible to describe complex land use and land cover transition processes in municipalities on the plateau and infer its possible effects on the Pantanal foodplain. The interactive map is flexible and, after selecting the study region, access to the information is done through direct interaction with the figures, such as calculating the transitions between thematic classes in the diagrams. Clicking the lines on the graph, one obtains immediately the areas converted from one specific class to another and, clicking on the flow at one of the classes, the area converted to the target class is shown (Figures 5 and 6).

The interactive map also allows to see the spatial transition areas on land use and land cover maps. The municipalities of Bela Vista, Terenos, Bonito, Nioaque and Jardim, located on the BAP plateau in the State of Mato Grosso do Sul, present the largest pasture areas converted to agriculture in the period, respectively 148.68 km², 94.36 km², 90.73 km², 79.26 km² and 62.74 km². Based on this, the transition diagram illustrated in Figure 7, generated from the STATISTICS → TRANSITION menu of the TerraClass interactive map, shows the

spatialization of the 148.68 km² transition area in Bela Vista municipality. It is highlighted in cyan on the map, obtained from the transition diagram, in which the thematic class Pasture is fixed in 2018 and 2020, the thematic class Temporary Agriculture of More Than 1 Cycle in 2022 is activated by clicking on the line that connects the years 2020 to 2022, which represents the transition flow.

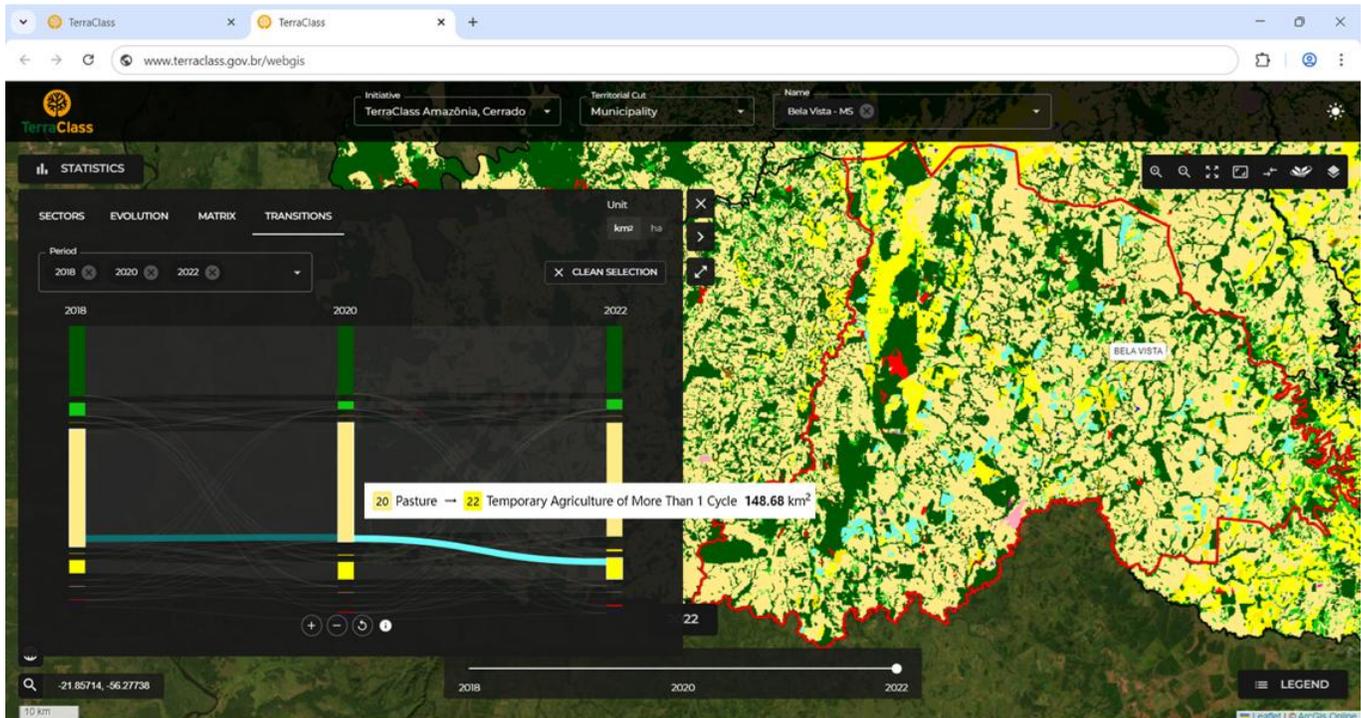


Figure 7 – Transition diagram in the municipality of Bela Vista, with the Pasture thematic class set in 2018 and 2020, the Temporary Agriculture of More Than 1 Cycle thematic class activated in 2022 and clicking on the line connecting the year 2020 to 2022. (Source: INPE; Embrapa, 2024).

The municipality of Bela Vista - MS, has been notable for the recent expansion of soybean cultivation, which can carry sediments to rivers, cause contamination of water bodies with agrochemicals and, consequently, impact the natural resources of the Pantanal floodplain (Colman et al., 2019; Mello et al., 2020).

In general, from 2018 to 2022, there was a loss of native vegetation in the 39 municipalities of the BAP plateau, due to the increase of deforestation in the Amazon and Cerrado biomes. Most of the forest regeneration areas persisted during this period and the lost area was converted to pastures, which still predominate in a large sector of the region. As a result, agricultural areas expanded mainly over pasture areas, initially with a production cycle, followed later by the intensification of crop and off-season production cycles.

IV. CONCLUSIONS

Using the computational tools available on the TerraClass GeoPortal and based on new mappings from 2018, 2020, and 2022 of the Amazon and Cerrado biomes, it was possible to quickly generate information on land use and land cover and its transitions in the 39 municipalities of the BAP plateau.

The spatial analysis showed that the transition from pasture to agriculture is the most significant dynamic found in the BAP plateau region, initially with a production cycle, followed later by the intensification of crop and off-season production cycles.

The results demonstrate the potential of the TerraClass Digital Platform to support territorial management, which will soon incorporate the 2024 mapping of the Amazon and Cerrado biomes. In the future, TerraClass mappings will also be carried out in other Brazilian biomes, especially in the Pantanal, making it possible to assess the impacts of changes in land use and land cover on natural resources throughout the BAP.

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