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Analysis of population variation in the Pantanal biome between 2010 and 2022 and the improvement of the IBGE Territorial Base for the 2022 census

Análise da variação populacional no bioma Pantanal entre 2010 e 2022 e o aprimoramento da Base Territorial do IBGE para o último censo

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Abstract

Recent scientific evidence has elucidated the substantial degradation that the Pantanal biome has experienced in recent years. This study aims to provide an analytical examination of the population dynamics within the Pantanal biome by comparing data from the 2010 and 2022 Demographic Censuses, while also incorporating advancements in the geospatial representation of census tracts in the latter census. The methodology employed includes the development and application of SIGBT to improve the tract grid, the analysis of variations in the resident population of rural tracts using heat maps, and a direct comparative analysis of the total number of residents, as well as gender-specific populations, in both censuses. The findings indicate significant disparities in population increases and decreases, as well as variations between male and female residents at the census tract level. Notably, a pronounced decline in the rural population of the Pantanal was documented, particularly within the central-northern region, encompassing the municipalities of

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Corumbá, Barão de Melgaço, and Aquidauana. The observed negative population flow in rural census tracts between 2010 and 2022, coupled with the occurrence of prolonged droughts and unprecedented wildfires in 2019 and 2020, suggests a potentially detrimental effect of these extreme climatic events on the residential stability of the rural communities in the Pantanal biome.
Keywords:
Heat map, Population dynamics, Wildfires.

Resumo

Evidências científicas vêm demonstrando com clareza o intenso processo de degradação que o bioma Pantanal tem sofrido nos últimos anos. O objetivo desse artigo foi apresentar uma análise da dinâmica da população residente no território do bioma Pantanal a partir da comparação dos dados do Censo Demográfico 2010 e dos resultados já divulgados do Censo Demográfico 2022 considerando, também, as melhorias na representação geoespacial dos setores censitários no último censo. Os métodos descrevem o desenvolvimento e a aplicação do SIGBT na melhoria da malha de setores, a análise da variação no número de moradores nos setores rurais por meio de mapas de calor e a comparação direta do número de moradores, de homens e de mulheres nos dois censos. Os resultados mostram uma diversidade expressiva entre aumento e redução de moradores e de homens e mulheres no nível do setor censitário. A diminuição da população na área rural do Pantanal foi significativa na sua porção centro-norte, principalmente nos municípios de Corumbá, Barão de Melgaço e Aquidauana. A ocorrência de um fluxo populacional negativo nos setores censitários rurais localizados no bioma entre 2010 e 2022 e a incidência de seca prolongada associada a queimadas sem precedentes nos anos 2019 e 2020, podem indicar um possível impacto negativo desses eventos extremos na permanência dos moradores na área rural do Pantanal.
Palavras-chave:
Dinâmica populacional, Mapa de calor, Queimadas.

I. INTRODUCTION

The Pantanal biome is undergoing an intense degradation process in recent years (Silva et al., 2011; Lima et al., 2015; Alho et al., 2017; Alho et al., 2019). The still well-preserved environment described by Junk and Cunha (2005) shows already clear scars from the economic development process foreseen by these authors almost 20 years ago. The change in the hydrological regime and the mono-modal flood pulse within the biome, caused by physical structures, such as hydroelectric plants, and by the expansion of agriculture and livestock farming in the biome's surroundings, has reduced its resilience to the impacts of climate changes in recent years. Furthermore, the headwaters of the main tributaries, responsible for keeping the Pantanal humid for most of the year have also suffered with such changes.

The fragility of intermittent flooded area ecosystems can be measured by the plant and animal species that inhabit these areas. Junk et al. (2006) found a low presence of endemic species in the Pantanal biome and

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a high presence of a large number of species adapted to a wide ecological range. These authors stated that "the composition and diversity of species in the Pantanal are the result of its paleo-climatic history and recent climatic and hydrological conditions" and that the ecological basis of this biodiversity is due to the presence of permanently flooded habitats, others that are permanently dry, and others that are periodically flooded.

The occurrence of a less intense rainfall regime and the predominance of a longer period of dry air in the years 2019 and 2020 over the Pantanal, leading to a significant drop in the level of the region's rivers and an increase in the incidence of fires, was described by Marengo et al. (2021). The impact of the degradation on this ecosystem caused by the unprecedented incidence of fires in this period, which consumed 31% of the Pantanal in a single year, can be estimated by the negative impact it had on the jaguar population in this biome, as consequences of hunger, dehydration, displacement, defense of territory, and low fertility (Barros et al., 2022).

While there is relatively broad knowledge about the various aspects that make up the complexity of the Pantanal biome, there is also a significant lack of scientific knowledge about several aspects, as described by Shulz et al. (2019). According to these authors, some of these aspects are quantitative studies of a social, economic and cultural nature, part of which is covered only by the Demographic Census of the Brazilian Institute of Geography and Statistics (IBGE). However, these data are collected only every 10 years.

The adoption of solutions based on free software by the Brazilian Government sphere is recent. Until the 1990s, governments bid for and contracted proprietary software licenses for most information needs, which greatly limited the ability to audit the quality of the contracted systems due to a lack of transparency, increased public spending on these services and restricted the dissemination of computational tools in institutions (Silveira, 2004).

It was only after the creation of legal support that paved the way for the adoption of new technologies based on free software that strategies began to change in public institutions. Among these legal supports, federal ordinances[1] and laws[2] stand out, which made viable the development of systems within the public service. The main advantages of free software, according to Hexsel (2002), are: low social cost; freedom in relation to proprietary technologies; independence from a single supplier; initial outlay close to zero; no

[1] Ordinance STI/MP No. 46, of 09/28/2016 (amended by Ordinance SGD/ME No. 3, of 06/27/2019), which provides for the provision of Brazilian Public Software.
[2] Art. 16 of Law No. 14,063, of 09/23/2021, which establishes that information and communication systems developed exclusively by the public administration are governed by an open source license, allowing their use, copying, modification and distribution without restrictions by all public bodies and entities.

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hardware obsolescence; robustness and security; possibility of adapting applications and redistributing modified versions; abundant and free support; and systems and applications that are generally highly configurable.

After several years of relying on proprietary software to update and maintain its Territorial Base, a team of IBGE employees, assigned to the IT and Geosciences Directorates, decided to develop a geo-processing solution based on free software in 2014. This solution was disseminated throughout the network of 27 State Superintendencies and part of the 564 Collection Agencies, which allowed the decision-making process on the most correct and pertinent way of updating geospatial information to be transferred o the state members of this network, reversing the centralizing logic that prevailed for almost 70 years. With the decentralization of mapping activities, agency teams were able to be trained to edit the geo-information layers of the Mapping System (SISMAP) and thus contribute to update the Territorial Base.

The development of the Geographic Information System of the Territorial Base (SIGBT) began in 2014 after it was found out that the proprietary software solutions available at the time did not meet IBGE's internal demand to involve agency technicians in the process of reviewing and updating the Territorial Base. One of the main obstacles was the diversity of infrastructure in the agencies, especially regarding the quality and speed of internet connection, a scenario that required the development of an offline solution that was both agile and efficient. The SIGBT was widely used to prepare the Territorial Base for the 2022 Demographic Census.

Therefore, the objective of this work was to analyze the population variation of residents, men and women, in the Pantanal biome, at the census tract level, between 2010 and 2022 and to present results of the improvement of the Territorial Base worked in a decentralized manner at IBGE with the use of SIGBT.

II. Materials and Methods

The Territorial Base (BT) is the graphic file that supports the census and other sample surveys conducted by IBGE (Macedo et al., 2012; IBGE, 2008). It consists of a graphic base of geo-referenced information containing the representation of geographic structures, census tracts and other elements that underpin the operational organization of the census, some sample surveys, dissemination of data from Population Estimates and territorial areas. These structures may be of a legal nature, such as the political-administrative division; of an analytical nature, linked to territorial patterns or specific population groups; or of an operational nature, intended to guarantee access and coverage of the census units.

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Regarding the territorial structures that make up the BT, the census tract underpins the operational organization of the interviews. It is a territorial collection unit whose size, number of households and establishments allow the census taker to complete his/her activities within a given time frame. In addition to census activities, sample surveys also use census grids as a reference.

These grids are not limited to the borders of census tracts, since the demand for data for various territorial divisions is increasingly intense. This set of geospatial information and records undergo annual update cycles, dispensing with data and cartographic inputs in adequate spatial and temporal resolution, capable of portraying the diversity of identities, behaviors, ways of life and environmental phenomena reflected in the organization of settlements. This set is capable of configuring the urban and rural frameworks of Brazil, translating into the reality of territorial arrangements, enabling users of geographic and statistical information to perform a consistent analysis of Brazilian geographic space and ensuring comparability between operations and multi-temporal analyses of the national territory occupation.

In BT's preparation for the 2022 Census, several technologies were incorporated into the update systems (such as a geo-service for updated high-spatial resolution images and the QGIS software add-on for decentralized offline editing) that resulted in the improvement of the geospatial representation of the census tracts of the derived layers. Quantum Geographic Information System (QGIS) is a multi-platform open-source software that has was rapidly developed and steadily adopted in recent years. "QGIS is regularly enhanced with new features to better meet the needs of users. This is achieved through the integration of a wide range of extensions from geographic information systems science, e.g. GDAL, GRASS, SAGA, Orfeo ToolBox (OTB), etc., as well as the development of a proprietary QGIS server and a real coding engine based on Python." (Baghdadi et al., 2018) The results presented in this work illustrate some of these improvements taking as an example the census tract grids in the Pantanal biome region of the 2010 and 2022 censuses.

Development of SIGBT

In 2014, IBGE adopted a model for the continuous updating of the BT, i.e., no longer working on updating only in the previous year of a census operation, which required more agile tools and systems for operators. At that time, however, BT's software was all proprietary licensed and had slow and inefficient editing processes because it was centralized and had closed coding.

Parallel to this, a team of analysts had been formed within IBGE, coming from the institution's specialized hiring process for technical positions held in previous years. These employees had two important characteristics: methodological knowledge of the activities performed by the institution, and some had IT

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technical capacity for system development. This was the start of the development of a more advantageous solution to carry out BT updating activities. Such a system should be designed to meet the following technological requirements: (1) be supported by a free platform that does not require the allocation of public funds for software licensing and that preferably has open-source codes to avoid future dependencies; (2) operate with low computational and network requirements to meet the different realities of users; and (3) have full customization capacity to adapt to the needs of BT and IBGE. Given these requirements, and considering the technical knowledge and stage of geo-processing evolution tools at the time, the system was defined as an external add-on for QGIS and its pyQGIS API with the graphical interface modeled after the Qt development environment and its pyQt API (Sherman, 2018).

The Geographic Information System of the Territorial Base (SIGBT) is a technological solution created in 2014 and whose design, implementation and approval stages have always been characterized by a constant collaborative development, where technicians from BT and related areas of IBGE participate and contribute to its improvement. The development of SIGBT was designed in a modular way, seeking to meet the methodological and conceptual priorities defined by IBGE. Its code was written mainly in Python, and the manipulated data managed by an SQLite database (and its extension SpatiaLite), made available to internal users for download and offline editing, from a versioned Git repository. This repository has the function of receiving Work Orders (WO) from SISMAP for offline editing and then importing the edited WO to be incorporated by SISMAP. Figure 1 illustrates the SISMAP architecture, its relationship with external databases, such as CNEFE (IBGE, 2018), and editing in QGIS with the SIGBT plugin.

Figure 2 illustrates the flow of Work Orders generated in SISMAP and the tasks performed by SIGBT in the offline environment. Among the main functionalities performed by SIGBT, the graphic operations performed on census tracts (divisions, aggregations, adjustments and ensuring comparability between grids) and on intra-tract layers (locations, streets, blocks and faces) stand out, as well as ensuring the topological and methodological consistency of the editions performed. The production of maps used in census operations is also performed by SIGBT.

Since the advent of SIGBT, three major data update cycles, aimed at census operations, have already been carried out using this system: the 2015 Population Count (which ended up being canceled due to lack of budget allocation), the 2016 Agricultural Census and the 2022 Demographic Census (which caused two update cycles due to two consecutive postponements).

Analysis of residents in the rural tract

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The variation of the total population in rural tracts in the Pantanal biome was developed using the kernel density estimation method (Okabe et al., 2009; Węglarczyk, 2018), which estimates the probability density function from a point layer generated by the centroids of the 2010 and 2022 tracts with the attributes of the total number of habitants in each tract. The kernel was configured with a radius of 90 km to cover all distances between the centroid points and regular 1 km cells. The matrix layers generated for each year underwent an algebraic operation of dividing the 2022 values by those of 2010, in which values above 1 indicate an increase and below 1 a reduction in population from 2010 to 2022. These two groups were separated for the purpose of comparative analysis.

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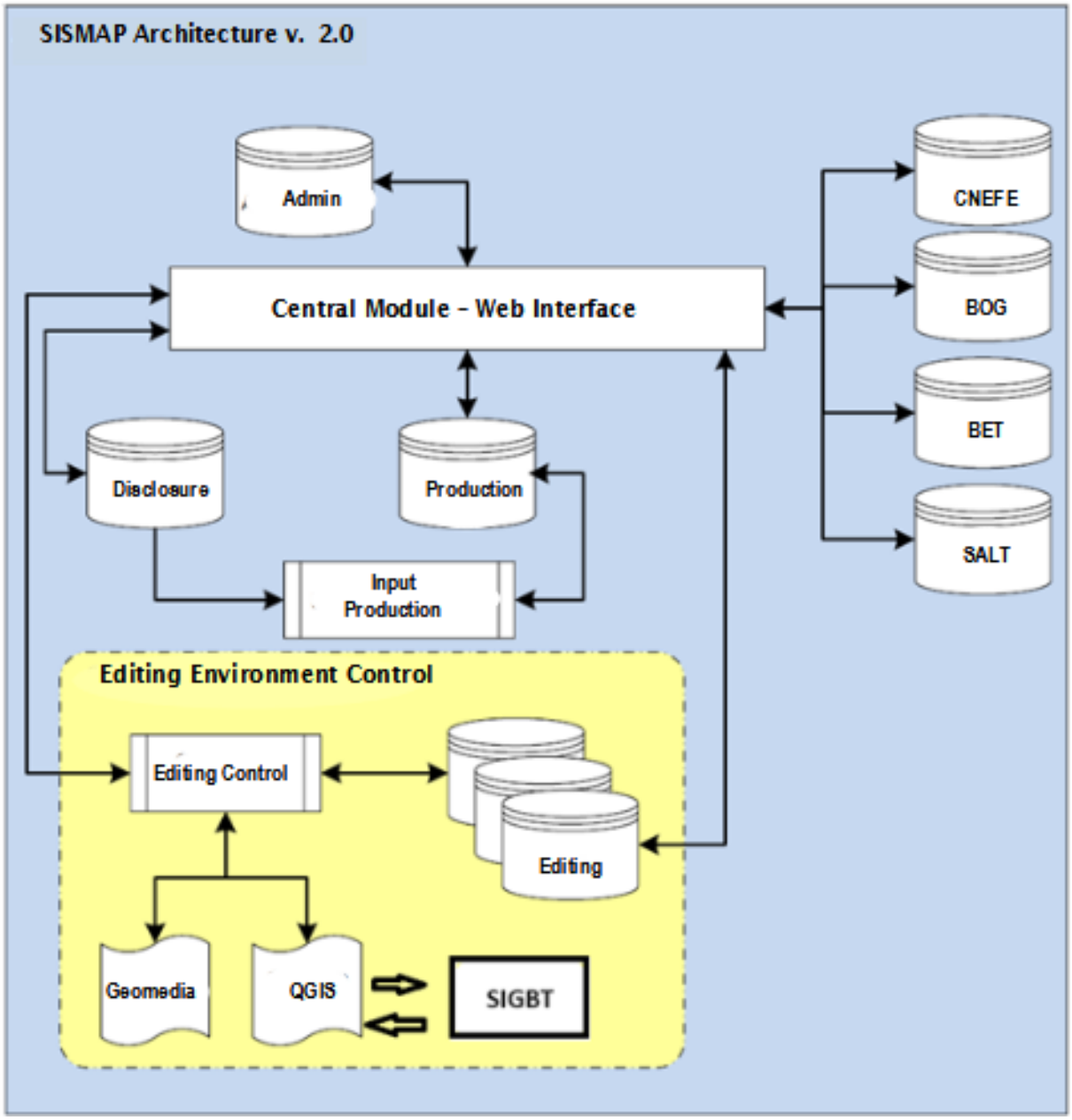

Figure 1 – Architecture from the offline editing flow SYSTEM with SIGBT. Source: Proposal to update the SISMAP of the Information Technology Directorate (DI/COBAD/GEGEO) from 2017 and adapted by the authors.

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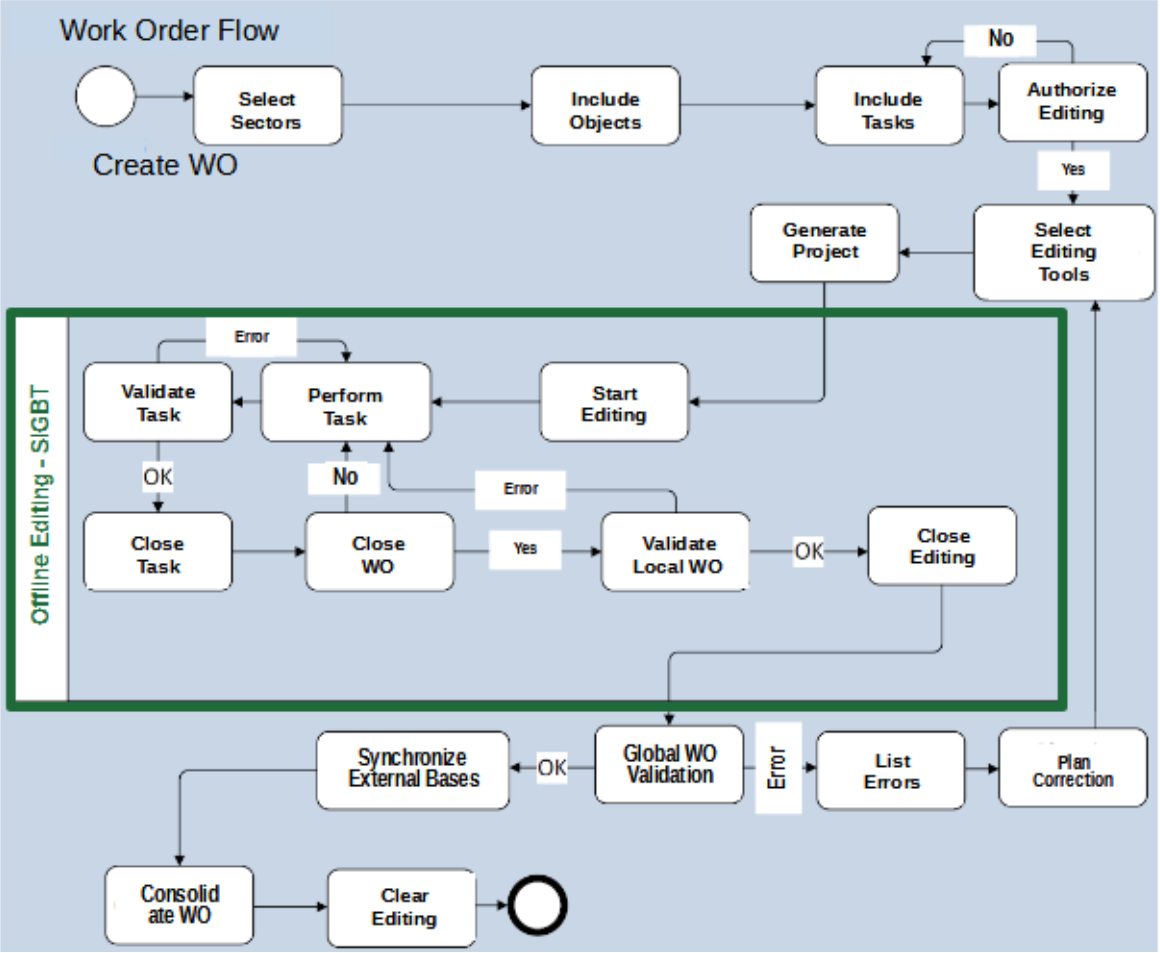

Figure 2 – Work Order Flow and tasks executed offline by SIGBT. Source: SISMAP update proposal from the IT Directorate (DI/COBAD/GEGEO) from 2017 and adapted by the authors.

Analysis of percent variation of residents between both census

The improvement of the census tract grid significantly improved both the collection of demographic data and the territorial representation in the dissemination of census results. However, this improvement increases the spatial difference between the grids of different censuses, which makes a direct spatial crossing between digital layers difficult. Due to that, to allow the geospatial comparison of population data between 2010 and 2022, it was necessary to edit the grids execute this analysis. In this edition, the same attributes which are the subject of this study were selected, i.e. the total number of residents, number of male and female residents. Then, an analysis was made of the history of census tract formation between 2010 and 2022, adding this history to the 2022 tracts. Subsequently, the tracts that underwent the aggregation process that occurred after the collection of the 2022 Census, but before the dissemination of the results used in this study, were removed from the analysis layers.

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The aggregated tract data were distributed among the original 2010 tracts. Afterwards, the edited tracts with the same census tract code (geocode) in 2010 were merged to allow direct spatial analysis. Finally, a selection was made by overlap area with the Pantanal biome boundary to select only the census tracts with more than 20% of its area within the biome boundary. Using the edited and comparable data, direct analyses were made of the differences in the total number of residents, the number of men, and women in all selected tracts, both urban and rural. The percentage changes from one census to the next were analyzed both tabular and spatially.

III. RESULTS AND DISCUSSION

Monitoring the dynamics of occupation from Brazilian territory and its social, legal, and economic manifestations is the main challenge of IBGE's BT activities. To update the geospatial representation of these dynamics, two large groups are considered: the Brazilian Territorial Division (BTD), which monitors the legal instruments developed by the federative entities over time, and the census tract grid with its internal graphic elements. The census grid of the 2010 Census within the Pantanal biome consisted of 431 tracts. The census grid used in the 2022 Census collection increased to 654 tracts. This 51.7% increase in the number of census tracts is due to three aspects: the expansion and densification of urban areas; the methodological refinement adopted; and the application of new technological inputs by IBGE that allowed the improvement of the representation from urban and rural spaces through more refined morphological criteria.

Identification of territories occupied by people and traditional communities (PTC)

Figure 3 shows the distribution of areas from Traditional People and Communities identified and registered in census tracts within the Pantanal biome. In 2010, there was only one indigenous tract within the biome. For the 2022 Census, eight other areas were identified as being occupied by indigenous people and one as *Quilombola*. In item C of this figure, one sees the improvement in the representation of the border from the indigenous area, which in 2010 was delimited with a blue polygon and in 2022 with a green polygon.

It is worth noting that even though it was not isolated in a census tract in 2010, residents were able to declare themselves indigenous when answering the color and race question in that census. However, with the improvement of the BT, the location of this traditional population became better defined. For the *Quilombola* population, it was necessary to identify the area of their community before the collection for the 2022 Census, as shown in highlight A of this figure.

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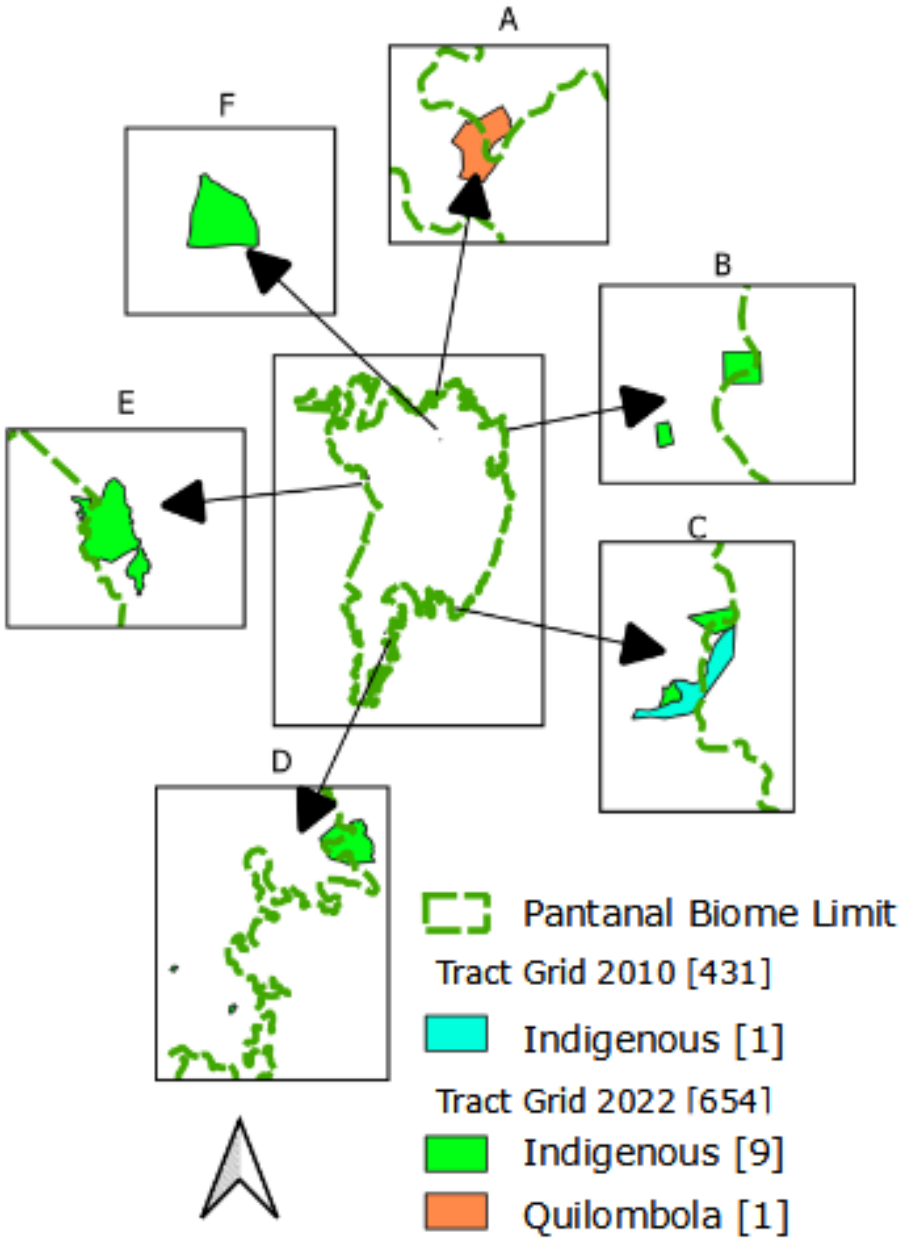

Figure 3 – New PTC areas identified for the 2022 Demographic Census. Prepared by the authors.

Morphological adjustments at the borders of census tracts

With the implementation of morphological criteria to improve the representation, mainly of urban and rural areas, several adjustments to the census tract grid were necessary to prepare the grid for the 2022 Demographic Census collection.

Figure 4 shows some examples of these adjustments in the tracts within the Pantanal biome. The yellow lines represent the boundaries of tracts from the 2010 census and the red ones from the 2022 census.

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Highlight A shows the boundary of a rural tract from 2010 (yellow) and the red line the result of the adjustments made for the 2022 census. In this case, the tract not only underwent adjustments on its borders, but was also subdivided in two. Highlight B shows a morphological adjustment isolating an area with rural characteristics close to the urban area that integrated parts of tracts from 2010.

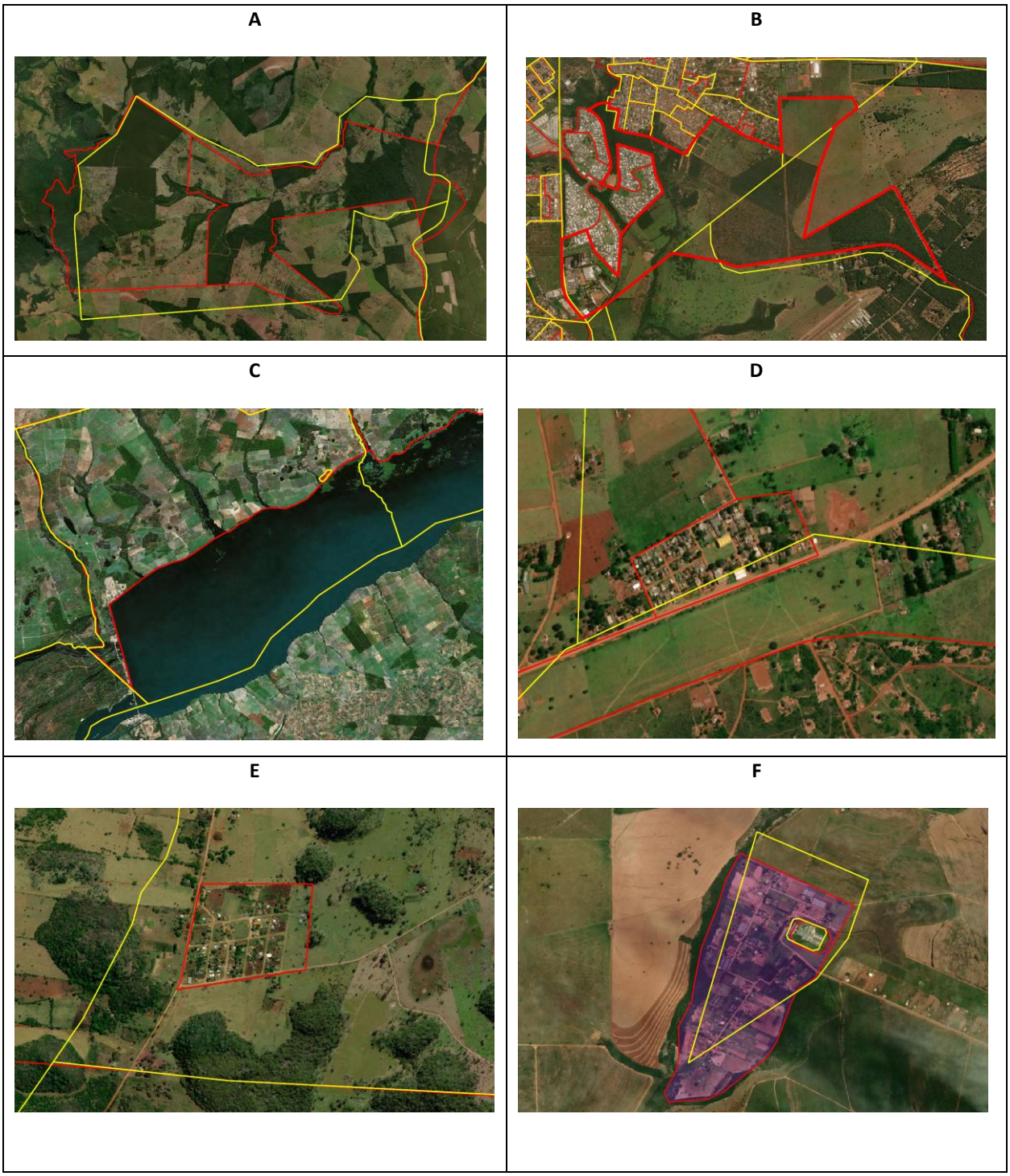

Figure 4 – Examples of adjustments to the census tract grid for the 2022 Demographic Census. Prepared by the authors.

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In this example, the rural part of the urban tract that was delimited by the straight yellow line became part of the neighboring rural tract, generating a single tract delimited by visible features on the ground, which facilitates the identification of its boundaries in the field. Highlight C shows an example of the separation from a water body that was part of the tract in 2010 and in 2022 it was isolated in a tract without homes. The purpose of this separation is to remove the territorial effect for the calculation of population density in census tracts. Highlights D and E present an example of the identification from a new rural cluster (or village) that did not exist in 2010 and, when isolated in a tract, its collection and results are now disclosed in more detail. Highlight F presents an example of adjusting the boundaries of a tract classified as an isolated urban center which, with the availability of high spatial resolution images, has now its boundaries better defined in the SISMAP database.

Analysis of aggregated population data by tract from the 2010 and 2022 censuses in the pantanal biome

As a result on the analysis from data of data of the 2010 and 2022 Censuses, released in the form of aggregates by census tract, the information derived from the kernel analysis that produces heat maps is initially presented. Figure 5 shows these maps generated by points derived from the centroids of only rural tracts (classified as situation 8 by IBGE) with the attributes of the total number of residents per tract.

In 2010, the variation of residents per cell varied between 0.32 and 16.94, with a higher concentration in two regions in the northern Pantanal biome and another two in the south-central portion. Between these two regions and also further south of the biome, it can be seen that on the 2010 map there is a light blue area, with an intermediate number of residents. In 2022, the variation in the number of residents per cell was greater, ranging from 0.004 to 26.58, with the highest concentration of residents in the rural area in the northern portion of the biome, which corresponds to the territory of Mato Grosso State.

According to Souza-Higa and Higa (2002), the decline of the rural population in the municipality of Barão de Melgaço - MT had already been observed since the 1980s. The main factors that drove the rural exodus in this municipality, according to the same authors, are: the difficulty of access to land by small producers who lost the ability to produce for their own subsistence and were unable to expand their properties to increase this production; the precariousness of the road infrastructure that made it difficult to access and distribute production; the insufficient number of primary schools, which encouraged parents to move to the city so that their children could receive a quality education; and the expansion of large estates with extensive livestock farming activities that did not offer employment opportunities in rural areas. More recent studies in other regions of Brazil point to these same factors as promoting the rural exodus (Hein; Da

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Silva, 2019; Breitenbach; Corazza, 2020; Viana, 2020; Prochnow et al., 2022). This indicates that the same factors are likely to persist in the Pantanal biome to this day.

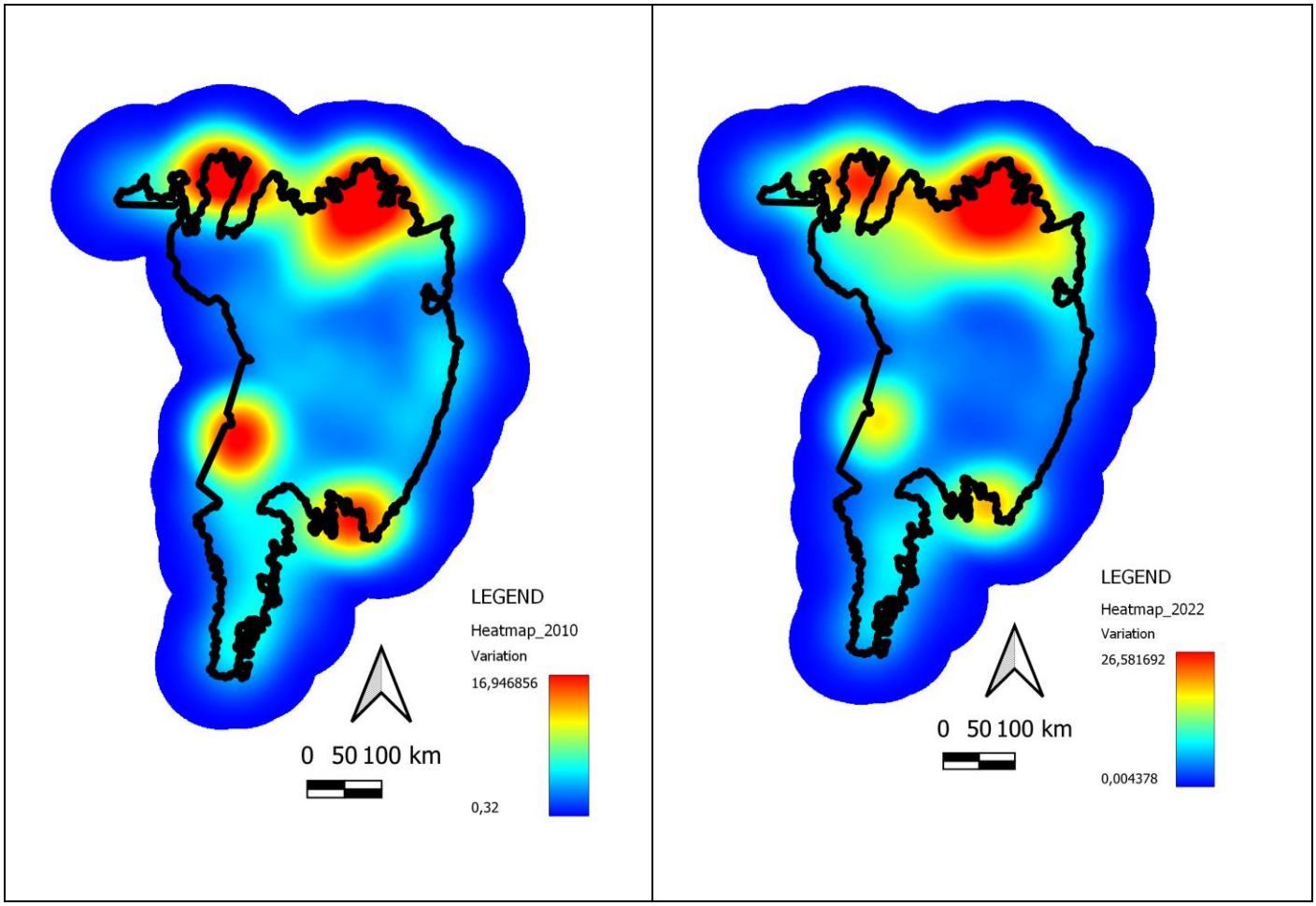

Figure 5 – Heat maps of the total number of residents in rural tracts in the 2010 and 2022 Censuses. Prepared by the authors.

Figure 5 also shows that in the central and southern portions of the biome, the concentration of residents in rural areas is proportionally lower compared to the 2010 information. Considering a relative increase in the total number of residents in the 2022 Census data, the maps show that the rural population was proportionally less concentrated in most of the Pantanal biome compared to 2010. Since this analysis took into account only residents of rural tracts within the biome, possibly there was an increase in the number of residents in urban tracts. However, in the preliminary analysis carried out in this study, with inclusion of urban tracts, the high concentration of residents in these areas overshadowed the variation occurred in rural tracts. That's why only rural tracts were chosen for this analysis. When comparing the total number of residents in the selected rural tracts, it was found that in 2010 there were 39,900 and in 2022 31,867

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inhabitants, i.e., from 2010 to 2022 there was a decrease of 20.13% in the total number of residents in the rural area of the Pantanal biome.

Figure 6 shows the results of the algebraic operation of dividing the number of residents in rural areas in 2022 by the number in 2010, divided by the official limit of the Pantanal biome. The map on the left shows, in color tones, the concentration of values above 1.02, that is, values that indicate areas where there was an increase in residents in rural areas between 2010 and 2022. These areas are concentrated, more clearly, in the NE and NW of the biome, with a lower intensity in the extreme south. The map on the right shows those areas with values below 0.989, indicating places with a reduction in the number of residents. As the figure shows, the central-southern region of the Pantanal biome is where rural areas with a decrease in residents are located between 2010 and 2022.

In another analysis, in which all tracts (urban and rural) with 20% or more of their area within the limits of the Pantanal biome were considered, the histogram of the distribution of the number of men and women in the tracts that are between the standard deviation values was first analyzed, thus removing the most extreme values from this distribution (Figure 7). This result shows that the reduction in female residents in the ranges up to -32% is more concentrated than that of male residents. The columns indicating an increase in female residents total 99 tracts, while the columns indicating an increase in male residents total 71 tracts. On the opposite side, in the columns indicating a reduction, the number of tracts with less women totals 184 and for men totals 146 tracts. These results indicate that the female dynamics within the Pantanal biome is more intense than that of male. This dynamic frequently occurs in rural areas where economic activity is declining and where women go out looking for work to maintain a minimum income for their family (Augusto; Ribeiro, 2005; Schneider et al., 2020), while men tend to remain in their place of origin, usually in rural areas, to preserve their property.

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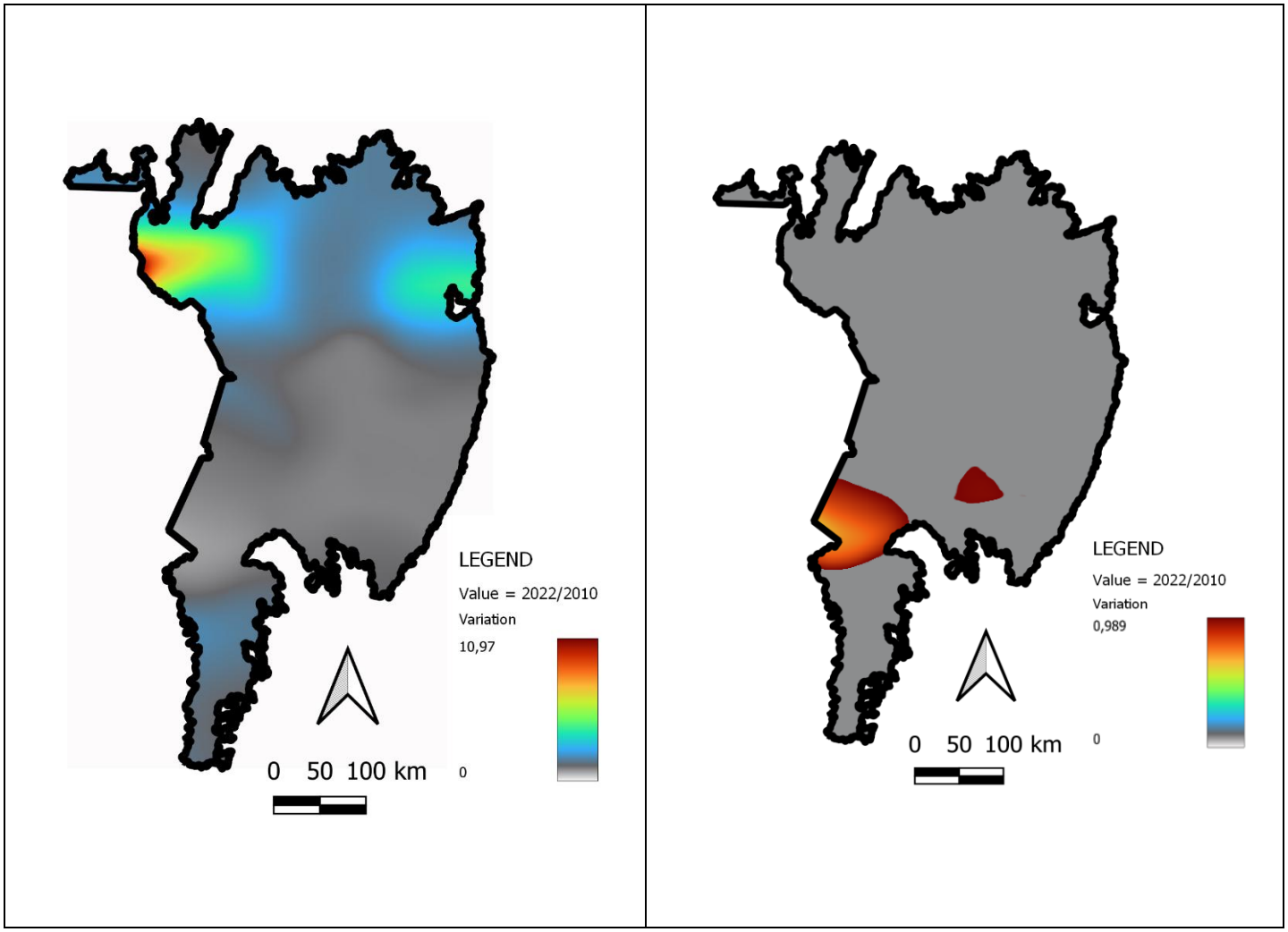

Figure 6 – Product of the division: the total number of residents in 2022 by the total number of residents in 2010. At the left highlighting values above 1 and at the right highlighting values below 1. Prepared by the authors.

In a social-anthropological study of elderly people in the rural area of two Pantanal communities at the municipality of Barão de Melgaço, Pignatti et al. (2011) highlighted some factors that explain the dynamics of men and women in this region. According to these authors, the children who remain on the land, despite the difficulties of working in the fields, do so because a lack of prospects for inclusion in other activities in the city, while women differ from men in that they are able to find employment as domestic workers, especially since education does not have a significant impact on this inclusion. As a result, a greater number of single men are observed in the communities studied, who are overlooked by women who work in the city, because they refuse the difficulties of life in a rural context. Although this study has a restricted geographic scope, it reveals aspects that certainly extend beyond these communities and can explain many of the factors that influence the dynamics of men and women in rural areas of the Pantanal biome.

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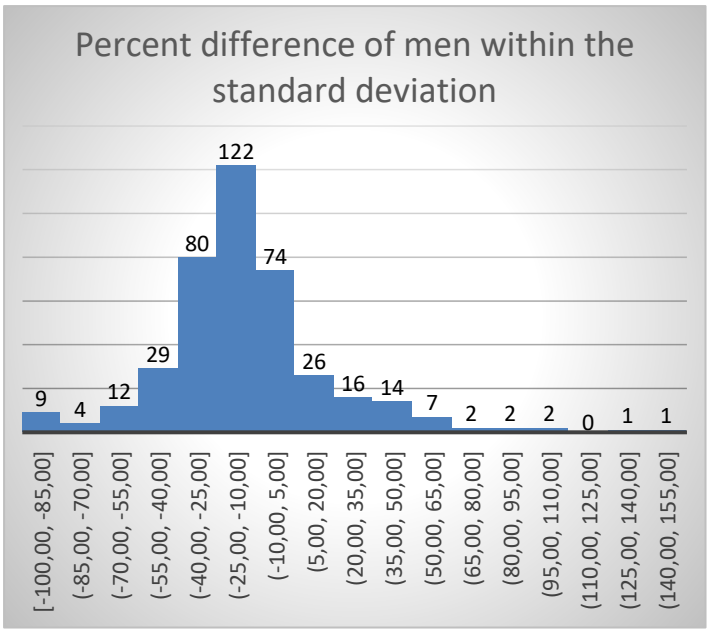

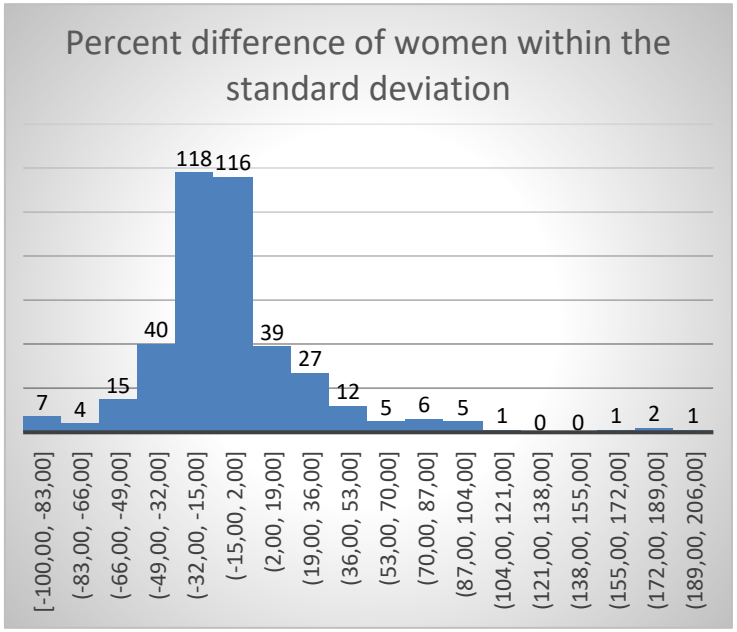

Figure 7 – Distribution of percentage range for increase/decrease of male and female residents within the standard deviation interval. Prepared by the authors.

Figure 8 shows maps with the percent distribution above 20% increase and reduction in the number of male and female residents within the biome, considering the boundaries of the municipalities that make up the area. The blue tones indicate an increase, the orange-red ones indicate a reduction. Analyzing the municipality of Corumbá, with the largest territory within the Pantanal biome, it can be observed that the reduction in the number of men predominates in most census tracts. In the central-eastern portion of the municipality, this reduction was above 50%. The number of women also decreased in this same area of the municipality, but in a smaller number of tracts, with half of them below 50%. On the other hand, the number of tracts with an increase in the number of women is significantly higher than tracts with an increase in the number of men.

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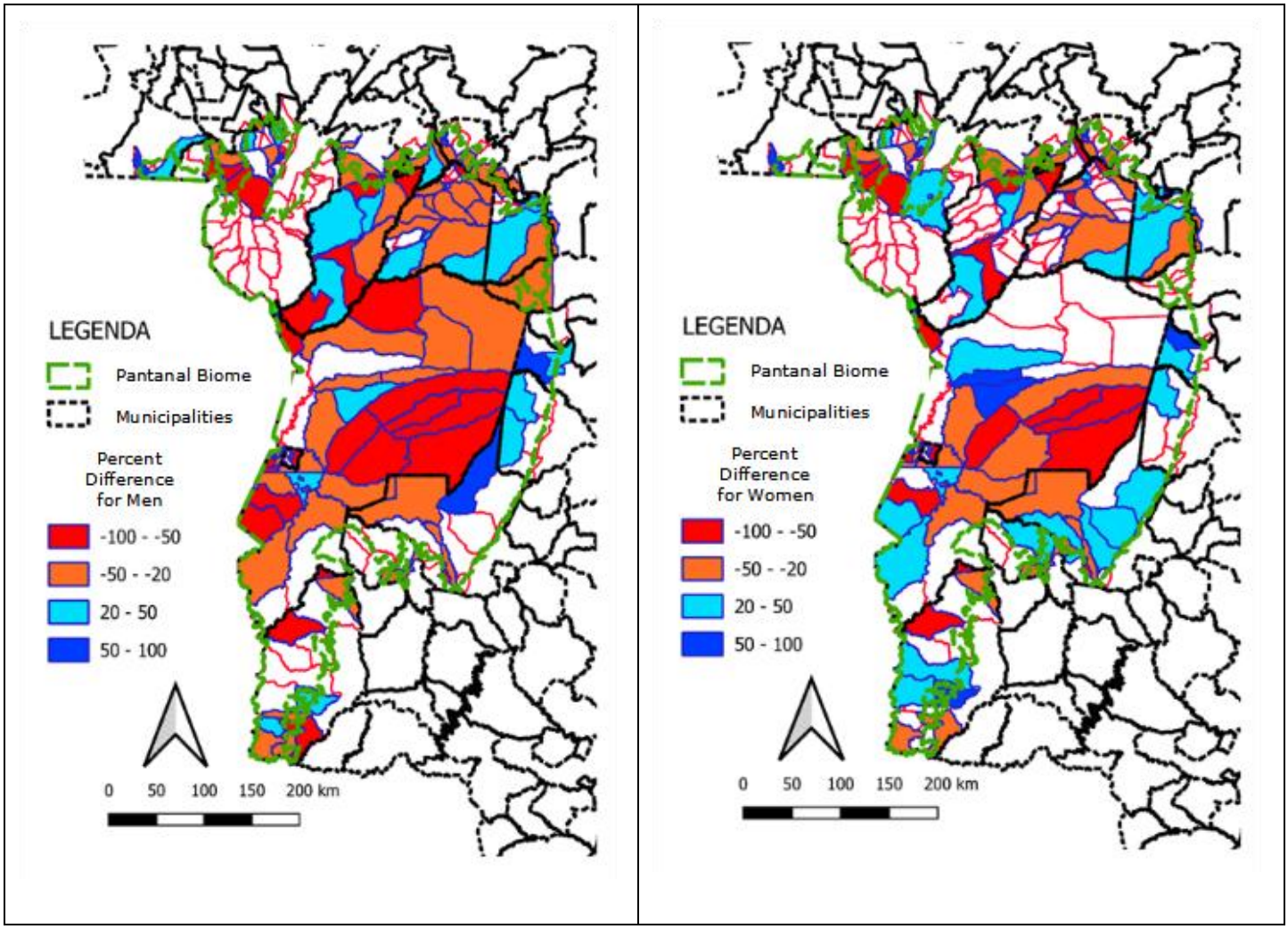

Figure 8 – Maps highlighting percentages of increase and decrease in the number of men and women above 20% in the Pantanal biome. Prepared by the authors.

Another municipality that stands out on these maps with a significant resident reduction is Barão de Melgaço. In this municipality, also a large number of tracts presented a higher reduction in the number of men than women. However, no tract showed a reduction rate above 50% among men. Poconé also shows a significant variation in residents, but in this case it oscillated between an increase and a decrease. In almost all tracts, there was a positive or negative variation above 20% among men.

Similarly to Poconé, Aquidauana shows positive and negative variations above 20% in the portion of its territory located within the Pantanal biome. However, unlike Poconé, Aquidauana shows a variation in the number of women in most tracts, while the variation in the number of men occurs in a smaller number of tracts. Finally, the municipality of Porto Murtinho shows a variation above 20% in almost half of its territory, with emphasis on the positive variation of women in the central portion of the municipality and negative in the extreme north and south of its territory.

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When analyzing the urban areas of these municipalities, despite not being visible in Figure 8 due to the scale, it can be seen that in Porto Murtinho there was a reduction of between 20% and 50%, of both men and women, in practically all urban tracts. In Corumbá, approximately half of the urban tracts had a decrease between 20% and 50% in the number of men and women in about one third of the tracts. In only eight census tracts in the city of Corumbá there was an increase in the number of both men and women out of a total of 161 urban tracts of this municipality.

Considering the impacts of the extreme weather events described by Marengo et al. (2021) that occurred in 2019 and 2020, added to the recurrent and more intense effects of both the drought and the scope of the fires that occurred in 2021. Combined with the delay in carrying out the Demographic Census, which was supposed to take place in 2020 but was only carried out in 2022. It is possible to infer that the data presented in this study reflect, to some extent, the impact that the environmental degradation caused by meteorological phenomena has had on the population dynamics within the Pantanal biome between 2019 and 2022. The environmental degradation caused by fires is likely to interfere with the economic sustainability of the inhabitants of this region, especially on the survival conditions of those who depend on the environment for their subsistence. The resilience of the inhabitants of the Pantanal biome is recognized by several authors, as observed in the literature review published by Schulz et al. (2019), but the exceptional and devastating nature of the fires observed in recent years may have generated a negative impact even on the permanence of this population in the Pantanal.

IV. CONCLUSIONS

The use of SIGBT, in a decentralized way by the State Superintendencies and by teams from the Collection Agencies, produced a significant improvement in the representation of the elements from the Territorial Base. This improvement leads to a more accurate data collection (operational nature), whether through field work to conduct interviews or through monitoring of the collection by supervision teams, and a dissemination of results better adjusted to the characteristics of the Brazilian territory, whether for legal or analytical purposes.

The results presented in this study show the intensity of population dynamics at the census tract level between the 2010 and 2022 Demographic Censuses. There was a significant reduction in the number of residents, mainly men, in the rural tracts of the main municipalities within the Pantanal biome, with emphasis

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on Corumbá, Barão de Melgaço, Aquidauana and Porto Murtinho. There was also a significant reduction in the number of women in these municipalities, but in some areas there was an increase of this population.

The distribution patterns of population dynamics, both tabular and spatial, show differences between the dynamics of men and women. These different patterns may be associated with factors observed in other regions of Brazil, when the predominant economic activity is in decline and women decide to leave to look for work in the cities while men tend to remain in the area to protect their property or land ownership.

The significant population dynamics observed within the Pantanal biome between 2010 and 2022 may have several causes, such as economic and social factors. However, one cannot exclude the possibility that environmental causes had a significant influence on the decision-making of Pantanal residents, especially after 2019, when extreme weather events occurred in three consecutive years. Complementary studies can assess this premise, mainly through interviews with residents of the areas where the greatest population reductions took place, whether male or female.

V. REFERENCES

ALHO, C. J. R.; REIS, R. E. Exposure of fishery resources to environmental and socioeconomic threats within the Pantanal wetland of South America. International Journal of Aquaculture and Fishery Sciences, Los Angeles, v. 3, n. 2, p. 22–29, 2017. DOI: https://doi.org/10.17352/2455-8400.000024.

ALHO, C. J. R. et al. Ameaças à biodiversidade do Pantanal brasileiro pelo uso e ocupação da terra. Ambiente & Sociedade, v. 22, 2019.

AUGUSTO, H. A.; RIBEIRO, E. M. O envelhecimento e as aposentadorias no ambiente rural: um enfoque bibliográfico. Revista Organizações Rurais e Agroindustriais, Lavras, v. 7, n. 2, p. 199–208, 2005.

BAGHDADI, N.; MALLET, C.; ZRIBI, M. QGIS and generic tools. London: ISTE Ltd., 2018. 310 p.

BARROS, A. E. et al. Wildfires disproportionately affected jaguars in the Pantanal. Communications Biology, 2022. DOI: https://doi.org/10.1038/s42003-022-03937-1.

BREITENBACH, R.; CORAZZA, G. Jovens rurais do Rio Grande do Sul/Brasil: questões de gênero na sucessão geracional. Revista Brasileira de Gestão e Desenvolvimento Regional, [S. l.], v. 16, n. 3, 2020.

HEIN, A. F.; SILVA, N. L. da. A insustentabilidade na agricultura familiar e o êxodo rural contemporâneo. Estudos Sociedade e Agricultura, v. 27, n. 2, 2019.

HEXSEL, R. A. Software livre: propostas de ações de governo para incentivar o uso de software livre. Curitiba: Universidade Federal do Paraná, 2002. (Relatório Técnico RT-DINF 004/2002).

IBGE – INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Referências técnicas para a elaboração da base territorial – BT. Rio de Janeiro, 2008. 24 p.

IBGE – INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Padrão de registro de endereços: definições e orientações de uso. Rio de Janeiro, 2019. 53 p. Disponível em:

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.63, n.2, p. 76 – 97, 8/2025
https://doi.org/10.5380/raega.v63i2.99620

https://biblioteca.ibge.gov.br/visualizacao/livros/liv101639.pdf. Acesso em: 26 mar. 2025.

JUNK, W. J.; CUNHA, C. N. Pantanal: a large South American wetland at a crossroads. Ecological Engineering, v. 24, p. 391–401, 2005.

JUNK, W. J. et al. Biodiversity and its conservation in the Pantanal of Mato Grosso, Brazil. Aquatic Sciences, v. 68, p. 278–309, 2006.

LIMA, C. R. N. et al. Variabilidade espacial da qualidade de água em escala de bacias – rio Cuiabá e São Lourenço, Mato Grosso. Revista Brasileira de Recursos Hídricos, Porto Alegre, v. 20, n. 1, p. 169–178, 2015.

MACEDO, R. C. et al. Considerações sobre a produção da base territorial do Censo de 2010. In: CONGRESSO BRASILEIRO DE CADASTRO TÉCNICO MULTIFINALITÁRIO, 2012, Florianópolis. Anais [...]. Florianópolis: UFSC, 2012.

MARENGO, J. A. et al. Extreme drought in the Brazilian Pantanal in 2019–2020: characterization, causes, and impacts. Frontiers in Water, v. 3, 2021. DOI: https://doi.org/10.3389/frwa.2021.639204.

OKABE, A.; SATOH, T.; SUGIHARA, K. A kernel density estimation method for networks, its computational method and a GIS-based tool. International Journal of Geographical Information Science, v. 23, n. 1, p. 7–32, 2019. DOI: https://doi.org/10.1080/13658810802475491.

PIGNATTI, M. G.; BARSAGLINI, R. A.; SENNA, G. D. Envelhecimento e rede de apoio social em território rural do Pantanal mato-grossense. Physis: Revista de Saúde Coletiva, v. 21, n. 4, p. 1469–1491, 2011. DOI: https://doi.org/10.1590/S0103-73312011000400016.

PROCHNOW, D. A. et al. Êxodo rural e sucessão geracional na região Sul do Brasil: uma análise a partir da experiência do município de Coronel Bicaco/RS. Colóquio: Revista do Desenvolvimento Regional, v. 19, n. 3, p. 97–116, 2022.

SCHNEIDER, C. et al. Mulheres rurais e o protagonismo no desenvolvimento rural: um estudo no município de Vitorino, Paraná. Interações, Campo Grande, v. 21, n. 2, p. 245–258, 2020. DOI: https://doi.org/10.20435/inter.v21i2.2560.

SCHULZ, C. et al. Physical, ecological and human dimensions of environmental change in Brazil's Pantanal wetland: synthesis and research agenda. Science of the Total Environment, v. 687, p. 1011–1027, 2019.

SHERMAN, G. The PyQGIS programmer's guide: extending QGIS 3 with Python 3. Chugiak: Locate Press, 2018. 252 p.

SILVA, J. S. V. et al. Evolution of deforestation in the Brazilian Pantanal and surroundings in the timeframe 1976–2008. Geografia, Rio Claro, v. 36, p. 35–55, 2011. Número especial.

SILVEIRA, S. A. Software livre: a luta pela liberdade do conhecimento. São Paulo: Editora Fundação Perseu Abramo, 2004.

SOUZA-HIGA, T. C. C. de; HIGA, N. T. Pantanal mato-grossense: aspectos fundiários e dinâmica populacional no município de Barão de Melgaço. Revista do Instituto Histórico e Geográfico de Mato Grosso, Cuiabá, v. 1, n. 60, p. 83–95, 2002. Disponível em: http://54.173.5.2/index.php/revistaihgmt/article/view/408. Acesso em: 27 mar. 2025.

VIANA, M. A. As transformações no espaço rural no município de Seropédica-RJ nas últimas décadas. Espaço e Economia, n. 19, 2020. DOI: https://doi.org/10.4000/espacoeconomia.16651.

ISSN eletrônico 2177-2738
RA'EGA, Curitiba, PR, V.63, n.2, p. 76 – 97, 8/2025
https://doi.org/10.5380/raega.v63i2.99620

WĘGLARCZYK, S. Kernel density estimation and its application. ITM Web of Conferences, v. 23, 2018. DOI: https://doi.org/10.1051/itmconf/20182300037.