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DINÂMICA PORTUÁRIA NA AMAZÔNIA: MUDANÇAS NO USO E NA COBERTURA DO SOLO NO BAIRRO ÁREA VERDE EM SANTARÉM (PA)

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ABSTRACT

Santarém municipality is located in Western Pará State, and it has become one of the main grain-flow outlets to foreign markets, through ports. Urban space is reorganized in the process to meet this demand, mainly in neighborhoods, such as Area Verde, which have been affected by port activity growth, in the last 20 years. Thus, the aim of the present study is to analyze the association between port expansion and changes in soil use and occupation, in Area Verde neighborhood, between 2002 and 2022. In order to do so, geoprocessing techniques, such as supervised classification of Google Earth images, from 2002, 2014 and 2022, obtained through the Quantum GIS software, were used. Three soil use and occupation classes were determined: vegetation cover, disturbed area and hydrography. Vegetation cover was the most representative class in Area Verde. It was followed by class 'anthropized area', which increased throughout the analyzed period-of-time. There was significant reduction in class 'hydrography', in the same period. Although not very intense, so far, port activity expansion has been changing the soil use and occupation, in Area Verde neighborhood. This process demands greater participation of public authorities in managing and planning these spaces in Santarém.

Keywords: Ports. Remote sensing. Geoprocessing. Socio-environmental impact.

RESUMO

O município de Santarém, no oeste do Pará, vem se consolidando como uma das principais saídas de escoamento de grãos, via portos, para o mercado internacional. Esse processo mostra a reorganização do espaço urbano para atender à esta demanda, sobretudo em bairros, como: Área Verde, os quais veem sendo afetados pelo avanço da atividade portuária, nos últimos 20 anos. Logo, o objetivo do presente estudo é analisar a relação entre expansão portuária e alterações no uso, e na cobertura, do solo no bairro Área Verde, entre 2002 e 2022. Para tanto, foram empregadas técnicas de geoprocessamento, como: classificação supervisionada de imagens obtidas pelo Google Earth, em 2002, 2014 e 2022, por meio do software Quantum GIS. Foram determinadas três classes de uso e de cobertura do solo: cobertura vegetal, área antropizada e hidrografia. Cobertura vegetal é a classe mais representativa em Área Verde, e foi seguida pela classe 'área antropizada', que cresceu durante o período analisado. Houve significativa redução da classe 'hidrografia', no mesmo período. Pode-se afirmar que, mesmo de forma não muito intensa, a ampliação da atividade portuária vem provocando mudanças no uso, e na ocupação, do solo no bairro Área Verde. Este processo demanda maior participação do poder público na gestão e no planejamento desses espaços, em Santarém.

Palavras-chave: Portos. Sensoriamento Remoto. Geoprocessamento. Impactos Socioambientais.

INTRODUCTION

Ports play key role in cities' economic, cultural and urban-territorial profile (Ribeiro; Beloto, 2020). They drive productive and industrial activities by allowing cultural exchanges and the flow of goods and people. Thus, cities with ports become important regional and global centers.

River transportation means comprise extremely complex networks in the Amazon, and it is its main circulation system. Moreover, it enables cargo ships' navigability all year long. Port activity is essential for commercial relations set by this region with the rest of the country and with the international market.

Understanding port dynamics in the Amazon, and its multiple facets, is essential for regional management and development, mainly when it comes to its impact on cities. These elements, in their turn, are considered specific to this region when it comes to population features, socio-territorial formation and geographic situation, among others.

The present research was carried out in Santarém City, Lower Amazonas mesoregion, Pará State. Santarém is the states' main regional development hub (Muniz, 2023). The city is located at the confluence of Amazon and Tapajós rivers, which are important waterways interconnecting municipalities in this region and, the region to the rest of the country.

Santarém is the only municipality in Lower Amazon housing a public port that has access to BR-230 (Transamazônica) and BR-163 (Cuiabá-Santarém) highways, besides river-sea access, from Pará River or Northern Amazon River, to the mouth of Tapajós River. It is a strategic port, since it integrates the road and waterway modes. It is used to dispatch cargo carrying the production from Brazil's Central-Western region through BR-163 and the Tapajós and Teles Pires rivers (CDP, 2023).

Nowadays, Santarém has 24 (twenty-four) port facilities, including private-use terminals, shipyards, support facilities and small public port facilities. These facilities required four leases, between 1999 and 2019, within the organized port area, and fifteen registrations and two authorizations, between 2018 and 2022, outside the organized port area (ANTAQ, 2024). These facilities were implemented due to the enactment of Santarém Participatory Master Plan (Law nº 20,534/2018), which was approved in 2018. It reorganized the municipality's riverfront and redefined its port areas. This process provided more legal security for investors interested in developing port activities. On the other hand, the new delimitations gave birth to conflicts because of these facilities' location in environmentally sensitive areas, such as Maicá Lake, where Port Zone II is located in.

Port activity is associated with territory and landscape transformation processes, since it significantly changes soil occupation and use forms. Several environmental and social damages are often reported in port areas, such as territorial conflicts, interference with landscape, urban sprawl, real estate speculation, intensified cargo flows through the territory, infrastructure works that compromise urban space quality, changes in life styles and culture, disordered urban expansion, environmental impact on watercourses and springs, as well as soil sealing (Pereira; Güntzel, 2022).

Port activity advancement has provided industrial development strategies, as well as socioeconomic and environmental problems deriving from Santarém riverfront's reorganization and new delimitation, mainly in neighborhoods located in port area, such as Area Verde, which is one of the neighborhoods mostly affected by this process.

The Geoprocessing tool can help assessing and monitoring port activity impact on its installation's influence area. Thus, geoprocessing techniques were herein used to analyze the association between port activity expansion and changes in soil use and occupation in Santarém municipality, mainly in the Area Verde neighborhood, between 2002 and 2022. The aim of the

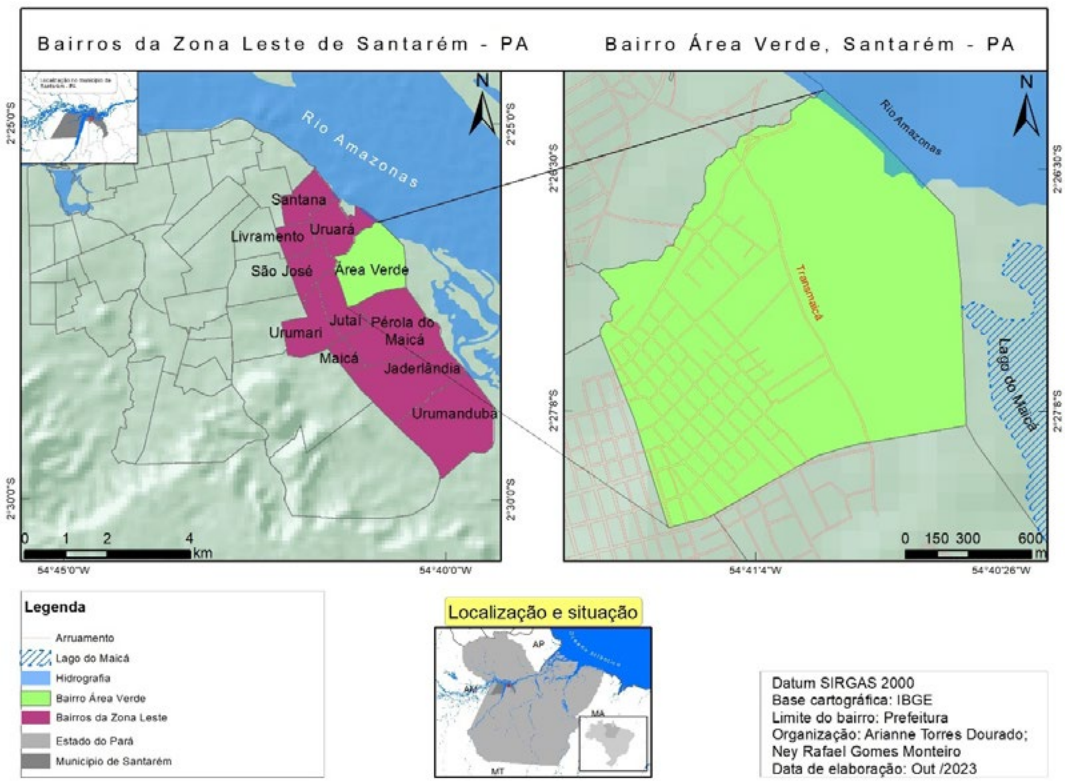
present study was to find the occupation period before, during and after the port expansion in Santarém. It must be done to contribute to discussions about this activity's effects on Santarém urban landscape' transformation.

MATERIALS AND METHODS

Study site

Area Verde neighborhood is located in the Eastern Zone [1] of Santarém City, Western Pará State. The city is bordered by the Amazon River (Figure 1) and by Maicá Lake.

Figure 1 | Area Verde neighborhood location: Eastern Zone of Santarém City - PA



Source: Elaborated by the authors (2023). Santarém database (2018).

Área Verde neighborhood has approximately 2.38km² (1.04km² of port area and 1.34km² of urban area) and encompasses different landscapes, as well as land use and occupation forms. It has been one of the urban neighborhoods mostly affected by port activity expansion in Santarém municipality.

1 According to Art. 119, § 2 of Santarém Master Plan, the Eastern Zone of the city is covered by following neighborhoods: Livramento, Uruará, Jutaí, Urumari, Maicá, Pérola do Maicá, Jaderlândia, Urumanduba, Santana and São José Operário.

Santarém is located on Amazon River and Maicá Lake's banks, and its riparian forest area extends from the Amazon River bed to Av. Transmaicá - this stretch is a port and floodplain area. Area Verde is also crossed by *Igarapé do Urumari*, which runs through the city and flows into *Praia do Ossos*, on the Amazon River.

Santarém's urban growth towards East enabled neighborhoods to emerge, such as the case of Area Verde. It is so, because of Urumari stream's overtaking, in the 1980s (Oliveira, 2008). Area Verde's urbanization process sped up from the 2000s, onwards, but it happened without any basic infrastructure service, basic sanitation (water and sewage), electricity and public transportation planning.

According to the Brazilian Institute of Geography and Statistics (IBGE, 2010), Area Verde neighborhood houses 3,090 inhabitants who carry out typically rural activities, such as farming and fishing. They cross the region selling goods and live in urban spaces. Therefore, there is a mix of urban and rural life styles, and it features the practices of residents who "stopped" being "rural" to "become urban".

METHODOLOGY

Geoprocessing and digital image processing techniques were used to develop the study, in addition to literature review, and cartographic and documentary survey. Supervised classification was carried out by using Google Earth images to analyze land use and occupation in Area Verde neighborhood, between 2002 and 2022.

The scenes were chosen according to the following criteria:

a) 2002, when there were no authorizations for port installation in Port Zone II;

b) 2014, after the authorizations were enacted; and

c) 2022, record of the current state landscape in the neighborhood.

The fact that they were free and had the lowest cloud cover rate in the scenes was taken into account to select the images, given the hard time getting images of these features in tropical regions.

The selected Google Earth images were captured in "winter" (January/June), when water level rises in the river (Table 1).

Table 1 | Dates of Selected Images and time of the year

Year	Image date	Time of the year
2002	June, 24.	River floods
2014	May, 27.	River floods
2022	July, 09.	River floods

Source: Elaborated by the authors (2023).

Images were saved in Joint Picture Experts Group (JPEG) format, in Google Earth software, and georeferenced in Quantum GIS (QGIS) software, version 3.22.16-Bialowieza. Then, images were subjected to supervised classification. This procedure sets the desired classes and collects training samples of the classes, so that the software's algorithm classifies the images based on sample values (Venturieri; Santos, 1998). Thus, three land use and occupation categories were determined, namely:

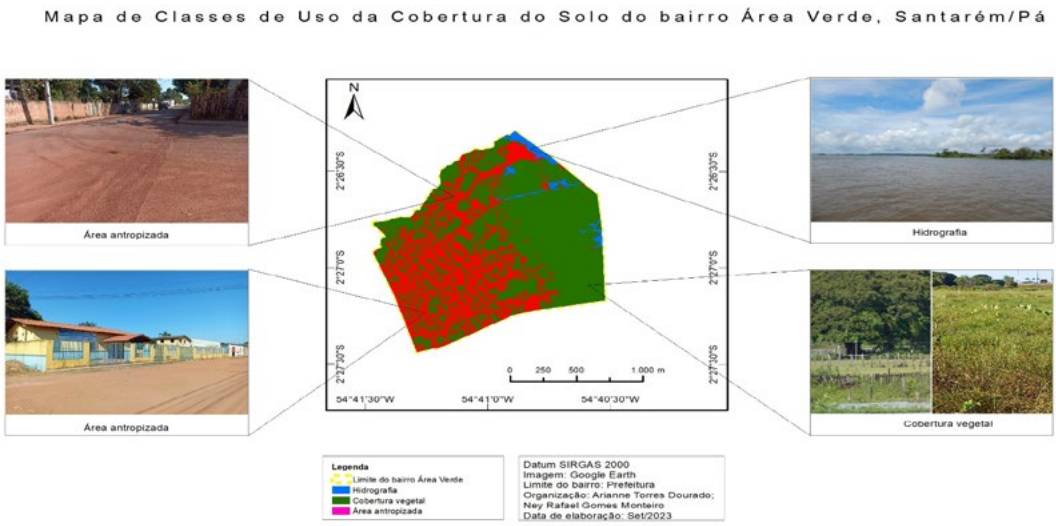
a) Vegetation cover: vegetation (at different stages) and grass species often found in unoccupied urban lots;

b) Anthropogenic area: any and all surfaces lacking vegetation, such as buildings, paved roads (or not), fields, unoccupied lots and sand strips on the beach; and

c) Hydrography: formed by waterbodies.

On-site assessment was carried out to confirm the classes identified in the images, which can be seen in Figure 2.

Figure 2 | Thematic classes mapped for Area Verde neighborhood in 2002, 2014 and 2022



Source: Elaborated by the authors (2023).

Approximately 30 samples of each class were collected through visual interpretation and homogeneously distributed among all scenes. The Maximum Likelihood Method was the adopted algorithm because it is one of the most common methods. This method is based on a pixel's probability to belong to a certain class (Venturieri; Santos, 1998). After the classification stage was over, post-processing was carried out by turning the "raster" image into vectors (polygonals), and it allowed quantifying the area of each determined class.

Finally, layouts were created based on the classifications from different years in QGIS environment. It was done for comparative purposes and for subsequent qualitative-quantitative analysis.

RESULTS AND DISCUSSION

Geoprocessing applied for soil use and occupation purposes: brief considerations

Geoprocessing techniques using has contributed to monitor, map and inspect changes on Earth's surface. Currently, such techniques are the best instrument applicable to territorial planning and management, as they encompass a set of technologies aimed at treating and analyzing a whole range of geographic data. Activities involving this knowledge are carried out by specific systems set for each application, the so-called 'Geographic Information Systems (GIS)' (Moraes *et al.*, 2006).

According to Fitz (2008, p. 23), GIS can be defined as:

> [...] system consisting of a set of computer programs that integrate data, equipment and people to collect, store, retrieve, manipulate, visualize and analyze spatially referenced data to a known coordinate system.

Therefore, GIS is applied to systems aimed at computationally processing data linked to a specific place on Earth's surface. Accordingly, GIS presents multiple application possibilities that allows events taking place for a certain period-of-time to be related to their region, or occurrence site. It generates information to allow territory's efficient management and to analyze soil use and occupation changes. Digital classification of satellite images is often used to do so.

According to Florenzano (2011, p.75), using image classification techniques enables automatically recognizing objects, depending on certain decision criterion. Data are grouped into classes, based on their spectral similarities.

Digital image classification can be supervised and unsupervised. The supervised type corresponds to the technique, according to which, the analyst identifies samples (pixels) belonging to the classes of interest. This process is carried out by the chosen algorithm, based on statistical techniques that locate the remaining pixels belonging to each class. The process to group images into classes based on unsupervised classification is automatically done by the algorithm, depending on pre-established statistical rules (Florenzano, 2011 p. 76).

The herein carried out supervised classification identify soil use and occupation classes for the proposed study analysis, because these classes are understood as being used by man (Rosa, 2007). Knowing the study site and the availability of data collected in the field are essential factors to achieve a successful classification through the aforementioned technique.

The analysis applied to oil use and occupation dynamics provides important elements to help better understanding the investigated sites' socio-territorial reality by enabling observation procedures based on the created or modified form, and on the time evolution of processes shaping reality. Furthermore, they give a clue on how such processes, mainly the anthropic ones, positively or negatively contribute to space transformation, as observed in the studies by Santos and Piroli (2015), and Silva (2020).

Thus, driven by the possibilities emerging from geoprocessing techniques' using, the aim of the present study was to understand the association between port dynamics and their impact on Santarém's urban zone, as discussed in the following sections.

PORT EXPANSION IN SANTARÉM

Santarém municipality is located in a region known for its high potential to develop multimodal transports. It is a strategic road integration axis that connects Northern and Central-Southern Brazil, from BR-163 highway [2](Cuiabá- Santarém) to Santarém Port. The highway and the port were built during the first stage of the National Integration Program (PIN). This Program intensified the governmental policy from the late 1940s, from the 1970s onwards, in order to increase the Amazon's participation in the national economy (Brasil, 1970a).

2 BR-163 is a longitudinal highway in Brazil. It has total length of 3,579 km; its main section connects Tenente Portela City, in Rio Grande do Sul state, to Santarém City, in Pará State. There is also a complementary section, located between Oriximiná and Óbidos cities, in Pará State.

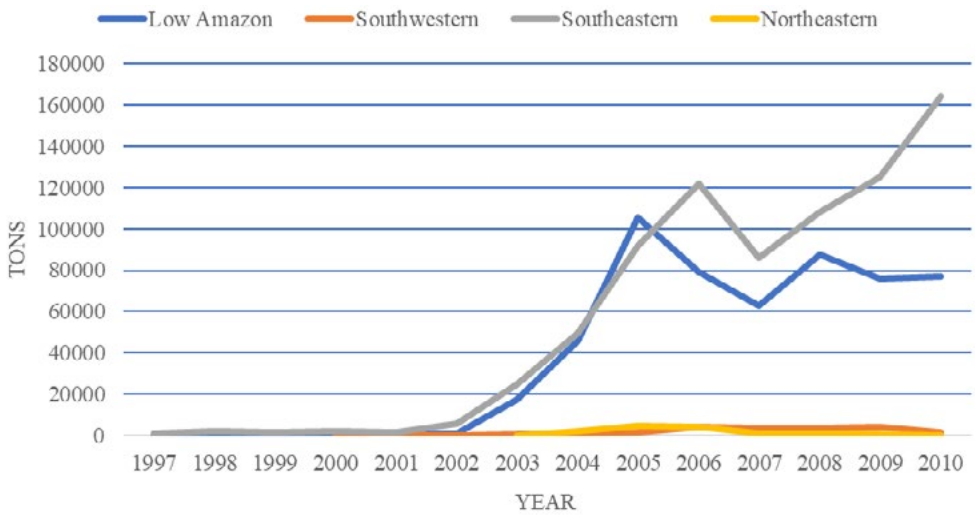
The federal government made large investments in infrastructure, in addition to strengthening multimodal transport (Brazil, 1970b), in order to redistribute soil and to encourage the agroindustry in the Northern and Northeastern regions, at that time. Colonization and agrarian reform programs were implemented based on people's transfer to areas by BR-163 highways. Tax incentives were granted to projects aimed at foreign trade developed at Eastern Amazon (Pará, Maranhão, Amapá, Tocantins and Mato Grosso states) (Brasil, 1970b; Brasil, 1971; Brasil, 1982). Santarém Port became a strategic integration site between the road and waterway modes due to the governmental stimulus to the agroindustry in Central-Western and Northern Brazil. This route was used to transport the cargo through both BR-163 and the Tapajós-Teles Pires Rivers. This route thus interconnected the productive centers of the aforementioned regions (CDP, 2023).

Federal government investments helped broadening soybean production in the Brazilian territory. According to Knorr (2017), nowadays, soybean is the main national commodity. Brazil is

> [...] one of the world's leading producers and exporters of grains, soybean meal and oil [...]. The cultivation of this Asian-origin plant begun South, but migrated to Mato Grosso State, to Western Bahia State, to Maranhão and Piauí states, and, most recently, to Pará State (Knorr, 2017, p.1).

According to results of the 1974 Municipal Agricultural Production (PAM), which was carried out by the Brazilian Institute of Geography and Statistics (IBGE), temporary agricultural products from Pará State were pineapple, herbaceous cotton, peanuts (in shell), rice (in shell), sweet potato, sugar cane and broad bean (in grain), beans (in grain), tobacco (in dry leaves), jute (in dry fibers), *malva* (in dry fibers), cassava, watermelon, melon, maize (grain) and tomatoes. Soybean emerged at productive scale in Pará State, in 1997, in Paragominas, Ulianópolis and Redenção municipalities, as well as in Southeastern Pará State. It was also observed in Santarém, Lower Amazonian region, according to the 1997 PAM by IBGE. From the 2000s onwards, Soybean farming expanded to other mesoregions in Pará State - considerable increase in soybean production is seen in Graph 1.

Graph 1 | Soybean production expressed in tons (t), in Pará State's mesoregion, between 1997 and 2010



Source: Elaborated by the authors (2024).

Soybean farming in Brazil grew towards the country's Northern region, and it represented increased demand for the Central-Northern Arco Norte Corridor System, which comprises road, railway and waterway transport axes. These axes account for cargo flow inputs in ports located in Northern[3] Brazil – at altitudes above the 16º S parallel (Brasil, 2016).

Nowadays, Central-Western regions' agricultural production flow mainly goes to Santos Port, Southeastern Brazil. Production travels long distances, mainly in highways and, residually, through railways or waterways (Brasil, 2016). However, in geographical terms, producers rather dispatch their products through the Central-Northern logistics corridor (Eixo Tapajós), which involves the BR-163/MT/PA Highway; Miritituba Cargo Transshipment Station Complexes (ETCs), in Itaituba, and Santarenzinho, in Rurópolis, both in Pará Satte; Tapajós River Waterway; Santarém Port; the Amazon Waterway; Vila do Conde Port Complex, in Barcarena (PA); Santana Port, in Santana (AP); and the secondary road-network of state highways (Brasil, 2016).

Despite the strategic relevance of Santarém Port for grain production flow from the Central-Western region, the first port area set for the city's first bulk terminal, the Santarém Solid Granule Fluvial Terminal, was only leased in 1999. It came into operation in 2003 to transport part of the grain production

3 Among the ports in the North, the following stand out: Porto Velho (RO), Miritituba - Itaituba, Santarém and Barcarena (PA), Itacoatiara and Manaus (AM), Porto de Santana (AP) and Itaqui (MA)

acquired by Cargill Agrícola S/A in Central-Western Brazil, both in Santarém and in its surrounding areas (Cargill, 2023).

Santarém Port's influence area expanded after Cargill Port became operational and BR-163 (Cuiabá-Santarém) was finally paved. In addition to the municipalities of Pará in the middle Amazonas, and Trombetas and Tapajós rivers' valley, Santarém Port's influence area expanded to Rondônia, Mato Grosso and Amazonas states. Production flow from Manaus Free Zone extended to the Central-Western region because Santarém became a logistical warehouse for it, since it received barge convoys. Since then, the number of port facilities leased, authorized or registered by the National Waterway Transport Agency (ANTAQ) has increased in this locality (Table 2). Such an increase has been recorded since 2018, when the new Santarém Participatory Master Plan was approved.

Table 2 | Evolution of the number of port facilities in Santarém over the last 24 years

Terminal name	Terminal type	Year of lease, authorization or registration
Terminal Fluvial de Granéis Sólidos de Santarém	Private use terminal	1999
Sociedade Fogás Limitada	Private use terminal	2001
TUP Bertolini		2005
Base Ipiranga Santarém	Private use terminal	2009
Portos Unirios II	Support facility	2017
Raizen Shell Ltda	Private use terminal	2018
Reicon Santarém	Support facility	2018
Sindicato Rural de Santarém	Support facility	2018
Estaleiro e Tornearia do Candinho	Shipyard	2018
B. M. Castro Eireli – EPP	Shipyard	2018
Terminal Itaipava Santarém	Support facility	2018
Distribuidora EQUADOR PP Ltda.	Private use terminal	2019
Rampa Samal	Support facility	2019
Hidroviária Tapajós	Support facility	2019
Terminal Hidroviário de Cargas e Passageiros de Santana do Tapará	Support facility	2019
Marques Pinto Navegação Ltda	Support facility	2019
Terminal Hidroviário de Cargas e Passageiros de Santarém	Support facility	2019
Hidroviário Erlonav	Support facility	2020
Registro Bertolini Santarém - Maicá	Support facility	2020
Tapajós Administração Portuária Ltda	Support facility	2020
Porto do DEER	Support facility	2021
Porto Prainha	Support facility	2021
Administração de bens de Infraestrutura – ABI	Private use terminal	2021
ATEM Santarém	Private use terminal	2022

Source: Elaborated by the authors (2023).

The Ministry of Infrastructure's (MINFRA) Ordinance n. 509/2019 redefined Organized Santarém Port's area, which was demarcated in 1993, one year after the new version of the Santarém Participatory Master Plan was approved. The old polygonals did not comply with the new Ports Law (law n. 12,815/2013), since the organized port area held ownership areas or areas under control or regular possession by private people, public areas owned or managed by public entities that did not have close relationship with Santarém Port's administration, and public areas intended for activities incompatible with the port (Brasil, 2016).

The organized Santarém Ports polygonal was changed two more times after this first modification in order to organize the port's space and its jurisdiction, through Ordinance n. 167, from November 12, 2020, and through Ordinance n. 539, from May 10, 2022.

Despite Santarém delimited, organized and determined riverfront, several locations within its jurisdiction were used in a disorganized and informal manner, such as passenger terminals, tourism terminal, shipyards, cargo terminal and warehouse for fish. They did not have the least necessary structure, and only served small and medium-sized vessels.

SANTARÉM PORT'S AREA

The 2018 Santarém Master Plan established 10 (ten) zones in the municipality to make this city's territory use and occupation more efficient, including the Port Zone (ZP), which was intended to implement public or private ports. The Port Zone was included in the municipality's riverfront planning (Santarém, 2018) and it is divided into three areas: Port Area I (AP I), Port Area II (AP II) and Port Area III (AP III, whose polygonal remains undefined) (Santarém, 2018).

According to item III of Article 142 of Santarém Participatory Master Plan, Port Area I delimitation in Santarém municipality begins at

> [...] the end of tourist Area and the recreational area of interest for the balneary, set in section I, and goes all the way to *Travessa Professor António Carvalho*, located in Fátima neighborhood, at geographic coordinates DATUM WGS 84: Pl 2025'37.5"§ $4°45'35.8"W — P2 2°25'08.0"S 54°43'46.9" W, except for the tip of *Praia do Maracanã* to *Rua Maracangalha*, which is included in the area referred to in section II; [...].

AP I covers Maracanã, Salé, Laguinho and Fátima neighborhoods, as shown in the map below (Figure 3).

Figure 3 | Map of Santarém municipality's Port Area I

Source: Elaborated by the authors (2023). Data: Santarém (2018).

Santarém Public Port is located in AP I, and it mainly operates with vegetable-origin solid bulk and fertilizers, and with liquid bulk deriving from petroleum (fuels and LPG), passengers (river and cruise) and general cargo (containerized and non-containerized) (Porto de Santarém, 2018).

The Port Area II polygonal was redefined by Art.142 of Santarém's Master Plan (law n. 20.534/2018):

> [...] V - Port Area II - Starting at *Avenida Borges Leal*, to *Rua Araguarina, Rua Antônio Simões, Rua Coelho Neto, Avenida Maicá, Rua Tauarí, Avenida Transmaicá*, to the geographical coordinate point - P2: LATITUDE 02°28°03.00" S and LONGITUDE 54°40°20.00"W, going all the way to point P3: Latitude 2°27°39.53"S54°39°15.84"W, followed by a straight line 500 meters from the Amazon River bank to point P4: Latitude 2°29°39.32"S Longitude 54°35"19.29"W; ends at point PS: Latitude 2°29°6.32"S Longitude 54°34°51.20.

Changes in Art.142 of the 2018 Master Plan gave more legal support and security to investors. This process may have encouraged the port activity expansion, mainly in Port Area II.

Port Area II is outside Santarém organized port area, on the right bank of the Amazon River, and covers the following neighborhoods: Prainha, Santana, Uruará, Area Verde and Pérola do Maicá. Private Use Terminal (TUP) modality facilities have already been authorized, and Support Facilities or Shipyards have been registered for this area (Figure 4).

Figure 4 | Location map of Port Area II, port facilities and included neighborhoods

Source: Elaborated by the authors (2023). Data: Santarém (2018); ANTAQ (2023).

Atem's Distribuidora de Petróleo S/A stands out among the TUPs installed in Port Area II, Area Verde neighborhood, mainly at *Av. Transmaicá* (Figure 5). Atem Port is the only one installed and operational in the aforementioned neighborhood. Its ANTAQ area authorized for port facility exploration corresponds to 34,684 m²: 1,164,000 m³/year of handling capacity and 8,340 m³ of storage capacity, for both liquid and gaseous bulks (fuels) (Brasil, 2022).

Figure 5 | Port of Atem's Distribuidora de Petróleo S/A

Source: Arianne Torres Dourado (2024).

Adhesion Contract n. 4/2022 by the Ministry of Infrastructure (MINFRA), from June 2022, authorized Atem's to explore the port facility called ATEM Santarém as Private Use Terminal (TUP). Its goal is to move and/or store liquid and gaseous bulks (fuels) destined for, or originating from, water transport (Brasil, 2022).

Port Area II also covers part of Maicá Lake (Figure 6), which is an ecological sanctuary, a natural nursery for unique aquatic fauna species and Amazonian birds. This region is also known as "large Maicá/Ituqui area", which is a floodplain region made up of areas that are often flooded between December and June. It is formed by a system of lakes measuring approximately 161 km^2, whose waters come from the Amazon River and are strongly influenced by Tapajós River (Vaz, 2017).

Figure 6 | Entrance to Maicá Lake in Santarém - PA

Source: Arianne Torres Dourado (2024).

Furthermore, Maicá Lake is a hub for tourist visits and is home to the oldest archaeological site in the municipality: Sambaqui de Taperinha, which is 8 thousand years old; and to many more recent sites (500 to 2 thousand years old) (Colón, 2018; Vaz, 2017).

There are *quilombola* and indigenous communities throughout the Maicá Lake area, as well as artisanal fishermen, settlers by the Institute of Colonization and Agrarian Reform (Incra) and urban area residents. The most populous neighborhoods around the lake are Area Verde (3,090 residents), Maicá (1,922 residents), Pérola do Maicá (1,227 residents), Jaderlândia (2,870 residents) and Urumanduba (675 residents) (Santos; Costa, 2019). Despite its location in the city's urban zone, this area has rural profile, with crops, orchards and mini farms for poultry, cattle, buffaloes, goats, pigs and horses' breeding.

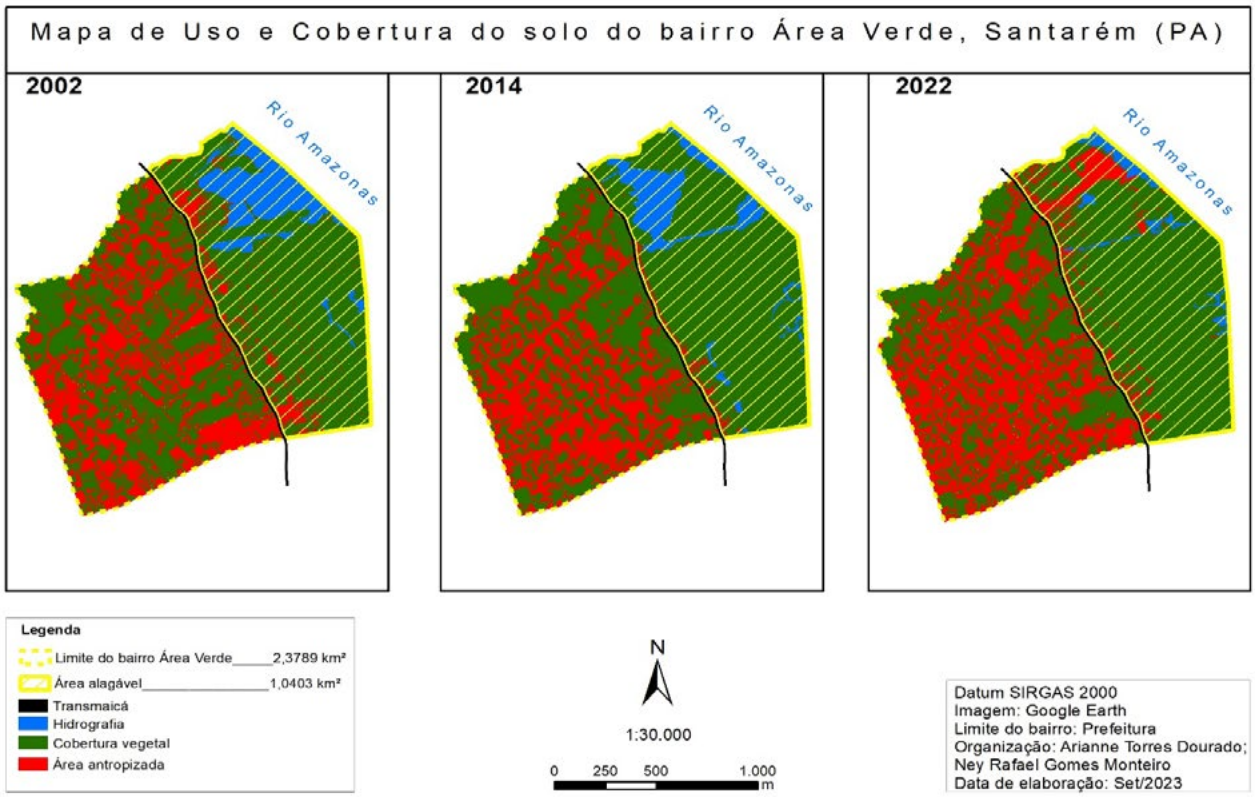
According to Serrão (2018), fishing in Maicá Lake is artisanal and small-scaled. It is the main income source for artisanal fishermen who live in its surroundings. It is the environment where most fishing is practiced in comparison to the rivers and streams in the region. Most of these fishermen sell their fish at the community and/or neighborhood port, on the streets and/or in their homes. Maicá Lake is their income and food source, and occupation and leisure environment.

SOIL USE AND OCCUPATION DYNAMICS IN ÁREA VERDE NEIGHBORHOOD

Área Verde neighborhood has a very peculiar socioeconomic and environmental context. Urban space in this neighborhood coexists with rural profiles, with potential areas for port activity, and with rich and diverse ecological spaces.

If one has in mind only three soil use and occupation profiles, it is possible observing changes in this neighborhood's landscape between 2002 and 2022 (Figure 7).

Figure 7 | Soil occupation map of Área Verde neighborhood in 2002, 2014 and 2022



Source: Elaborated by the authors (2023).

The rate of area occupied by the aforementioned classes in 2002, 2014 and 2022 can be seen in Table 3.

Table 3 | Class Area rate in 2002, 2014 and 2022, in comparison to the total area of Area Verde neighborhood

Total area of Area Verde neighborhood in km²	**2.38**		
	2002	**2014**	**2022**
Classes	% in comparison to the neighborhoods' total area	% in comparison to the neighborhoods' total area	% in comparison to the neighborhoods' total area
Vegetation cover	64	68.49	64.10
Anthropic area	28.5	21.85	33.57
Hydrography	7.50	6.32	2.20

Source: Elaborated by the authors (2023).

The class 'vegetation cover' prevailed in the study site throughout the analyzed period and it corresponded to all vegetation types, at different stages, and to grasses. It represented not only the small and medium-sized trees abundant in the neighborhood, but the undergrowth, vines and all vegetation located in public areas, on sports fields, in vegetable gardens, on sidewalks, in flowerbeds, in addition to lots and abandoned sites.

The existing urban agriculture in the neighborhood contributes to the 'plant cover' class through vegetables and fruits' crops grown by residents in their own backyards. This feature guarantees healthy eating and generates income by providing personal consumption food for markets within the neighborhood and for other locations in the city.

According to Pimentel and Costa (2014), Área Verde neighborhood got its name from the exuberance of the countryside vegetation and from several fruit trees in the neighborhood. Despite advancements in urbanization and vegetation removal for subdivisions, the study site still presents a wooded environment with leafy fruit trees in public and private areas (Figure 8). Santarém has approximately 25% of its urban area wooded (Santarém, 2022).

Figure 8 | Characteristic afforestation of Área Verde neighborhood

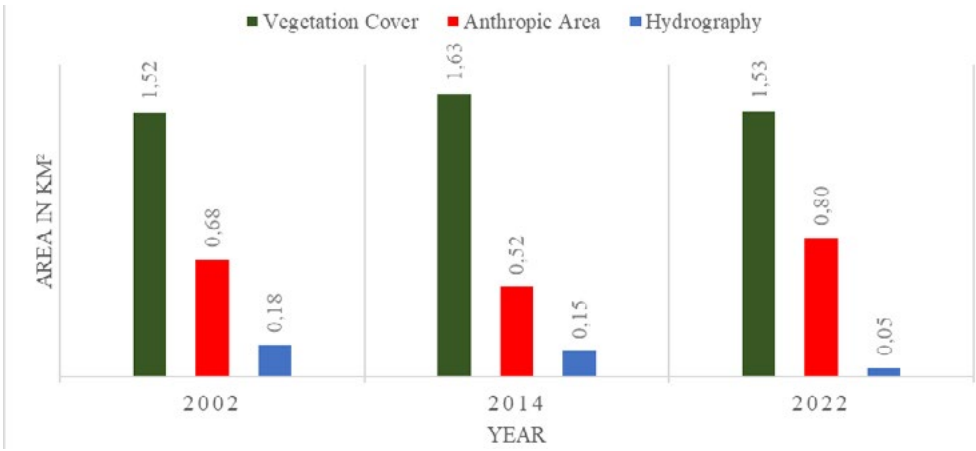
a) Countryside vegetation b) small and medium-sized trees in public spaces c) private property with small and medium-sized trees d) abandoned lot with low vegetation

Source: Arianne Torres Dourado (2024).

Approximately 43.69% of the total study site is a port/flood land composed of dense and homogeneous vegetation, and riparian forest, which conserves the environment around the Amazon River and Maicá Lake. This territorial portion's vegetation cover showed few changes during the analyzed period, except for the place where the Atem Port was built in. Changes in vegetation cover, between 2002 and 2022, in Área Verde, are more evident in its urban portion due to the urbanization and property speculation processes.

The 'anthropic area' class presented the highest growth rate between 2002 and 2022 (+18.26%). It is the second most representative class in the neighborhood. One can observe variation in square kilometers (km^2), in the anthropic area, among the three analyzed periods-of-time (Graph 2). It decreased between 2002 and 2014, and increased between 2014 and 2022. The 'vegetation cover' class had opposite behavior; it increased between 2002 and 2014, and decreased between 2014 and 2022. Despite differences between one image and another, the analysis of the visual aspect in Figure 7 does not allow comparing changes in the 'anthropic area' class, between 2002 and 2014, unlike the other two classes. However, the vector files of pollination raster files allowed calculating the areas and comparing results recorded for each classification (Graph 2).

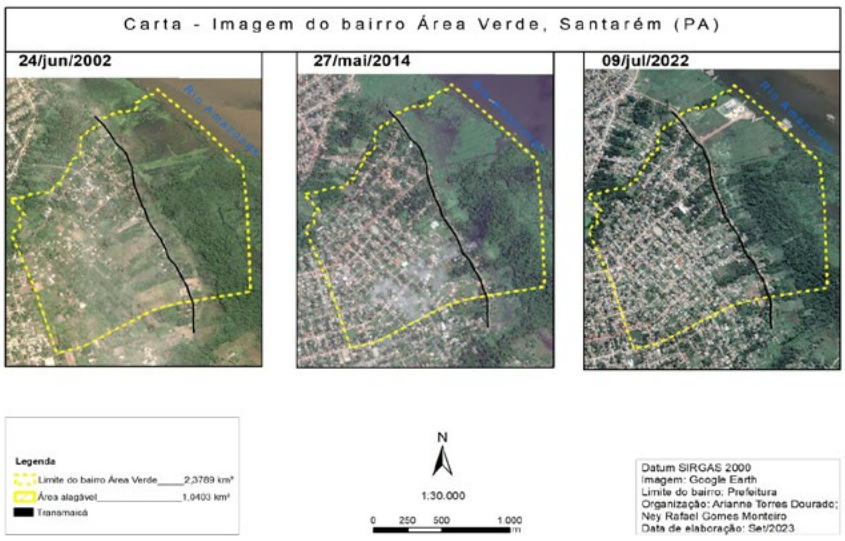
Graph 2 | Variation in km² of soil use and occupation classes in Área Verde neighborhood in 2002, 2014 and 2022



Source: Elaborated by the authors (2023).

In 2002, anthropic area in Área Verde was discontinuous, mostly covered by fields, by large unoccupied lots and by few buildings located far from each other (Figure 9). The study site was little urbanized at that time and it was not officially established and delimited as neighborhood. It presented urban agglomeration features due to spontaneous occupation and illegal subdivision that took place after the Urumari stream was overtaken in the 1980s. The stream was a natural obstacle to urban growth in Santarém municipality towards East, "[...] giving the possibility for the emergence of Jutaí, Maicá, Jaderlândia, Urumary, Livramento and Área Verde neighborhoods [...]" (Oliveira, 2008, p.04).

Figure 9 | Google Earth images of Área Verde neighborhood from 2002, 2014 and 2022



Source: Elaborated by the authors (2023).

According to Freitas *et al*. (2021), after Igarapé do Urumari was surpassed, from the 1990s to 2020, Santarém's urban expansion headed towards the Eastern city, mainly around the Curua-Úna (PA-370). Santarém's urban expansion became denser from the 1990s onwards due to intense migration from rural areas to the city. This migration was driven by soybean crops' introduction and expansion, since it forced the incorporation of large agricultural areas to Santarém municipality.

Therefore, the urbanization process in Área Verde neighborhood was accelerated, but it did not follow a plan. Basic infrastructure services, basic sanitation (water and sewage), electricity and public transportation were only implemented after the emergence of urban agglomerations, and it was slow and gradual. Área Verde was granted with neighborhood status in 2006 after the first Santarém Participatory Master Plan (law n. 18051, from December 29, 2006) and it was delimited in 2008, by law n. 18080, from June 20, 2008, which was amended in 2012, by law n. 18884, from January 13, 2012.

The studied territory configuration changed over the years and, in 2014, it was possible observing anthropic areas closer to each other. They had minimal dimensions and gave rise to a configuration organized into blocks (Figure 9). Área Verde configuration has headed towards Av. Transmaicá, which is close to Amazon River banks and to Maicá Lake (to the East of the neighborhood). The same trend was observed in 2022. This spatial urban configuration in the neighborhood moved towards the river. According to Freitas *et al*. (2021), it is common, given Santarém riverside-city's profile.

An urban network remained throughout the whole analysis time, and its layout was at odds with the city, near Av. Transmaicá, due to large vegetation cover areas (Figure 9) presenting rural features. The neighborhood formed a "green belt" that, according to Silva (2011), features Santarém's neighborhoods dedicated to agricultural production, as Área Verde.

The new road-network configuration in this neighborhood is another important point to be highlighted in the 'anthropic area' class. According to Santarém Urban Mobility Plan (Decree n. 817/2022 – GAP/PMS, from December 16, 2022), in 2015, Área Verde neighborhood did not have any paved roads, only roads covered with laterite and natural bed. In 2020, the first asphalted roads were opened: *Marcílio Dias* and *13 de Outubro* streets (Figure 11), and they give access to *Av. Transmaicá* and the port area in the neighborhood.

Figure 12 | Asphalted roads in Área Verde neighborhood and a vehicle on it

a)Intersection between *Marcílio Dias* and *13 de Outubro* streets b) vehicle on 13 de Outubro street

Source: Arianne Torres Dourado (2024).

This new traffic corridor in Área Verde neighborhood resulted from several factors, such as increased urban expansion, investments in the port area and the need of greater traffic, both to meet the population and the port's demand. This demand forced the municipal administration to invest in infrastructure in this neighborhood.

In 2020, the aforementioned roads were paved and, in 2022, the Atem port became operational. Vehicles' flow increased in the neighborhood as the new roads connected the neighborhood to the city's important highways. Keinen *et al*. (2021) state that roads surrounding port areas tend to increase truck traffic on roads that make cargo flow easier. This profile brings along mobility issues due to lack urban-arrangement structure.

The intersection between *Marcílio Dias* and *13 de Outubro* streets is a public transportation route in Área Verde neighborhood, and it has heavy cargo-truck traffic. According to Santarém (2022), this stretch had low traffic-incidents up to 2015, based on the five density levels (very low or zero, low, medium, high and very high). The number of cargo vehicles increased, and it affected both their speed and flow, after the roads were coated with asphalt. This density level was expected to increase.

Despite the negative impacts of asphalt paving on Área Verde, it brought social benefits to the community, in general, by providing greater comfort to road users, reducing vibrations and discomfort during travel, both for drivers and passengers on public transport. It also brought along

greater mobility, which made the access to essential services easier by connecting distant areas in the neighborhood to the main roads leading to the city's commercial center, to hospitals, schools, shops and leisure, in addition to real estate appreciation and local circular economy increase.

As presented by Miranda (2023), urbanization processes and port facilities' implementation imply changes in soil use and occupation, and it can be observed through geoprocessing. Anthropogenic changes reflect on most of the territory surrounding ports, as presented in the present results.

The 'hydrography' class was the one losing most spatial representation during the analyzed period, with decreasing trend (Table 4). There was noticeable area loss, even during river flooding. This result is similar to others that have identified hydrography reduction through image classification techniques (Diniz; Takahasi, 2022; Gass; Silva; Fuchs; Martins, 2019). Previously, floodable area loss was only observed in the herein assessed neighborhood during the low-water season, when Amazon River level is low.

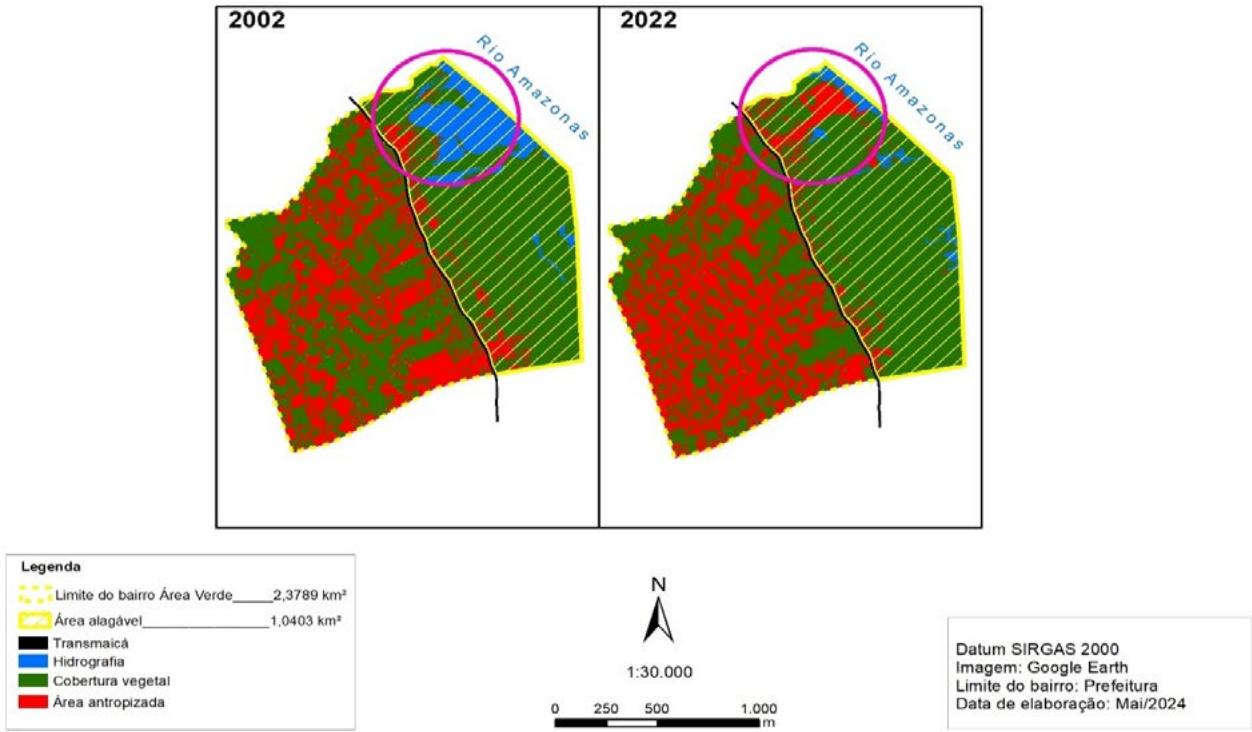
Table 4 | Growth rate of classes 'vegetation cover', 'anthropic area' and 'hydrography', in Área Verde neighborhood, between 2002 and 2022

Classes	Area in km² (2002)	Area in km² (2022)	Growth rate in %
Vegetation cover	1.52	1.53	026
Anthropic	0.68	0.80	18.26
Hydrography	0.18	0.05	-71.17

Source: Elaborated by the authors (2023).

This dynamics is observed in the neighborhood's port/floodplain area, which is often flooded in the rainy season, between January and June, when the rivers are full. It is usually dry between July and December, in the "Amazonian summer", at the ebb of the Amazon River. However, in 2022, a permanent anthropic area was formed in part of the existing wetland area, even during the river flood period (Figure 13). The National Waterway Transport Agency (ANTAQ) had a license to explore the port facility leased to Atem's Distribuidora de Petróleo S/A.

Figure 13 | Change in the 'hydrography' class of Área Verde port/floodplain area between 2002 and 2022



Source: Elaborated by the authors (2024).

In 2022, there was no occurrence of flooding in the perimeter due to the landfill made for Atem Port implementation and to the entire infrastructure to stop the water from Amazon River to advance during the flood. Difficulty to drain the rainwater towards the Amazon River is another consequence of the landfill – the water accumulates on the surface of land located in front of the site.

Área Verde residents had their access to both the Amazon River and Maicá Lake limited after Atem port installation and land in the port area was sold to investors - these areas are fenced and/or landfilled. According to Serrão (2018), there are 13 artisanal fishermen associated with the Colony of Fishermen and Fisherwomen Z-20 (CPP Z-20) in Área Verde, and they are part of the Base Center of the Green Area; therefore, they need access to the Amazon River and to Maicá Lake for fishing purposes. The Federal Court, among other decisions, prevented Atem's from restricting fishermen's access to the project's surroundings due to complaints, on May 21, 2020 (Pará, 2020).

If one has in mind that the whole neighborhood area dedicated to port activity is located on Amazon River banks and in Maicá Lake, and that a large land fraction is already owned by port investors and fenced, one must pay close attention to the fact that residents are prohibited to access the Amazon River and/or Maicá Lake through these lands. This problem affects their fishing activity, leisure and/or tourist practices.

FINAL CONSIDERATIONS

Port expansion in Western Pará State is a dynamic process that has been implemented from a multimodal perspective. Its goal is to consolidate the region as logistics corridor for grains' exports, mainly soybeans coming from Mato Grosso State.

Santarém plays key role in this process, and the consequences of it can be observed in both its rural and urban areas, due to its importance as regional hub for services and trade.

One can notice the effects of port expansion in the urban area, with emphasis on Área Verde neighborhood - the present object of study -, with straight impact on the urban structure, on residents' way of life and on the environment, mainly on Maicá Lake's influence area. This area is used for fishing; for buffalo, cattle, poultry, goat and horse breeding; for tourism, leisure and as means of access to the Amazon River.

It should be noticed that the port area in Área Verde is not yet fully occupied, since the installation and operation license for a private-use port terminal was only issued by the competent bodies in 2023. However, it is possible observing significant changes in soil use and occupation in Área Verde for 20 years, as well as 'hydrography' class decrease because of the landfill implemented for the Atem Port construction project.

Thus, although it is not yet very intense, the port activity expansion in Santarém's urban area has been changing soil use and occupation in it, mainly in neighborhoods located in the municipality's port area, such as Área Verde neighborhood. This process demands greater participation by public authorities in these spaces' management and planning, not only from the regulation viewpoint, but also in organization and urban planning aimed at the safety and quality of life of people living there.

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