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Papers

The Novel Ecosystems of the Sertão Carioca: Landscape Transformation and Land Use History in the Piabas River Basin (1968-2018), Rio de Janeiro

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Abstract

Landscape transformations are a historical product of social relationships with the environment. Thus, ecosystems modified by these agencies respond to these transformations by developing ecological novelties, most of all in ecosystem structure and composition. Nowadays, we understand these cultural landscapes as social-ecological systems composed of novel ecosystems. The areas which are distant from central Rio de Janeiro, known as Sertão Carioca, were originally used for agriculture and are now being affected by urban sprawl. The remnant ecosystems maintain traces of its land use history. Therefore, the Piabas river basin, an important part of the Sertão Carioca, was analyzed herein with the aim of identifying the land use history and land cover transformations which occurred between 1968 and 2018. Aerial photos from 1968 and satellite images from 2018 were used to compare the land use and land cover mappings for both years on the same scale 1:10,000. In 1968, the Piabas river basin presented a predominance of agriculture (63%), where permanent and temporary crop and banana plantations could be observed. We also verified remnant forests (25%) and fruit trees planted around houses (4.3%) in the mountainous areas. In 2018, there was a predominance of an emerging submountainous pluvial forest ecosystem (47%). The forest expansion occurred due to the decline in banana cultivation and the decree that created the Pedra Branca State Park (PEPB). As a result, only 10% of the permanent and temporary crops remain. The urban area growth stands out (539%) in comparing the variations of this 50-year transformation, registering the city's arrival in the Sertão. This urban sprawl mostly occurred in lowland ecosystems. The lack of a territorial planning that reconciles and prioritizes biodiversity conservation and agroecological practices in the urbanization process will affect the quality of life conditions of people who live in this region.

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INTRODUCTION

From the perspective of historical ecology, the landscape can be understood both as a spatial unit (like a watershed) and as an analytical category which represents the material manifestation of the relationship between human beings and their environment (CRUMLEY, 1994). It is an interdisciplinary field that investigates the dialectical relationship between human and natural processes manifested in the landscape. Thus, different cultural practices and ideas about resource use take shape and the landscape then retains the physical evidence of these mental activities (CRUMLEY, 1994).

We start from the definition of Hobbs et al. (2013) to introduce the discussion object of this article in understanding novel ecosystems as systems composed of

> "abiotic, biotic and social components that, by virtue of human influence, differ from those that have historically prevailed, having a tendency to self-organize and manifest new qualities without management" (HOBBS et al., 2013 p. 58).

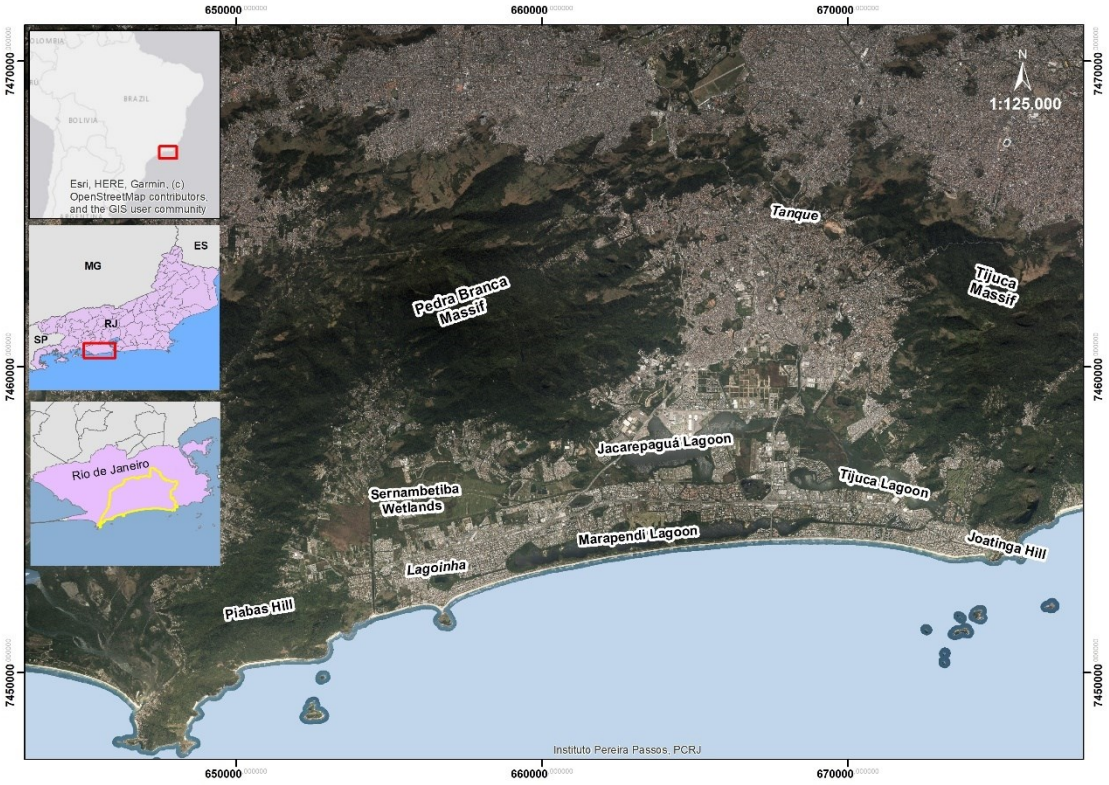
At the same time,

> "novel ecosystems are composed of non-historical species configurations that have arisen through anthropogenic environmental changes, land use change, species invasions, or a combination of these factors. Thus, these ecosystems are the result of human activity, but do not depend on their management for their maintenance." (HALLET et al., 2013, p. 17).

In this sense, we understand that the ecological succession trajectories of Rio de Janeiro forests present ecological novelties both from the presence of several exotic species and from changes in the dominance pattern of native species resulting in urban forests formed by a mosaic of novel ecosystems, managed systems and conserved forests (SOLÓRZANO et al., 2021).

In connecting this premise with historical ecology approaches, we found the pioneer description of Magalhães Corrêa in 1936, which reveals the physical, biological, cultural and social aspects of a region called the *Sertão Carioca*, then in the Federal District of Brazil, a territory corresponding to the current area of the municipality of Rio de Janeiro. According to the book "*O Sertão Carioca*" (CORRÊA, 1936), this region covers the entire plain of Jacarepaguá between the Tijuca and Pedra Branca Massifs. It consists of geomorphological slope and lowland units through which the tributary rivers of the Jacarepaguá, Camorim, Tijuca, Marapendi and Lagoinha lagoons flow. Accordingly, the *Sertão Carioca* goes through the forested slopes of the Tijuca and Pedra Branca Massifs from Joatinga Hill to Piabas Hill in the east-west direction and from Tanque to the coastal beach in the north-south direction. It passes through the extensive flooded fields of clayey and organic deposits of fluvial-lacustrine influence such as Campo de Sernambetiba and the sandy deposits of marine influence formed by shorelines and their restinga ecosystems (Figure 1).

Figure 1 – Location of the *Sertão Carioca* according to Corrêa (1936).



Source: The authors (2020), from the Rio de Janeiro City Hall database (PCRJ, 2014).

Galvão (1963; 1965) understands the *Sertão Carioca* as the entire rural area of the then State of Guanabara, comprising the districts of Santa Cruz, Campo Grande, Jacarepaguá and Realengo. These locations were characterized by landscapes with low population density and had agriculture as the most important economic activity. Expressive and varied agriculture was developed until the beginning of the 21st century in function of the dynamic interests of the market (including sugarcane, coffee, citrus, banana, persimmon, and subsistence gardens), along with pasture areas for exotic species planted to feed horses, oxen and mules.

Another important component of the landscape transformation and historical ecology of the Pedra Branca Massif was charcoal production, and today it is found on practically all of the massif slopes with the plateaus of the old charcoal plants forming anthropogenic soils with charcoal fragments (SOLÓRZANO et al., 2021). This stage in the Atlantic Forest's environmental history of charcoal production was responsible for major changes in the structure and composition of the forest. A large part of the forest regenerated naturally due to the production and forest management techniques undertaken (selective logging and spatial dispersion of charcoal activity), in turn presenting changes in species composition and decreased diversity (SOLÓRZANO et al., 2021). Therefore, a cyclical succession of different uses and occupations resulted in a sequence of recent transformations of this landscape that was once rural and now urban.

Oliveira and Fernandez (2020) show how the urban expansion process occurs, historically accompanied by impacting actions especially presenting aspects related to the structure, composition and functioning of socio-ecological systems. These authors describe the social metabolism that correlates daily life, energy demands (both calories and fuel), the ways of life and local knowledge of those who lived with the mountains and plains bordering the *Sertão Carioca*.

The Piabas river basin, analyzed in the present article, composes this region and presents great approximation with a historicity of actions, processes and patterns which in the past followed similar paths to those described in Oliveira and Fernandez (2020).

OBJECTIVES

As a general objective, we seek to understand the landscape transformation process and analyze the land use and land cover changes that occurred in the period from 1968 to 2018 in the Piabas River basin in RJ, Brazil.

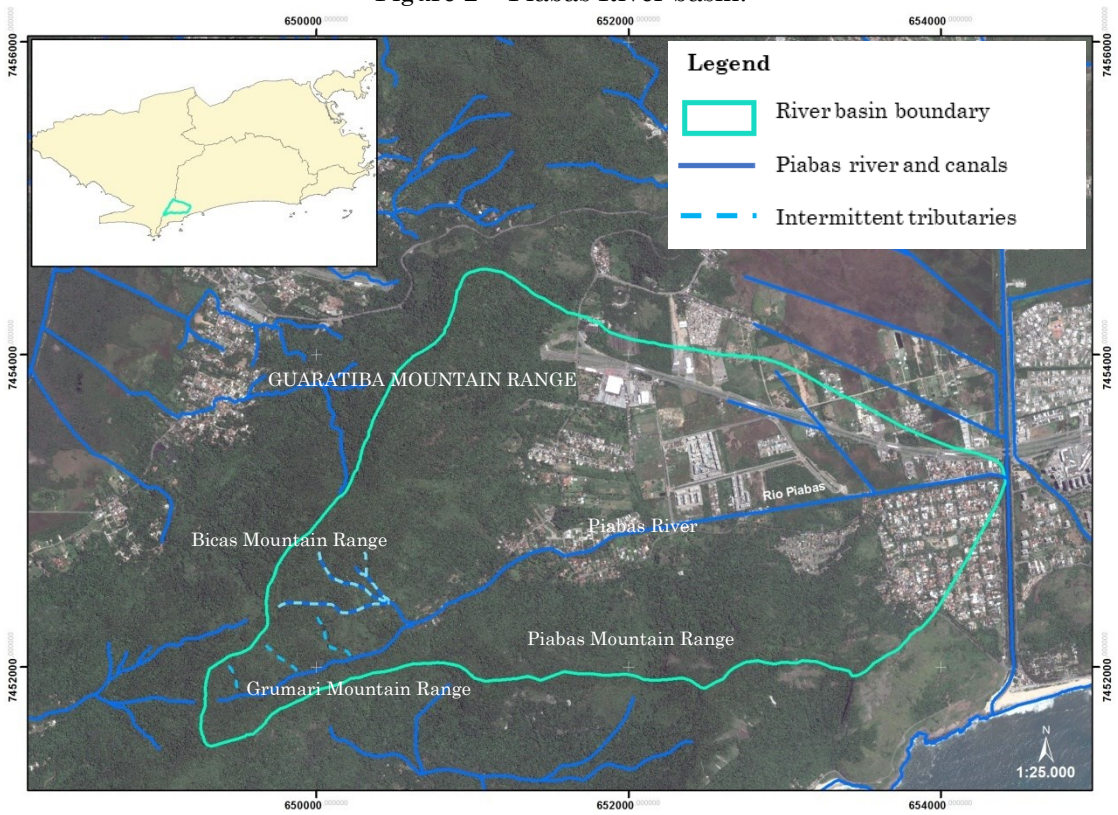
The specific objectives of this article are: (i) to map the land use and land cover of the Piabas River basin for the year 1968; (ii) compare the 1968 mapping with the 2018 mapping, identifying and quantifying the changes observed in these 50 years; and (iii) identify areas of novel ecosystems produced as a result of the landscape transformation process.

MATERIALS AND METHODS

Study area

The Piabas river basin, which is part of the *Sertão Carioca* landscape, is 860ha and its limits are formed by the slopes of Serra de Guaratiba in the Pedra Branca Massif (Figure 2). Noronha and Freitas (2020) describe the geological, geomorphological and pedological aspects of the basin which, associated with the morphoclimatic and biogeographic conditions of the region, enabled the occupation of forest ecosystems on the slopes, herbaceous and woody wetland ecosystems in the fluvial-lacustrine plains and restinga ecosystems in the lowlands with marine influence.

Figure 2 – Piabas River basin.



Source: the authors, adapted from Noronha and Freitas (2020) and from Rio de Janeiro City Hall database PCRJ (2014).

It is in this scenario that cultural, political and economic interferences historically took place, which, at the confluence of their actions, provided reactions that reflect the different landscape transformation processes studied in this article.

Methodological procedures

The process consisted of searching for the oldest aerial photographs of the study area obtained in 1968, and cataloged in the Instituto Pereira Passos (IPP), which is the institute of Rio de Janeiro City Hall responsible for the city database organization, collection of the Prefeitura da Cidade do Rio de Janeiro, which is the City Hall of Rio de Janeiro (PCRJ). These aerial photographs have an analog format and used remote detection obtained from overflight with an aerophotogrammetric camera, presented in gray levels, with a spatial resolution of 2 meters. The selected images were

digitized, mosaiced and georeferenced in the ESRI/ArcGIS 10.5™ program from the topographic databases of the municipality at a 1:2,000 scale and from the axes of public places available in the PCRJ database (PCRJ, 2014), using the Plane Coordinate System, Datum SIRGAS2000 UTM Zone 23s. The 2018 satellite image refers to the WorldView-2 orbital sensor, RGB bands, with a spatial resolution of 1.84m, available in the city hall database.

The Piabas river basin was delimited by manual vectorization according to Christofoletti (1980) using topographic bases on a scale of 1:2,000 and hydrographic bases on a scale of 1:10,000 available in the PCRJ database. The land use and land cover were mapped in the 1968 image with the generated shapefile of the Piabas river basin, which was later compared with the 2018 mapping, available in the SIGFloresta application (PCRJ, 2014).

The land use and land cover mapping prepared for the year 1968 followed the procedures described in Noronha and Fico (2021) related to the 2018 mapping. The polygons were manually vectorized in the ESRI/ArcGIS 10.5™ program from visual interpretation of the images using the same land use and land cover classification system of the SIGFloresta application (PCRJ, 2014).

Next, crossing the 1968 image with the 2018 land cover mapping basis provided a reinterpretation and classification of the mapped polygons for the year 1968. The research and reading of the works of Corrêa (1936) and Galvão (1963; 1965), historical literature which describe and analyze the past natural, social and economic characteristics of that region, were fundamental for visually interpreting and classifying the land use and land cover related to the 1968 image which reflects the descriptions made by these authors as it was from a similar period.

The land use and land cover classification system adopted by the Secretaria Municipal de Meio Ambiente da Cidade do Rio de Janeiro, which is the Secretariat of the Environment of the City of Rio de Janeiro, has 15 classes and is adapted from IBGE (2012) and CONAMA Resolution 6/1994, which defines the characteristics of forests in different successional stages in the State of Rio de Janeiro (NORONHA; FICO, 2021; SIGFloresta (PCRJ,2014)). According to Noronha and Fico (2021), the urban forest in Rio de Janeiro is essentially composed of secondary vegetation, which regenerates and develops after undergoing some type of past or current intervention that involves removal or loss of tree biomass and other life forms.

Based on the concept of novel ecosystems proposed by Hobbs et al. (2013) and in the analyzes performed by Solórzano et al. (2021), we methodologically assume that the areas classified as dense ombrophylous forest in the initial and intermediate stages in the 2018 mapping can be considered novel ecosystems, as they would represent a new successional trajectory with the presence of anomalous exotic and native species (OLIVEIRA et al., 2013; PEPE, 2020; SOLÓRZANO et al., 2021). The Piabas river basin mostly had another type of land use and land cover in the 1968 image, which went through a forest transition process and which are currently not the target of intervention or management.

The transformations observed in these 50 years were identified and quantified from the interpreted spatial analysis of the images and by comparing data from the attribute tables of each mapping in the Excel program.

RESULTS AND DISCUSSION

Land use and land cover mapping in the Piabas river basin for the year 1968

The aerial photograph of 1968 reproduces an expressive scenario of the relationship between the relief conditions, the agricultural aptitude of the soils, the usage and occupation types and patterns, and the political and economic perspectives in force at the time, resulting in a fundamentally agrarian landscape. Covering the neighborhood of Recreio dos Bandeirantes, the Piabas river basin presented a predominance of agricultural practices represented by banana crops on the slopes and vegetable crops in the lowlands in the 60s, as illustrated in Figure 3 of the land use and land cover mapping from 1968.

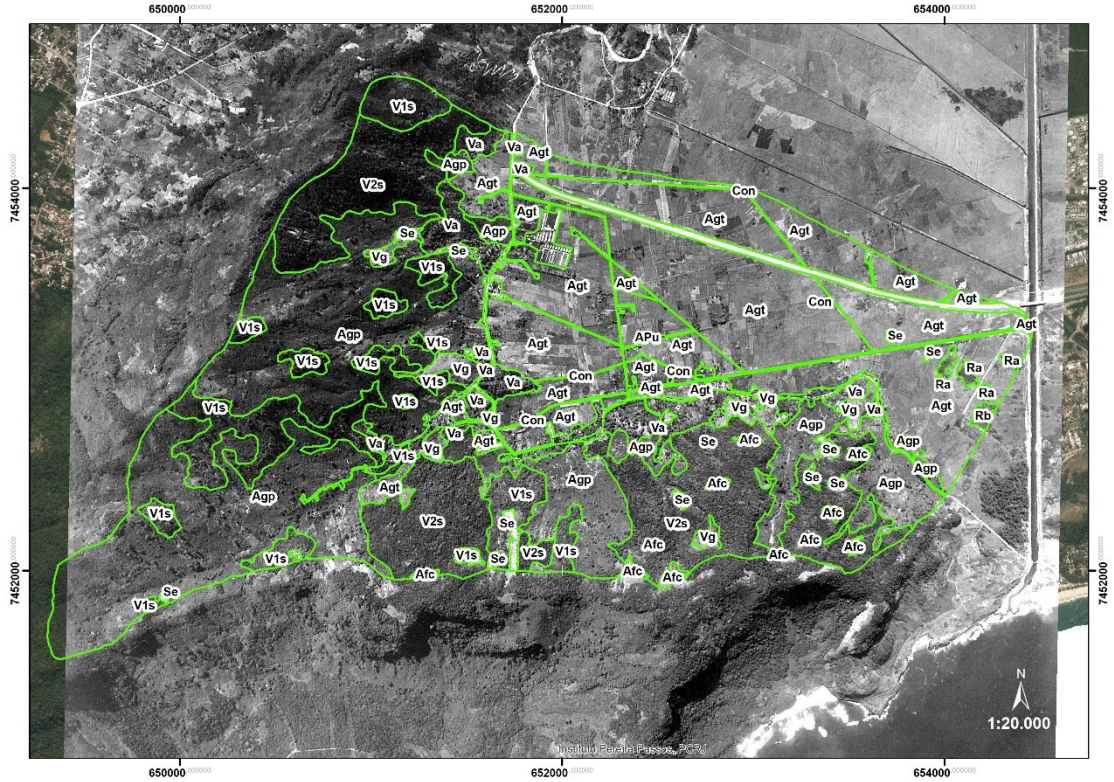
As pointed out by Galvão (1963), the role played by the relief conditioned the different agricultural practices that were distributed in the *Sertão Carioca*, more specifically in the Vargens region. Added to the interests of the food supply market and the agricultural aptitudes of the soils, a pattern in the development of certain perennial or temporary crops which met the immediate consumption of the city's population can be observed in the landscape.

A predominance of permanent crop agricultural use (Agp) class with banana crops is evident in the mountains, where for centuries wood, firewood and charcoal were extracted (OLIVEIRA et al., 2011; OLIVEIRA, 2015;

OLIVEIRA; SHEEL-YBERT, 2018; SALES et al., 2020). Larger forest fragments with characteristics of higher tree density, classified as submontane dense ombrophylous forest in the intermediate regeneration stage (V2s) present good representation on the slopes, followed by smaller fragments dispersed in the agricultural matrix, classified as submontane dense ombrophylous forest in the initial regeneration stage (V1s).

Peri-urban agglomerates (Apu) formed by dirt roads, farmers' houses and a set of sheds are present in the lower third of these mountains, in contact with the lowland areas. Such areas are therefore configured as agricultural production/flow and local commerce convergence points in the region. The class mapped as natural/anthropogenic vegetation mosaic (Va), which comprises the assemblages of specimens that form fruit orchards planted around and at the back of the houses, also has good representation in the lower reaches of the slopes.

Figure 3 – Land use and land cover map of the Piabas River basin for the year 1968.



Legend: V1s: Submontane Dense Ombrophylous Forest in initial regeneration stage; V2s: Submontane Dense Ombrophylous Forest in intermediate regeneration stage; Ra: Arboreal Restinga; Rb: Shrubby Restinga; Afc: Rock outcrop with rupestrian vegetation; Va: Natural/anthropogenic vegetation mosaic; Vg: Grassland; Con: Continental water bodies; Se: Barren; Agp: Permanent crop; Agt: Temporary crop; Apu: Peri-urban area. Source: The authors (2020).

Lowland areas have a predominance of temporary farming agricultural use class (Agt) (Figure 3). These lowland areas were mostly formed by cattail wetlands (*Tipha dominguensis* Pers.), caixeta woody wetlands (*Tabebuia cassinoides* (Lam.) DC.), and arboreal and shrubby restinga ecosystems before the establishment of agricultural practices to supply the city (CORRÊA, 1936). The drainage works represented by the channels visible in the aerial photograph resulted in "dehydration or drying" of these hydromorphic soils and enabled installation of horticulture highly demanded by the city (GALVÃO, 1965).

Regarding the historical use of the region, Galvão (1963) points out that sugarcane cultivation prevailed until the beginning of the 19th century in the lowlands which had been drained since that time. The slopes in this period showed a predominance of more conserved forest stretches, and others subjected to selective logging of tree species for charcoal production (SALES et al., 2020). Then there was a rapid passage of coffee from around 1830 to the end of the 19th century (around 1870) that predominated on the slopes of the massifs, and a certain abandonment of sugar cane plantations, with the lowlands undergoing a

slow regeneration process of wetland ecosystems and stretches used for subsistence gardens. In a short time, the coffee plantations grown on the slopes of Rio de Janeiro lost strength due to production for the Paraíba do Sul River valley, causing the *Sertão Carioca* region to enter a stagnation phase in the agricultural market, which lasted about 50 years from 1880 to mid-1930. In this period, a mosaic of forest fragments in a natural and managed regeneration process, the presence of permanent crops and maintained selective logging of tree species for charcoal production can be observed. In turn, the lowlands remained following their wetland regeneration process and maintenance of subsistence gardens during this period.

Following the assumptions and definitions proposed by Hobbs et al. (2013) and analyzes performed by Solórzano et al. (2021) in the Tijuca and Pedra Branca Massifs, it is worth assuming that the natural regeneration of vegetation during this period, which advanced from a successional stage to a secondary forest, became composed of a mixture of native and exotic species that existed in the area and in neighboring remnants. Thus, the successional trajectory began to incorporate species that did not originally evolve in this biome, at the same time favoring native species adapted to local conditions, presenting never-before-seen density and dominance patterns with a new assemblage of species. This ecological novelty led to establishing an emerging forest ecosystem, or novel ecosystem, occupying the slope areas, while the lowland areas were once again colonized by hydrophilic species.

Market conditions from the third decade of the 20th century favored banana cultivation in the favorable soils of the slopes and vegetables in the drained lowlands of Jacarepaguá and Vargens, reaching 63% of the area of the Piabas River basin (Figure 3; Table 1).

Table 1 - Absolute values and percentages of the land use and land cover mapping in the Piabas river basin in 1968.

Legend	Abbrev.	Area (ha)	%
Agricultural use, Temporary Crop	Agt	270.6	31.5
Agricultural use, Permanent Crop	Agp	267.1	31.1
Submontane Dense Ombrophylous Forest, Intermediate Stage	V2s	146.2	17.0
Submontane Dense Ombrophylous Forest, Early Stage	V1s	71.4	8.3
Natural/anthropogenic vegetation mosaic	Va	37.3	4.3
Periurban Area	Apu	33.9	3.9
Grassland	Vg	14.3	1.7
Barren	Se	6.4	0.8
Rocky outcrop with rupestrian vegetation	Afc	4.7	0.5
Continental water bodies	Con	4.1	0.5
Arboreal Restinga	Ra	2.9	0.3
Shrubby Restinga	Rb	1.1	0.1
Total		**860**	**100**

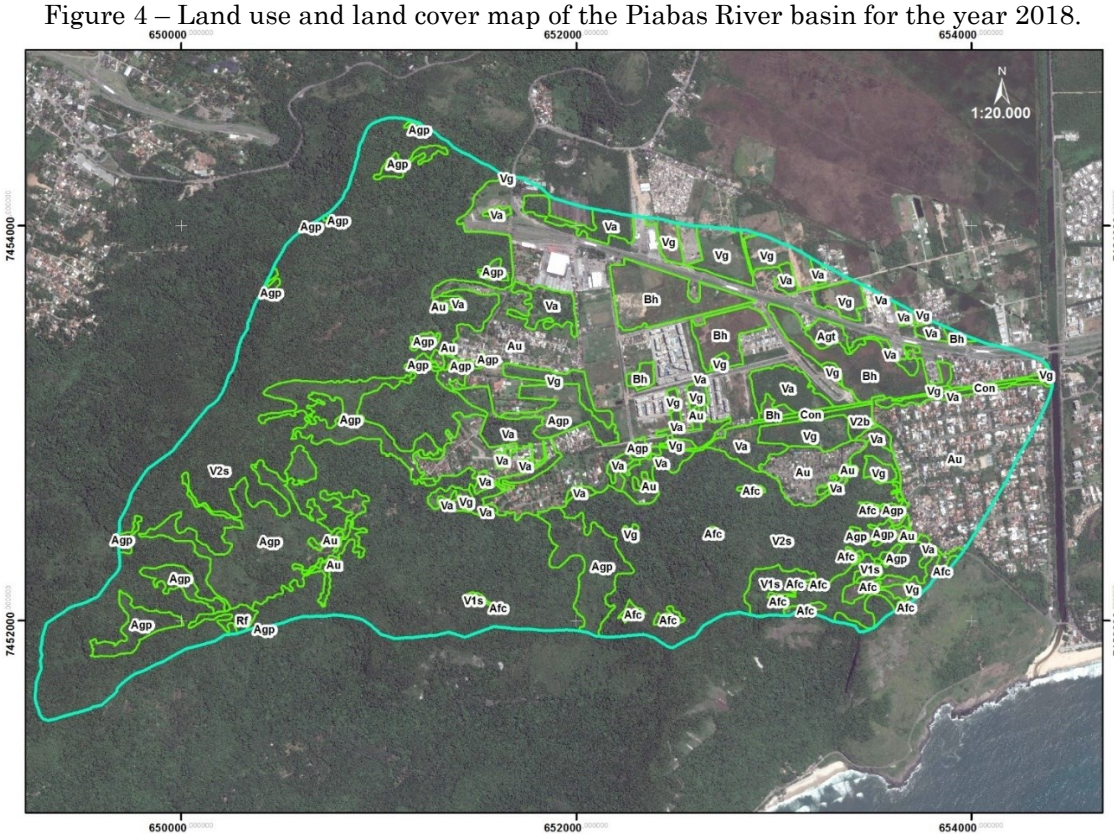
Source: The authors (2020).

The intermediate and early stage forest classes correspond to 25% of the area, followed by the natural/anthropogenic vegetation mosaic classes and peri-urban areas that represent 4.3% and 3.9%, respectively. The other classes make up a total of 3.9% of the area of the Piabas River basin (Table 1).

Land use and land cover mapping in the Piabas river basin for the year 2018

The land use and land cover mapping for the year 2018 (SIGFloresta (PCRJ, 2014)) reveals a very different landscape from that seen 50 years earlier (Figure 4). Banana plantations no longer predominate on the slopes of the mountains as in 1968, but novel forest ecosystems in the intermediate regeneration stage (V2s). These emerging forests retain the marks of past uses in their structure and composition with the presence of several exotic species (notably fruit trees such as jackfruit, jambo, mango and avocado) and native species with anomalous distribution patterns (such as *Guarea guidonia* (L.) Sleumer and *Joannesia princeps* Vell.) (OLIVEIRA et al., 2013; PEPE, 2020; SOLÓRZANO et al., 2021).

Figure 4 – Land use and land cover map of the Piabas River basin for the year 2018.



Legend: V1s: Novel submontane forest ecosystems in early regeneration stages; V2s: Novel submontane forest ecosystems in intermediate regeneration stage; V2b: Novel lowland forest ecosystems in intermediate regeneration stage; Bh: Herbaceous wetland; Afc: Rock outcrop with rupestrian vegetation; Va: Natural/anthropogenic vegetation mosaic; Vg: Grassland; Rf: Afforestation; Con: Continental water bodies; Se: Barren; Agp: Permanent crop; Au: Urban area. Source: Adapted from SIGFloresta (PCRJ, 2014).

The advance of this secondary vegetation and the consequent retreat of banana plantations in the mountains may have been driven by the creation of the Pedra Branca State Park (*PEPB*), whose creation law nº. 2,377 was published on June 28, 1974 (INEA, 2013). The *PEPB* in this stretch of Serra de Guaratiba has its limit at 100m. Any type of agricultural use is prohibited from this altitude, as it is configured as an activity in disagreement with the objectives of an Integral Protection Conservation Unit (*Unidade de Conservação de Proteção Integral - UCPI*), State Park category, as governed by the National System of Conservation Units (*Sistema Nacional de Unidades de Conservação - SNUC*) (BRAZIL, 2000). Federal Law nº. 9,985/2000).

The creation of this *UCPI*, which represents 46% of the area of the Piabas River basin, probably resulted in abandoning a large part of the banana plantations that were distributed on the slopes. In other words, the insecurity about land tenure, the legal impediment of its use with farming and the growing advance of urban expansion in the lowland areas were the likely motivators that "imposed" a change in the way of life, mainly in the younger generation of residents, sons of the previous generation of farmers, as Fernandez (2016) very well points out. Even so, stretches of this mountain range with banana cultivation are currently found within the limits of the *PEPB*, although in the process of decline and with little management, surrounded by a forest recovery process. It is still possible to find small farmers in different parts of the southern slope of the Pedra Branca Massif producing bananas and using mule transport (Figure 5).

Figure 5 – Farmers in the Piabas River basin using horses and mules to transport bananas.

Source: The authors (2020).

In the lower third of the slopes, between 100m and 50m, we observe a mosaic composed of the forest edge in the intermediate regeneration stage, small patches of banana cultivation agricultural use (Agp), natural/anthropogenic vegetation mosaic (Va) and grassland (Vg). There is a fringe of occupation between 50m and 25m with smaller farms or houses of older farmers who remained there and small local businesses. The orchards and backyards in this stretch of slopes serve as buffer zones between the more urbanized areas and the forest remnants. This is a less densely occupied front, but already characterized and classified as an urban area (Au) in the land use and land cover map for the year 2018 (Figure 4).

Condominiums of houses and buildings predominate in the lowland areas, in addition to the urban infrastructure consisting of public spaces, commerce, schools, gardens of ornamental plants, sheds, lots under construction and public service equipment to meet the demand of a growing population. This occupation intensified in 2012 with the opening of the Grota Funda Tunnel, but it began around the year 2000, with the region being prepared to host a series of mega-events based in Rio, such as the Pan American Games in 2007, FIFA FanFest in 2010, Rock in Rio in 2011, Rio +20 in 2012, World Youth Day and Confederations Cup in 2013, World Cup in 2014 and the Olympic and Paralympic Games in 2016. According to Freitas and Elias (2017), the Regulations formulated in the Master Plan in the legal instruments related to urbanization and in public policies aimed at environmental conservation were made more flexible in favor of a neoliberal marketing logic that contemplated the projects of large construction companies and developers to the detriment of the demands of the population.

Few remnants of herbaceous wetlands (Bh) confined to the consolidated urban area remain. The appreciation of these lowland areas due to real estate speculation at the end of the 1970s led to the expulsion of tenants who used the land for temporary cultivation of vegetables, as anticipated by Galvão (1963). At that time there was no immediate need for real urban expansion and occupation, with these lands serving as a future market reserve. This fact favored the natural regeneration of species typical of marshy ecosystems. With the rapid and recent urbanization, such lowland ecosystems were being pressured and replaced by urban infrastructure.

What is then observed in 2018 as a response to this whole process is the predominance of novel submontane forest ecosystems in the intermediate regeneration stage (V2s), which occupy about 47% of the study area, constituting values well above those mapped for the year 1968 (Table 2).

Table 2 - Absolute values and percentages of the land use and land cover mapping in the Piabas river basin in 2018.

Legend	Abbrev.	Area (ha)	%
Novel submontane forest ecosystems, intermediate stage	V2s	400.6	46.6
Urban Areas	Au	216.9	25.2
Agricultural use, Permanent Crop	Agp	85.7	10.0
Natural/anthropogenic vegetation mosaic	Va	53.9	6.3
Herbaceous wetland	Bh	37.2	4.3
Grassland	Vg	36.8	4.3
Novel submontane forest ecosystems, early stage	V1s	13.6	1.6
Rocky outcrop with rupestrian vegetation	Afc	6.3	0.7
Novel lowland forest ecosystems, intermediate stage	V2b	2.6	0.3
Continental water bodies	Con	2.2	0.3
Agricultural use, Temporary Crop	Agt	2.2	0.3
Afforestation	Rf	2.0	0.2
Total		**860**	**100**

Source: Adapted from SIGFloresta (PCRJ, 2014).

The urban areas class also shows a substantial increase compared to 50 years ago, reaching 25% of the basin area. However, the agricultural use classes suffered a great decrease, especially for crops with temporary crops. Together, the agricultural use class corresponds to 10.3% of the study area. The natural/anthropogenic vegetation mosaic class maintained almost similar occupancy rates between the two years analyzed (4.3% in 1968 versus 6.3% in 2018). The remaining wetlands that resisted the urban expansion process represent 4.3% of the study area. Values of the same order of magnitude were mapped to the grassland class. It is noteworthy that most of the polygons classified as such are found in lowland areas, representing vacant land awaiting a construction process.

The reduction in percentage values of the novel forest ecosystems in the initial regeneration stage (V1s) from 8.3% to 1.6% may be a result of the advancing process of their successional stage; we raised the hypothesis that part of the areas classified as V1s in 1968 evolved their structural characteristics being classified in 2018 as V2s. It is noteworthy that this transition took place through natural regeneration processes, since the only afforestation project developed in the basin only contributes 0.2% of the study area. The other classes (Afc, V2b and Con) make up a total of 1.3% of the studied area.

Landscape transformations between 1968 and 2018 in the Piabas river basin

The largest relative transformation refers to urban areas that underwent a variation of 539%, which corresponds to an increase of 183ha from 1968 to 2018 (Table 3). This increase was notably due to the use and occupation transformation in lowland areas, previously used for temporary farming, but then went through a regeneration period of wetland ecosystems which today is mostly occupied by the urban area class. It is estimated that part of the abandoned crops and wetland areas were also replaced by the grassland class, which in the near future will tend to give way to the urban areas class due to the fact that the West Zone has been the main urban expansion target of the city of Rio de Janeiro in recent years, both in irregular housing and in regularized subdivisions, and also due to the flat relief condition which has easy access in these lowland areas. The restinga remnants mapped in 1968 were locally extinct and transformed into urban areas. Depending on the public policies in force in recent years of low incentives for nature conservation and pressures from the real estate sector, the same fate for the remaining wetland ecosystems that resist in the Piabas River basin lowland areas will occur, meaning grounding, compaction and sealing of hydromorphic soils, and urban occupation. In turn, this process enhances the already existing susceptibility of these areas to flood events, causing considerable damage and environmental impacts (PONTES et al., 2017).

Table 3 – Absolute and percentage variation of land use and land cover in the period 1968 and 2018.

Legend	1968 (ha)	2018 (ha)	Variation %
Peri-urban Area / Urban Area	33.9	216.9	539.4%
Submontane Dense Ombrophylous Forest, Intermediate Stage	146.2	400.6	174.0%
Grassland	14.3	36.8	157.4%
Natural/anthropogenic vegetation mosaic	37.3	53.9	44.5%
Rocky outcrop with rupestrian vegetation	4.7	6.3	34.5%
Continental water bodies	4.1	2.2	-45.4%
Agricultural use, Permanent Crop	267.1	85.7	-67.9%
Submontane Dense Ombrophylous Forest, Early Stage	71.4	13.6	-81.0%
Agricultural use, Temporary Crop	270.6	2.2	-99.2%
Arboreal Restinga	2.9	0.0	-100.0%
Shrubby Restinga	1.1	0.0	-100.0%
Barren	6.4	0.0	-100.0%
Lowland Dense Ombrophylous Forest, Intermediate Stage	0.0	2.6	-
Herbaceous wetland	0.0	37.2	-
Afforestation	0.0	2.0	-

Source: The authors (2020).

The intermediate-stage submontane forest class presented a much smaller percentage variation than that of urban areas (174%), but it stood out if we consider the absolute values with an area gain of 254.4ha from 1968 to 2018. This increase was likely caused by the expansion of forested areas over abandoned banana plantations and the evolution of forest fragments at an early stage, resulting in a mosaic of novel ecosystems which, according to CONAMA Resolution nº 6/1994, can be classified as forest in an intermediate regeneration stage.

The natural/anthropogenic vegetation mosaic class presents a good contribution to the green areas of the basin during the analyzed period. Pedreira et al. (2017) point out that there is no single and universal definition for the concept of green areas. A green area can generally be considered as any space that has a predominance of vegetation cover composed by either arboreal, shrubby or herbaceous elements, native or not, present in different ways in public or private areas, associated with a green infrastructure which involves for example urban afforestation, urban forest remnants, backyards, woods, orchards, agricultural crops, squares, garden beds and urban parks. Even though this class is, in most cases, composed by exotic fruit trees such as mango, jackfruit, jamelão and avocado, it remains more important for the basin functioning and for providing ecosystem services (COSTANZA et al., 2014) than if they were reversed to impermeable urban areas or vegetation of grasses of the colonião grass species (*Megathyrsus maximus* (Jacq.) BK Simon & SWL Jacobs), which occupies many slopes of the Pedra Branca Massif, causing a series of impacts on ecosystems associated with the Atlantic Forest (FERNANDEZ et al., 2015; INEA, 2013).

FINAL CONSIDERATIONS

A sequence of land use and occupation periods which change according to the historical and dynamic demands of the market, society and public policies can be seen from the mid-18th century to the present day. Following Pepe's (2020) systematic line of the landscape transformation process and the agencies undertaken over time, and the information published by Corrêa (1936) and Galvão (1963; 1965), it is possible to highlight general milestones and patterns of these transformations and its socioecological results.

What generally stands out in this historical transformation process is an expansion of the areas occupied by novel forest ecosystems on the slopes in favor of the retreat of banana plantations due to the creation of the *PEPB*, and the expansion of urban areas in the lowlands over the remaining herbaceous and woody wetlands and areas dedicated to agriculture. Labor relations and the interest of new generations in urban jobs are also factors to be considered in the abandonment of agricultural activities, and in the processes of cultural

erosion and loss of local agrobiodiversity knowledge.

The region comprising the study area and surroundings has been the target of intense speculation and urban expansion in recent years. Added to this, the scarcity of basic public sanitation services and the lack of planning and territorial management that prioritizes environmental conservation and values an agriculture managed with agroecological principles.

From the perspective of the municipal scale through a comparison and analysis of historical data from the SIGFloresta mapping of land use and land cover in the municipality (PCRJ, 2014) similar dynamics to this can be observed in other parts of the city such as Guaratiba, Campo Grande, Santa Cruz and Mendanha-Gericinó, each with its own historical, cultural, political-economic and environmental particularities, as observed by Oliveira (2017) in a historiographical study which analyzes the memories and identity construction processes of the notions of rural and urban evoked by different actors of Planning Area 5 in the West Zone of the City of Rio de Janeiro.

As a consequence, a scenario of urban densification is envisaged for the municipality, notably in the lowland areas of the west zone, with the replacement of areas with good agricultural aptitude and the wetlands by urban and impermeable areas. If deprived of adequate planning and infrastructure, such processes will amplify the already negative impacts on the quality of life conditions in the city of Rio de Janeiro.

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AUTHORS' CONTRIBUTION

Felipe Noronha conceived the study, mapped and analyzed the data, wrote the text and revised the manuscript. Marcelo Motta de Freitas wrote parts of the text and revised the manuscript. Alexandro Solórzano contributed to the conceive the study, wrote parts of the text and revised the manuscript.